

The Deer-Vehicle Collision Phenomena in the United States

by

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B.Sc., University of Victoria, 1983

M.Sc., University of Saskatchewan, 1988

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## **ABSTRACT**

Deer-vehicle collisions in the United States (US) have increased dramatically over the last 50 years. Over one million deer-vehicle collisions are estimated to occur throughout the nation annually. These collisions result in hundreds of human deaths, thousands of human injuries, and billions of dollars in motor vehicle damage and health care costs. The increase in deer-vehicle collisions is partly the result of a growing deer population, caused largely by human manipulation of natural ecosystems. Awareness of the hazard deer pose is essential for drivers. Deer represent a dynamic, spatial and temporal hazard. Driver knowledge about deer at any time is critical for hazard awareness. State driver licensing agencies and state departments of transportation are the primary sources of information regarding driving hazards for most drivers. Through driver manuals, driver licensing agencies advise new drivers of hazards and provide strategies for dealing effectively with the hazards. Using nationally standardized warning signs, state departments of transportation advise drivers of potential hazards found along state highway systems. The first extensive nation-wide historical retrospective of the state driver manuals was conducted. The study assessed how new drivers have been informed of the hazard deer pose as this hazard has evolved. The assessment shows, although generally increasing in content, the information provided by state driver licensing agencies has been inconsistent from decade to decade, and from state to state. This inconsistency has left potentially millions of US drivers without fundamental knowledge of the growing deer hazard and/or strategies for dealing with the hazard. Recommendations and an exemplar for improving driver manuals are provided. The first historical retrospective of the standardized warning signs used by state departments of transportation was conducted to assess the effectiveness of these signs for advising drivers of deer hazards. The assessment shows standard deer warning signs used by state departments of transportation provide little temporal information for drivers. The paradigm shifting, risk matrix-based, colour-coded, Wildlife Hazard Rating System® (WildHAZ®) was developed to augment and transform

conventional standard static deer warning signs into variable message signs that provide drivers with more consistent and comprehensive warnings about the deer hazard. The results of a web-based questionnaire survey regarding the WildHAZ® system demonstrated the majority of drivers who responded to the survey understand the system and would respond in a manner that should reduce their potential for a wildlife-related motor vehicle collision and/or the potential severity of such a collision. The majority of the survey respondents indicated that they would prefer a system like WildHAZ® to be used on roads and highways. Simulations of the effect of the WildHAZ® system on mean vehicle speeds were conducted. The results of the simulations suggest WildHAZ® system augmented deer warning signs could lead to fewer and less severe deer-vehicle collisions, if mean vehicle speeds were reduced at high risk periods. The risk matrix-based, colour-coded concept incorporated in the WildHAZ® system may have the potential to warn drivers of other spatially and temporally dynamic hazards.

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**ACRONYMS**

AAMVA	American Association of Motor Vehicle Administrators
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ANOVA	Analysis of Variance
CFFDRS	Canadian Forest Fire Danger Rating System
DMS	Dynamic Message Signs
DVC	Deer-vehicle Collision
FEVR	Fédération Européenne des Victimes de la Route
FHWA	Federal Highway Administration
HREB	University of Victoria Human Research Ethics Board
ICBC	Insurance Corporation of British Columbia
ITE	Institute of Transport Engineers
JCUTCD	Joint Committee on Uniform Traffic Control Devices
km	kilometres
kmh	kilometres per hour
mph	miles per hour
MUTCD	Manual of Uniform Traffic Control Devices
MVASHD	Mississippi Valley Association of State Highway Departments
NCSHS	National Conference on Street and Highway Safety
NJC	National Joint Committee
NSC	National Safety Council
SGI	Saskatchewan Government Insurance
TAC	Transportation Association of Canada
US	United States
VMS	Variable Message Sign

## **TRADEMARK DECLARATIONS**

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## **DEDICATION**

This dissertation is dedicated to the late Dr. Harold D. Foster. Harry was a great scholar, supervisor, mentor and friend.

## **1.0 THE DEER-VEHICLE COLLISION PHENOMENA IN THE UNITED STATES**

### **1.1 Introduction**

While highway safety in the United States (US) has improved significantly over the last 50 years, deer-vehicle collisions in the nation have increased dramatically (Huijser et al., 2008). Between one million and 1.5 million deer-vehicle collisions are estimated to occur throughout the country each year (Conover et al. 1995; Romin and Bissonette, 1996; US General Accounting Office, 2001). These collisions result in hundreds of human deaths, thousands of human injuries, and billions of dollars in motor vehicle damage and social costs (Figure 1.1). State Farm Mutual Automobile Insurance Company (2012) predicted one driver in every 170 American drivers would be involved in a deer-vehicle collision in 2013. In some American states, the likelihood of a driver being involved in a deer-vehicle collision is much greater. In the state of West Virginia, State Farm Mutual Automobile Insurance Company (2012) predicted one driver in every 40 drivers in the state would be involved in a deer-vehicle collision in 2013. The number of American states in which the deer hazard potential was estimated to impact more than one in 100 drivers doubled between 2008 and 2011 (Figures 1.2 and 1.3). In some American states, deer-vehicle collisions account for a growing percentage of all reported collisions. Deer are by far the animal most frequently involved in animal-vehicle collisions (Hughes et al., 1996). In 1978 and 1979, deer-vehicle collisions in Wisconsin accounted for only 5.1% and 4.7% of all collisions, respectively (Wisconsin Department of Transportation, 2012). From 1996 to 2011, the number of deer collisions as a percentage of all yearly collisions reported in the state averaged 15.2%. Deer-vehicle collisions represent both an economic and social burden to the US of America.



Deer-vehicle collisions involving small passenger vehicles



Deer-vehicle collision involving a SUV

Figure 1.1 Deer-vehicle interactions

## 1.2 The Deer-Vehicle Collision Phenomena

Deer currently represent a growing hazard to drivers in all US states. The multi-billion dollar cost of deer-vehicle collisions, and their human fatalities and injuries, is a burden to individuals, insurance companies, and the state and federal governments. The high number of deer-vehicle collisions occurring in the US is a perplexing phenomenon. Over one million deer-vehicle collisions are estimated to occur each year in the US. Ironically, deer were extirpated or nearly extirpated from over 20 US states in the late 19<sup>th</sup> and early 20<sup>th</sup> century. At that time, less than 500,000 deer were estimated to exist in the entire country. Deer-vehicle collisions appear to have been relatively rare events in the 1920's and 1930's. The incidence of deer-vehicle collisions remained low until the late 1960's. From that period on, deer-vehicle collisions have been increasing steadily each decade. Currently, over 30 million deer are estimated to inhabit the US. Deer are involved in vehicle collisions throughout the lower forty-eight states, Hawaii and Alaska. While once a predominantly rural occurrence, deer-vehicle collisions increasingly occur in urban environments.

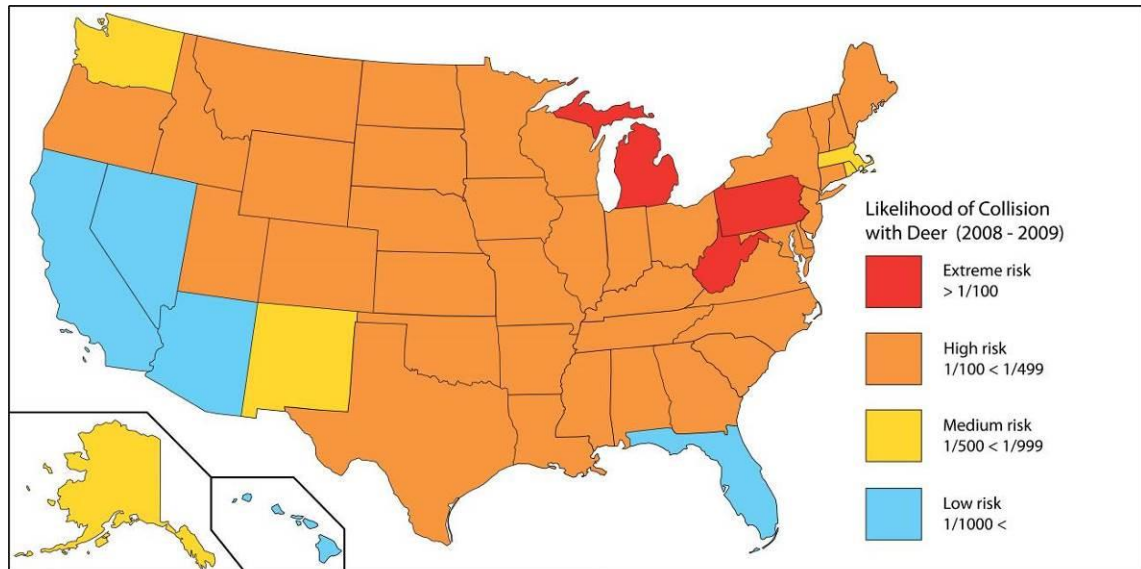


Figure 1.2 Likelihood of collision with deer in the US (2008/2009)  
(Data source: State Farm Mutual Automobile Insurance Company (2008))

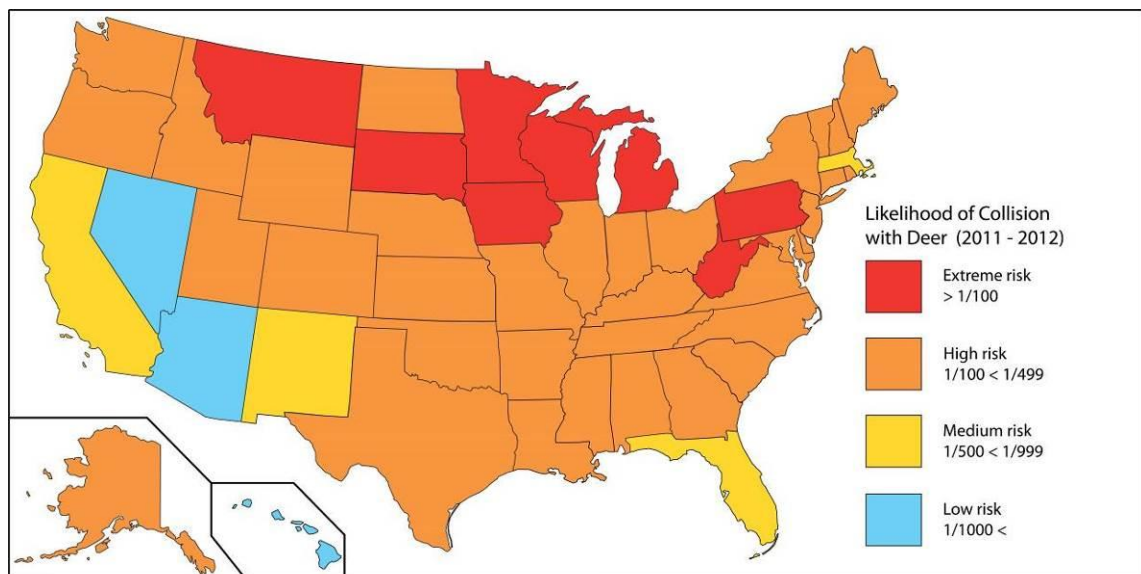


Figure 1.3 Likelihood of collision with deer in the US (2011/2012)  
(Data source: State Farm Mutual Automobile Insurance Company (2010))

Åberg (1981) identified three basic countermeasures to reduce wildlife-vehicle collisions:

1. Reducing the population of wildlife,
2. Preventing wildlife from entering roads and highways, and
3. Modifying driver behavior.

With regards to modifying driver behaviour, the efforts of state driver licensing agencies and road and highway authorities in the US to educate and advise drivers of the deer hazard as it has developed in the nation has not been comprehensively studied or evaluated.

### **1.3 PURPOSE AND OBJECTIVES**

The goal of this research is three-fold: (1) to develop a historic retrospective of both the known and suspected causes of the current deer-vehicle collision phenomena in the US; (2) to develop a comprehensive, nation-wide, historical retrospective on the primary methods used by state driver licensing agencies and state departments of transportation to communicate the hazard deer represent to drivers as the phenomena evolved; and (3) develop new approaches for increasing driver knowledge and awareness of the deer hazard to improve driver ability to understand and respond effectively to the hazard.

My research has four primary objectives:

1. Identify the factors that have either contributed, or currently contribute, to the growing nation-wide deer-vehicle collision phenomena experienced by drivers on roads and highways in the US.

2. Conduct a historical review of the information state driver licensing agencies in the US have provided to new drivers in state driver manuals regarding deer hazards on roads and highways as the deer-vehicle collision phenomena evolved.
3. Conduct a historical review of how road and highway authorities in the US have used traffic control devices to advise drivers of potential deer hazards on roads and highways as the deer-vehicle collision phenomena evolved.
4. Develop potential approaches to address shortcomings or weaknesses identified in how US state driver licensing agencies and state departments of transportation communicate the deer hazard risk to drivers.

As a first step, it is essential to understand the causes and magnitude of the deer-vehicle collision phenomena in the US.

Chapter 2 provides a historic retrospective on the factors that have contributed to the evolution of the current deer-vehicle collision phenomena in the US. Aspects of human involvement and interference over the last three centuries in the country's natural ecosystems are examined. The consequences for drivers in the 20th century of the systematic removal of deer and their natural predators which occurred in many US states in the 18th and 19th centuries, followed by the reintroduction of deer into predator-free regions of the country and the imposition of strict state hunting restrictions, are examined.

Chapter 3 provides a historic retrospective on the information US state driver licensing agencies have provided regarding the deer hazard to new drivers in state driver manuals published over the last 60 years. The strengths and weaknesses of the driver manuals are examined. Recommendations are made with regards to how the state driver manuals could be improved to better educate new drivers of the growing

hazard deer pose for all drivers in the US. An exemplar to provide direction for future state driver manual development is provided.

Chapter 4 provides a historic retrospective on the development of traffic warning signs over the last 110 years in the US. The evolution of deer crossing signs used by US state departments of transportation is examined and the shortcomings of these static warning devices are identified. The Wildlife Hazard Rating System® (WildHAZ)®, a new and unique dynamic wildlife hazard warning system is proposed to improve and increase the amount of timely information provided to drivers regarding the diurnal and seasonal variation of the deer hazard in the US. Examples of the proposed implementation of the new wildlife hazard warning system are provided.

Chapter 5 provides the details of an anonymous questionnaire survey used to determine if drivers in the United States and Canada would understand the Wildlife Hazard Rating System® (WildHAZ)® and if these drivers would respond to the system in a manner that would reduce their potential for a wildlife-vehicle collision and/or reduce the potential severity of such a collision. The results of the survey are presented.

Chapter 6 provides the details of a three-stage methodology developed to test and evaluate the potential effectiveness of the Wildlife Hazard Rating System® (WildHAZ®) on driver behaviour. The methodology incorporates (1) focus groups, (2) driving simulation and (3) field testing. The approach proposed provides a structured, statistically-based approach that has not been previously used for evaluating either conventional wildlife warning signs, or any other conventional traffic warning signs. The system installation, maintenance and management costs of testing and evaluating the WildHAZ® are estimated.

Chapter 7 summarizes the findings of the preceding chapters, and provides a synopsis on how US state driver licensing agencies can improve their state driver manuals to better prepare new drivers for the growing nation-wide deer hazard, and how US state departments of transportation can provide more timely and meaningful information regarding the deer hazard to all drivers operating vehicles on state roads and highways.

Chapter 8 concludes the dissertation and provides insight into future research with the WildHAZ® system and the potential for applying the risk matrix-based, colour coded concept of warning drivers of other spatially and temporally dynamic driving hazards.

Chapter 9 provides a listing of all the reference materials used in the dissertation.

## **2.0 EVOLUTION OF THE DEER-VEHICLE COLLISION PHENOMENA IN THE UNITED STATES**

*“In particular, the return of the white-tailed deer to its original range in North America ranks among the world’s greatest wildlife management success stories.” (Marchington, R.L., 2004, p.5 in McDonald and Miller (2004)).*

*“However, no deer management technique that increases the chances of a DVC will be, or should be publicly accepted.” (Rutberg and Naugle, 2008, p.61)*

### **2.1 Introduction**

An estimated one to 1.5 million deer-vehicle collisions occur each year in the United States of America (US) (Conover et al. 1995; Romin and Bissonette, 1996; US General Accounting Office, 2001). While many factors contribute to the deer-vehicle collision rates, in large part they are an unexpected and undesirable consequence of human interference and manipulation of natural ecosystems. Less than 100 years ago deer were scarce (Downing, 1987) and deer-vehicle collisions were extremely rare events during the early part of the 20<sup>th</sup> century (Stoner, 1925; Gordon, 1932; Sperry, 1933; Davis, 1934; Warren, 1936a; Warren, 1936b; Starrett, 1938; Dickerson, 1939; Davis, 1940). Deer-vehicle collisions are positively correlated with greater deer abundance (Blouch, 1984; Etter et al., 2001). The dramatic increase in deer populations, in particular, white-tailed deer (*Odocoileus virginianus*), is the direct result of human activity (Clay et al., 2012). The near-exponential growth in deer populations is not the result of one single human intervention, but rather the culmination of 200 years of large-scale land use change, the overhunting of deer and their predators, and the removal of deer-hunting indigenous peoples; followed by state initiatives to protect deer that resulted in increased deer populations (Paddock and Yabsley, 2007). The purpose of this chapter is initially to identify and examine the factors that may have historically contributed, or currently contribute, to the current deer-vehicle collision phenomena experienced by drivers in the US. Following this, the social and economic costs of deer-vehicle collisions (DVC)

occurring in the US will be examined to determine the extent of the burden borne by the nation.

## 2.2 Deer in the United States

Deer inhabit every state in the continental US (Seton, 1953; Rue, 1978) (Figure 2.1). There are two species of indigenous deer: Mule deer (*Odocoileus henionus*); and, White-tailed deer (*Odocoileus virginianus*) (Murie, 1974). In Hawaii, a US state with no indigenous species of deer, Axis deer (*Axis axis*) from southeast Asia were first introduced to the island Moloka’I in the 1860’s and, more recently, to Maui and Lana’I where large herds are now established (State of Hawaii, 2012).

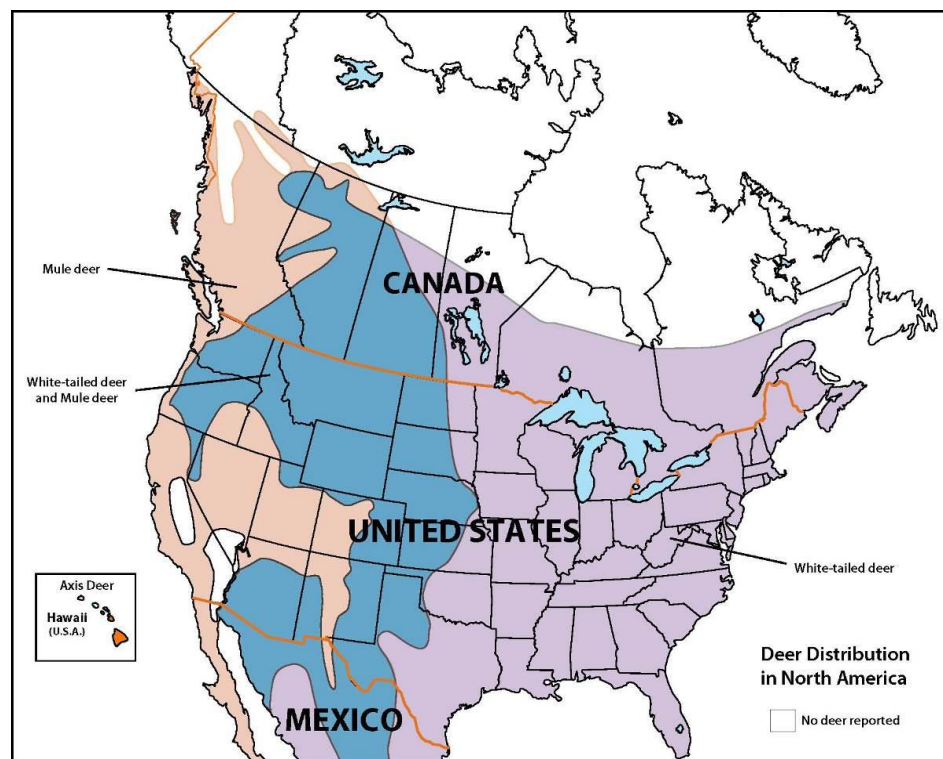


Figure 2.1 Distribution of deer in North America (adapted from Seton (1953) and Rue (1978))

### 2.3 Historic Deer-Vehicle Collision Trends

Although scientific investigation of motor vehicle-related wildlife mortality on United State's highways began in the mid-1920's, deer vehicle collisions did not become an issue for study until the late 1950's and 1960's. Initially, simple highway wildlife mortality surveys, consisting of carcass identification and counting, were conducted by researchers across the US. Deer were not commonly found among the species of wildlife typically reported. Stoner (1925) did not report deer among the 225 wildlife carcasses he found along 632 miles (1011 km) of highways in Iowa. Surveys in Idaho in 1929 and 1931 by Gordon (1932) did not report encountering deer among the species of animals found. Similarly findings are reported by: Sperry (1933) who conducted a 1932 highway survey of 763 animal carcasses along 685 miles (1096 km) in Idaho and Colorado; Davis (1934) who surveyed 500 miles (800 km) of highway from Iowa to Massachusetts; Warren (1936a; 1936b) who surveyed 760 miles (1216 km) of Colorado highway during the summers of 1935 and 1936; Starrett (1938) who in 1937 surveyed 7,529 miles (12,046 km) of highway in central Illinois during 219 trips; Dickerson (1939) did not report a single deer carcass among wild animal carcasses found during more than 75,000 miles (120,000 km) of travel over a three year period in Alabama, Arizona, Arkansas, California, Florida, Georgia, Illinois, Mississippi, Missouri, New Mexico, Oklahoma, Tennessee, Texas, and Virginia; and, Davis (1940) who observed wildlife mortality along 6 miles (9.6 km) of highway in Texas. Despite these findings Dreyer (1935) does indicate there were reported instances of deer, being killed on highways between 1938 and 1939 in an assessment of national motor vehicle-related wildlife mortality. Jahn (1959) appears to have published the first paper addressing the issue of vehicle-related deer mortality in the US. Wisconsin Conservation Department seizure reports for deer carcasses found on Wisconsin highway, he found annual state deer mortality increased from 360 in 1946 to 1,443 in 1955. Into the 1960's, highway mortality of deer was becoming a more widespread issue in the US (Thompson, 1967). In 1968 and 1969, over 21,000 deer were reported killed on Pennsylvania state roads by the

Pennsylvania Game Commission (Bellis and Graves, 1971). By the mid-1990's, at least 1.5 million deer-vehicle collisions were estimated to occur annually in the US (Romin and Bissonette, 1996).

## **2.4 Decimation of Deer Populations in the United States**

The deer population in the US in the 1600's was estimated to be about 30 million (Seton, 1953). By 1900, there were virtually no deer left in Pennsylvania and it was estimated Missouri had a deer population of only 400 (Flinn et al., 2012). The extensive exploitation of deer and their habitat in the US began upon the arrival of European settlers (McDonald and Miller, 2004). For early settlers, deer provided a valuable source of food. Overexploitation of deer in the latter half of the 19<sup>th</sup> century led to major declines in the deer population (Cote et al., 2004). Before state and federal legislation and regulations were effectively administered, fatigue was apparently the only limit to deer harvesting (McDonald and Miller, 2004). Deer were hunted by both subsistence and market hunters (Figures 2.2, 2.3 and 2.4). In the US, market hunters systematically supplied a growing population and European markets, as well as growing numbers of workers employed in the rapidly expanding railroad and mining industries, (McCabe and McCabe, 1984; McDonald and Miller, 2004). By the end of the 1800's, deer had been extirpated from much of their range (McDonald and Miller, 2004). Population estimates of white-tailed deer at the end of the 19<sup>th</sup> century range from 300,000 in 1890 to 500,000 in 1900 (Downing, 1987). In the southeastern region of the US, remnant populations were limited to river swamps and rugged mountainous regions, areas largely inaccessible to humans (McCabe and McCabe, 1984). Deer were eliminated in the Piedmont regions and the more accessible areas of the Appalachians. In the northeastern region of the US, only small remnant populations survived in the mountains. By 1830, deer were rare east of the Allegheny River, and becoming scarce in the western regions of the country (Anonymous, 1830a). In the US Midwest, the few remaining deer persisted along the bottoms of remote, uninhabited river valleys. In the western states, a few remnant

populations existed along river bottoms and drainages. National white-tailed population estimates at the end of the 19<sup>th</sup> century range from 300,000 in 1890 to 500,000 in 1900 (Downing, 1987). Deer were extirpated or almost extirpated in twenty-two states (McDonald and Miller, 2004) (Table 2.1). In the late 1900's, a live wild deer in Pennsylvania was considered a curiosity (Seton, 1953).

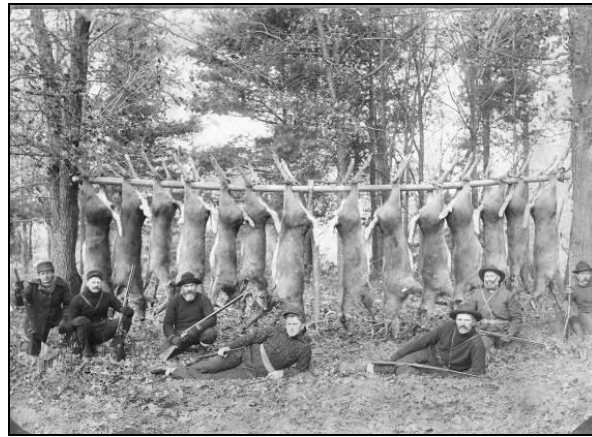


Figure 2.2 Wisconsin deer party  
(Source: T.A. Taylor, McMillian Memorial Library Digital Collections)



Figure 2.3 New Hampshire deer hunt  
(Source: Wikipedia, Creative Commons Attribution-ShareAlike License)

Table 2.1 White-tailed deer herd populations by US state  
(adapted from McDonald and Miller (2004))

<b>State</b>	<b>Deer Herd Population</b>	<b>Period</b>
Alabama	1,000	1915
Arkansas	< 500	1930
Colorado	Almost extirpated	1920s to 1930s
Georgia	Almost extirpated	Early 1900s
Idaho	Almost extirpated	Not available
Illinois	Extirpated	1878 – 1893
Indiana	Extirpated	1893
Iowa	Almost extirpated	1898
Maryland	Almost extirpated	Not available
Mississippi	Almost extirpated	1900 – 1925
Missouri	Almost extirpated	1900s
Montana	Almost extirpated	1941
Nebraska	Almost extirpated	1930s
New Jersey	Almost extirpated	1900
New York	Almost extirpated	1880 – 1890
North Carolina	Almost extirpated	1900 – 1925
Ohio	Extirpated	1904
Oklahoma	500 (estimate)	1917
Pennsylvania	Almost extirpated	Not available
South Carolina	Almost extirpated	1915 – 1920
Tennessee	Almost extirpated	1900
Texas	Almost extirpated	1890s
Vermont	Extirpated	1880s
West Virginia	Almost extirpated	1900s
Wyoming	Almost extirpated	1890s

## 2.5 Restoration of Deer Populations in the United States

The current increasing incidence of deer-vehicle collisions in the US is, in large part, related to deer restocking initiatives. For a period of almost a century, deer were virtually absent from large parts of the US (Downing, 1987; McDonald and Miller, 2004). The return of white-tailed deer to its original range in the US is considered to rank among the world's greatest wildlife management successes (Downing, 1987; McDonald and Miller, 2004). Recognizing the importance of deer for hunting, State

governments began initiatives to re-introduce and protect deer. Throughout the eastern US, deer restoration efforts began in the late 1800s (McDonald and Miller, 2004). Early efforts to restore deer populations were funded by private individuals and state natural resource agencies. In 1900, market hunting of deer in the US was effectively stopped by the passage of the Lacey Act by the US federal government (McDonald and Miller, 2004). Since the 1920s, strict hunting regulations in the US have resulted in increased deer populations. This effect was most dramatic on private lands and in parks, where hunting was completely banned (Diefenbach et al., 1997; Porter and Underwood, 1999; Brown et al., 2000). In 1937, the Pittman-Robertson Act created a source of funding for wildlife restoration initiatives by the states (Downing, 1987). The act's funds enabled larger, more comprehensive efforts to restore deer populations between the 1930s and the 1950s (Figures 2.5 and 2.6). By the 1960s and 1970s, most white-tail restoration initiatives were completed (Table 2.2). During this period, enforced regulations protected deer from exploitation. Where deer hunting was been allowed, state game laws favoured the hunting of males, thus increasing female survival and continued population growth (Ozoga and Verme, 1986). This outcome combined with the creation of wildlife refuges and management areas, and aggressive restocking programs, contributed to the restoration of white-tailed deer in the US.

As a result of these programs, deer populations in the US increased rapidly during the 1960s to 1970s (McShea et al., 1997). During the mid-1990s, several south-eastern and mid-western States began translocating large numbers of deer, primarily from Michigan, North Carolina, Texas and Wisconsin. At least 25 US states received relocated deer (McDonald and Miller, 2004). US state governments' efforts to restock deer were extremely successful. In 1925, it was estimated Missouri had a deer population of only 400 (Flinn et al., 2012). By 2012, the population of deer in Missouri was estimated to be 1.4 million (Lien, 2000). There are presently estimated to be over 30 million white-tailed deer in the continental US (Bagley, 2013).



Figure 2.4 Deer restocking release in Georgia in 1960's  
(Source: Georgia Wildlife Resources Division)



Figure 2.5 Deer restocking release in 1990's  
(Source: US Bureau of Land Management)

**Table 2.2 United States state White-tailed deer restocking periods**  
(Adapted from McDonald and Miller, 2004)

<b>State</b>	<b>Deer Herd Restoration Period</b>	<b>Estimated 2004 Deer Herd Population</b>
Alabama	1926 - 1998	1,750,000
Arkansas	1915 – 1991	1,000,000
Colorado	1964 – 1965	9,000
Florida	1941 – 1978	800,000
Georgia	1928 – 1992	1,000,000
Idaho	1985 – 1989	300,000
Illinois	1903 – 1953	750,000
Iowa	1884 – 1940s	340,000
Kentucky	1919 – 1999	600,000
Louisiana	1949 – 1980s	1,000,000
Maryland	1914 – 1963	296,000
Mississippi	1931 – 1980	1,750,000
Missouri	1925 – 1957	1,000,000
Montana	1945 – 1951	375,000
Nebraska	1959 – 1960	250,000
New Jersey	1903 – 1968	160,000
New York	1889 – 1976	1,100,000
North Carolina	1890 – 1987	1,100,000
Ohio	1919 – 1972	700,000
Oklahoma	1942 – 1972	475,000
Pennsylvania	1906 – 1968	1,570,000
Rhode Island	1967 – 1971	12,000
South Carolina	1950 – 1989	1,000,000
Tennessee	1932 – 1985	1,000,000
Texas	1938 – 1991	3,800,000
Vermont	1878	132,000
Virginia	1926 – 1992	1,000,000
West Virginia	1921 – 1992	925,000
Wyoming	1949 – 1953	70,000

## **2.6 Deer Restocking Successes in the United States**

In the eastern States, the success of state deer restocking efforts was accelerated by five primary factors:

1. deer population dynamics,
2. large scale landscape modifications,
3. reductions in natural predators,
4. relocation of American Indians, and
5. reduced hunting pressures.

Collectively, these factors created a situation which resulted in an explosive population increase in white-tailed deer in a relatively short period of time.

## **2.7 Deer Population Dynamics**

Deer populations increase, decrease or remain stable in a balance between reproduction and mortality (Pierce et al., 2011). Deer have extremely high reproductive potential and their populations can increase rapidly (DeNicola et al., 2000). All species of indigenous deer in the US periodically exhibit sudden increases in population density (Leopold et al., 1947). Historically, these increases, or “irruptions” often coincided closely in time and space with the removal of deer predators, such as cougars and wolves. White-tailed deer have several biological characteristics that contribute to their rapid and prodigious population growth when food is abundant and predators are absent (Paddock and Yabsley, 2007). These characteristics are:

1. longevity,
2. polygamy,
3. short gestation period,

4. early reproductive maturation,
5. high reproductive rate,
6. high offspring survival,
7. tolerance for high densities, and
8. relatively indiscriminate food preferences. (Leopold et al., 1947; Geist, 1998; Paddock and Yabsley, 2007).

In urban settings white-tailed deer live on average 8 to 12 years (Clay et al., 2012). White-tailed deer are a polygamous species (Pierce et al., 2011). Their gestation period ranges between 190 and 210 days. In Missouri, up to 30 percent of fawns breed at 6 months of age and produce offspring by the time they are one year old (Flinn et al., 2012). In addition, the majority of adult does in Missouri produce twin fawns each year. In the absence of predators and hunting, the annual mortality of deer older than 6 months of age is less than 5% (Pierce et al., 2011). Given a suitable environment, white-tailed deer can potentially double in number every two years (Paddock and Yabsley, 2007). Kelker (1947) found deer herds with an even sex ratio can increase at 62% annually in the wild. The white-tail deer population in George Reserve in Michigan increased from 10 deer in 1975 to an estimated 220 deer by 1980 (McCullough, 1984). Unlike most wild mammal species, white-tailed deer can survive at extremely high densities (Leopold et al., 1947). Underwood and Porter (1997) found a white-tailed deer density of 150 deer per square mile (60 deer per square kilometre) in Saratoga National Historical Park. White-tailed deer are very adaptable herbivores that can survive on a wide range of vegetation.

## **2.8 Large Scale Landscape Modifications**

The greatest factor contributing to the rapid increase in deer populations in the US has been increased forage (Cote et al., 2004). Forest protection and intensive agriculture fostered deer population growth (DeNicola et al., 2000). Widespread agriculture dramatically increased deer habitat throughout the 20<sup>th</sup> century (Alverson

et al., 1998; Porter and Underwood, 1999). Forest harvest practices and the resulting interspersed habitats have provided deer with good cover and abundant forage (Diefenbach et al., 1997). Deer population growth was also fuelled by increased numbers of forest canopy openings that have increased forage (Waller and Alverson, 1997). Deer populations increase as forest land is opened up (Seton, 1953; McDonald and Miller, 2004). In the eastern states, many farms, fields and previous harvested forests, abandoned in the 1800s and early 1900s, became reforested by the gradual encroachment of successional trees and shrubs (Paddock and Yabsley, 2007). Fragmented wildlife habitats and suburban sprawl have created the ideal “edge” environment for deer (Clay et al., 2012). Where predators are absent, the urbanization of rural land has led to the transformation of land to higher deer potential. Urban sprawl and suburban development have created extremely productive deer habitat (DeNicola et al., 2000). The biological carrying capacity of urban areas for deer can be over 38 deer per square kilometre (100 deer per square mile) (Lien, 2000). White-tailed deer are very adaptable to urban and suburban environments (Pierce et al., 2011). The abundance of food and protection from natural predators and hunters has led to an increasing number of deer in urban and suburban areas throughout the US (DeNicola et al., 2000).

## **2.9 Reductions in Natural Predators**

Prior to European settlement, cougars (*Puma concolor*) and wolves (*Canis lupus*) inhabited large regions of the US (Figures 2.7 and 2.8). These large carnivores played a significant role in regulating deer populations and keeping deer in relative balance with their habitat (Fuller, 1989; Pierce et al., 2011). It has been estimated that a single cougar kills upwards of 48 ungulates a year (Bieir, 1999). As domestic livestock began replacing native ungulates, wolves gained a reputation as livestock killers (Young and Goldman, 1944). To protect their livestock, European settlers were vigilant in their efforts to eradicate wolves and cougars. By the middle of the 1900s, wolves had been extirpated from most of the US (Paquet and Carbyn, 2003).

Similarly, cougars were eliminated from most of eastern US (McCullough, 1997). Across the US, reductions in natural predators contributed to increased deer populations (Cote et al., 2004). Without natural predators, deer populations increase rapidly (Saether et al., 1996; Messier, 1994; McCullough, 1997; Potvin et al., 2003). The large scale reintroduction of wolves and cougars to their former ranges in the US, albeit very unlikely, could lead to significant reductions in deer populations.

### **2.10 Relocation of American Indians**

One aspect of the pre-European settlement environment in the US that needs further study is the relationship American Indians had on deer populations. Historically, deer were an integral and important part of the American Indian way of life. Prior to the European settlement of North America, deer provided an essential source of dietary protein and the raw materials necessary for many of the necessities for American Indians (Figure 2.9). Many American Indian tribes depended on deer for subsistence (McDonald and Miller, 2004). Through their hunting, American Indians played an important role in deer population dynamics. So important was deer hunting to American Indians, it was one reason US used to substantiate claims for land tenure by these peoples (Anonymous, 1830b). In 1830, the relationship of American Indians and deer in eastern US was permanently altered when the Senate and House of Representatives of the US of America passed the Indian Removal Act (US Government, 1830).

The legislation enabled the US Federal Government to negotiate with the Native Americans for their removal to federal territory west of the Mississippi River in exchange for their ancestral homelands east of the Mississippi River. The removal of Native Americans was supposed to be voluntary process (Library of Congress, 2010). However, great pressure was put on Native American leaders to sign removal treaties.

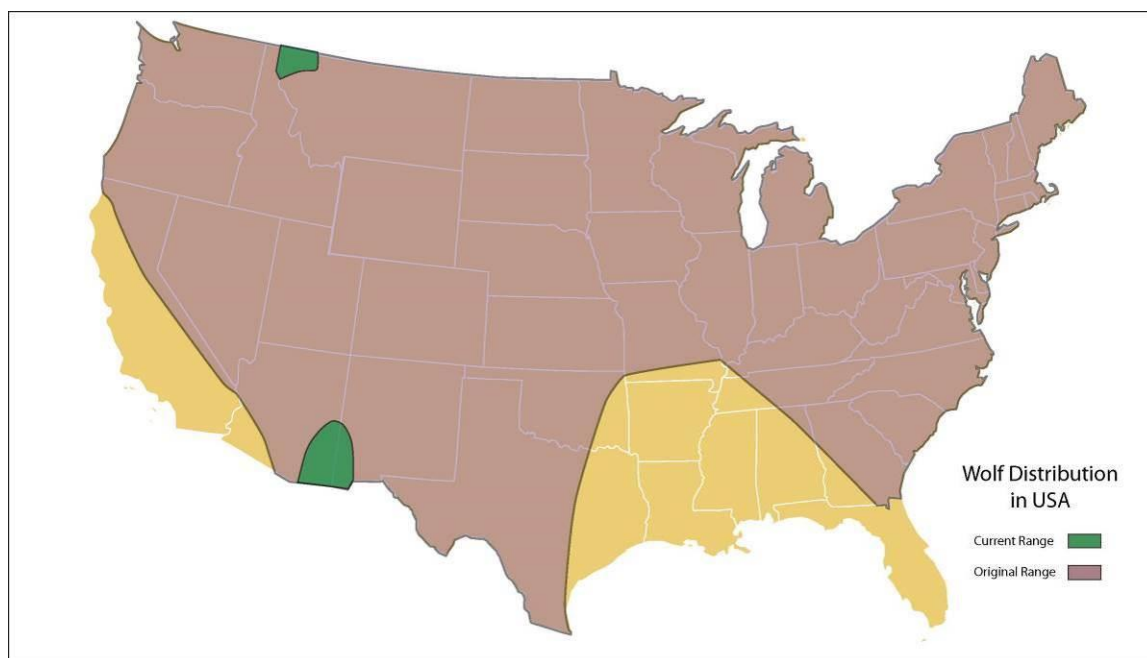


Figure 2.6 Wolf distribution in the US  
(adapted from Banfield (1974) and Grooms (1993))

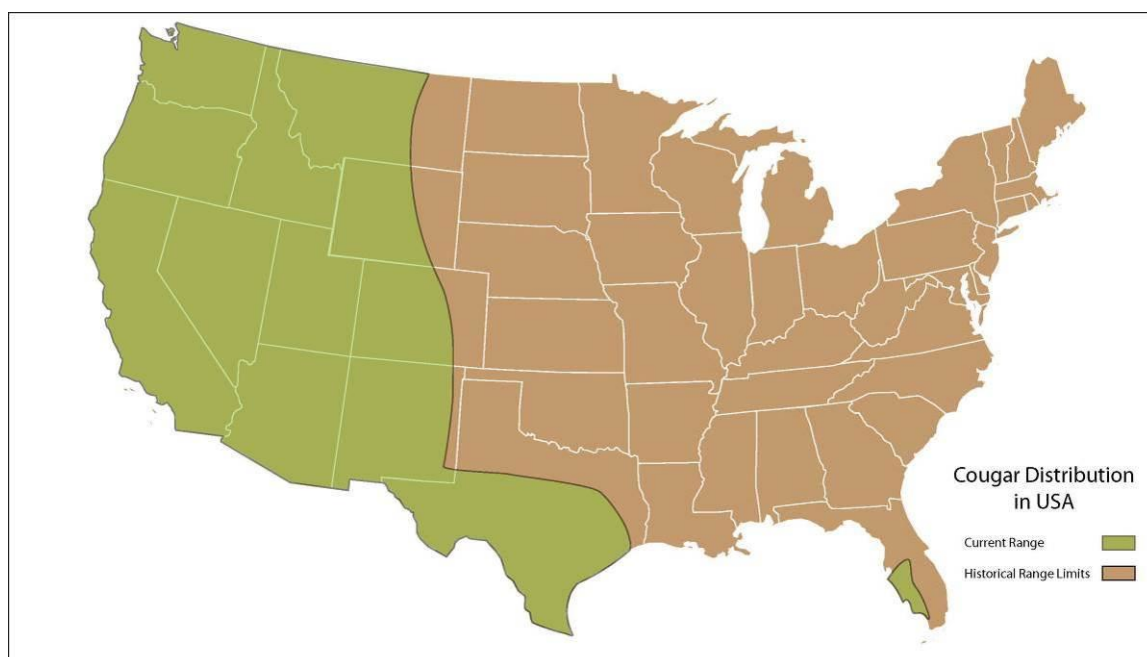


Figure 2.7 Cougar distribution in the United States  
(adapted from Danz (1999) and Bowers et al. (2004))



Figure 2.8 American Indian preparing deer hide in 1941  
(Source: United States Indian Service)

The passage of the act signalled the inevitable removal of most American Indians from states east of the Mississippi River. The Indian Removal Act resulted in the mostly forced emigration of approximately 90,000 American Indians (Anonymous, 1830a). Thousands of forcibly relocated American Indians died along the “Trail of Tears.” The relationship of American Indians to deer populations in the eastern States prior to 1830 appears not to have been studied. The effect on deer populations caused by the large scale absence of American Indian hunters in the States where deer restocking initiatives occurred also appears not to have been studied. However, if one assumes each of the 90,000 American Indians relocated by the Indian Removal Act consumed the equivalent of one deer a month year, over 1 million deer a year would have been harvested from the deer herd population. It is conceivable the number of deer harvested for consumption in the eastern States would have been significantly greater now, if the relocated American Indians had remained in their ancestral land, and increased at the same rate as that of the white inhabitants, and deer had remained

a dietary staple for the American Indians. Continued deer hunting by American Indians in the eastern States may have played an important role in controlling deer populations, and thus reducing the potential for deer-vehicle collisions.

## **2.11 Reduced Hunting Pressures**

Today hunting is the primary factor governing deer populations in rural and urban areas (Mormann et al., 2012). In the absence of hunting, the annual mortality of deer older than 6 months of age is low (Pierce et al., 2011). Since the 1920s, strict hunting regulations in the US have resulted in increased deer populations (Cote et al., 2004). This effect was most dramatic on some private lands and in parks, where hunting was banned completely (Diefenbach et al., 1997; Porter and Underwood, 1999; Brown et al., 2000). Where deer hunting has been allowed, state game laws have favoured the hunting of males, thus increasing female survival and continued population growth (Ozoga and Verme, 1986). The deer population increased from the 1960s to 1970s due to reductions of hunting pressures (McShea et al., 1997). However, the number of deer hunters in the US stabilized or decreased with diminishing social acceptability of hunting (Brown et al., 2000; Enck et al., 2000; Riley et al. 2003). Between 1991 and 2006, the total number of hunters in the US declined from 14.1 million to 12.5 million (US Department of the Interior, Fish and Wildlife Service and US Department of Commerce, US Census Bureau (2001); US Department of the Interior, Fish and Wildlife Service and US Department of Commerce, US Census Bureau (2006). Concurrently, in response to hunting safety issues, private land owners and municipalities in the US have been increasingly reluctant to permit hunting (Kilpatrick et al., 2002). State game hunting laws have been reformed to allow the hunting of more female deer and fawns. Removing does and fawns from the general deer population would reduce reproduction rates. However, hunters in the US have been reluctant to hunt these segments of the deer population (Riley et al., 2003; Cote et al., 2004).

## **2.12 Animal-Related Vehicle Collisions in the United States**

Each year in the US, approximately 4.0% of light-vehicle (e.g. passenger cars, sport utility vehicles, vans and pickup trucks) collisions involve striking an animal (National Highway Traffic Safety Administration, 2003). In 2001 to 2002, deer represented the most common large animal involved in these collisions (86.9%). Approximately half (54.5%) of the animal-related collisions involved a direct impact with the animal, and the remainder (44.8%) resulted from the driver attempting to avoid striking the animal. Of those collisions in which the driver tried to avoid the animal, 29.0% involved the vehicle leaving the roadway, 21.4% involved the vehicle striking a tree, pole or guardrail, and 17.3% involved the vehicle rolling over. In 2002, deer collisions accounted for nearly 16% of all police-reported motor vehicle collisions in Wisconsin (Wisconsin Department of Transportation, 2003)

## **2.13 Human Fatalities and Injuries Related to Deer-Vehicle Collisions**

The number of human fatalities resulting from animal-vehicle collisions has been rising over the late twenty years (Table 2.3). Deer represented the most common large animal involved in these collisions (National Highway Traffic Safety Administration, 2003). In 2011, 7.9% of passenger cars and 5.3% of utility trucks involved in deer collisions resulted in a fatality or injury to an occupant (Wisconsin Department of Transportation, 2012). In the US, between 2001 and 2002, most injuries sustained in large animal were strains/sprains (36.5%) and contusions/abrasions (33.9%), and involved the head/face (28.1%), neck (22.7%) and upper torso (15.3%) (Center for Disease Control, 2004). The majority (94.5%) of the neck injuries were strains and sprains while 62.5% of the head/face injuries were contusions, abrasions or lacerations.

Table 2.3 Human fatalities in animal-related collisions by United States states (1993-2007)  
Source: Highway Loss Data Institute (2008)

State	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Alabama	0	3	2	5	1	3	3	4	3	4	1	4	2	4	2	41
Alaska	2	1	1	2	1	3	1	1	3	1	3	2	1	2	6	30
Arizona	4	2	2	2	2	7	2	2	1	3	3	4	2	1	5	42
Arkansas	2	0	2	3	3	4	3	2	3	3	2	2	3	2	1	35
California	4	6	9	6	5	3	5	3	8	9	2	5	3	7	4	79
Colorado	3	1	3	4	3	5	6	5	6	7	2	4	6	4	3	62
Connecticut	0	0	0	0	0	0	0	0	1	2	1	0	0	1	0	5
Delaware	0	0	0	1	0	0	0	1	2	1	1	2	1	0	0	9
Florida	2	5	0	2	6	6	6	1	4	3	8	5	0	6	4	58
Georgia	4	8	3	2	4	4	2	4	6	9	9	5	3	4	8	75
Hawaii	0	0	0	0	1	0	0	2	1	1	0	1	0	0	0	6
Idaho	1	2	0	4	3	2	1	3	0	2	2	3	3	6	1	33
Illinois	8	7	2	8	2	6	5	5	6	4	7	7	11	2	5	85
Indiana	3	2	5	5	1	6	4	4	6	4	3	5	3	4	4	59
Iowa	0	1	1	4	4	4	2	1	3	3	11	3	4	10	11	62
Kansas	0	2	2	9	7	4	1	3	3	4	0	4	4	5	8	56
Kentucky	3	2	2	4	2	4	1	2	3	3	3	4	6	4	4	47
Louisiana	2	1	3	2	0	2	2	2	3	0	3	2	3	3	3	31
Maine	2	0	3	3	0	5	3	3	1	3	5	5	2	2	5	42
Maryland	0	3	0	0	1	0	4	3	0	1	4	1	0	3	2	22
Massachusetts	0	0	0	0	0	1	2	0	1	0	1	0	0	0	2	7
Michigan	4	2	7	6	4	4	6	2	9	2	8	2	8	12	11	87
Minnesota	4	3	6	5	3	2	3	2	6	8	7	9	3	6	7	74
Mississippi	2	6	4	3	3	1	4	5	5	2	5	1	5	2	5	53
Missouri	2	2	3	1	6	3	8	6	5	7	7	6	4	4	5	69
Montana	5	1	6	1	8	2	2	2	0	3	3	3	8	7	6	57
Nebraska	1	1	1	3	4	2	2	2	0	0	2	3	4	4	1	30
Nevada	0	0	2	1	0	0	0	3	2	4	0	1	1	1	2	17
New Hampshire	0	1	0	0	1	2	2	2	2	1	2	3	1	1	1	19
New Jersey	1	0	2	0	0	2	1	6	1	3	2	2	3	2	0	25
New Mexico	1	3	0	2	2	2	2	2	2	1	4	7	2	5	1	36

Table 2.3 Human fatalities in animal-related collisions by United States states (1993-2007) (continued)  
Source: Highway Loss Data Institute (2008)

State	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
New York	2	4	2	7	5	12	5	5	4	1	7	6	6	4	5	75
North Carolina	2	4	5	3	0	4	5	0	7	3	6	7	4	1	9	60
North Dakota	1	1	0	1	1	0	1	2	0	1	0	3	2	3	2	18
Ohio	3	3	0	4	2	5	7	6	5	7	8	8	11	14	10	93
Oklahoma	2	7	4	3	1	5	5	6	3	7	5	7	8	8	6	77
Oregon	1	3	6	3	1	0	1	1	1	1	2	0	2	2	4	28
Pennsylvania	6	11	6	5	3	5	3	4	6	13	16	3	9	13	9	112
Rhode Island	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
South Carolina	2	1	1	0	4	4	5	3	9	4	5	3	3	7	4	55
South Dakota	2	1	0	1	2	1	2	3	4	6	2	6	1	2	3	36
Tennessee	4	6	1	4	3	1	1	2	4	2	3	3	3	2	6	45
Texas	9	12	5	19	18	18	6	15	14	15	20	18	14	27	17	227
Utah	0	2	0	1	2	2	5	2	4	3	1	7	1	2	4	36
Vermont	0	0	2	0	1	1	3	2	0	0	2	0	1	1	2	15
Virginia	1	2	1	2	1	2	6	3	4	1	1	1	6	6	4	41
Washington	0	1	2	1	0	6	5	1	1	2	4	7	0	1	2	33
West Virginia	2	0	4	1	3	1	1	5	4	0	6	4	2	1	2	36
Wisconsin	3	5	9	6	10	5	6	6	11	5	11	13	10	8	15	123
Wyoming	1	3	4	4	2	4	2	1	0	1	2	3	1	6	1	35
TOTAL	101	131	123	153	136	165	152	150	177	170	212	204	180	222	223	2,499

#### **2.14 Cost of Deer-Vehicle Collisions to the Insurance Industry**

Estimates on the cost of deer-vehicle collision vary dramatically. The average cost of a deer-vehicle collision is approximately \$4500US (Huijser et al., 2008). According to State Farm Mutual Automobile Insurance Company (2009), the average insurance claim for a deer-vehicle collision in the US in 2009 was \$3,050US. In Pennsylvania, deer-vehicle collisions cost insurers more than \$31,000US per incident (McGuinness, 1997).

#### **2.15 Cost of Deer-Vehicle Collisions for the United States Federal and State Governments**

The cost implications of deer-vehicle collisions for the federal and state governments in the US have not been comprehensively studied. However, according to Miller et al. (2011), the costs of motor vehicle collisions, paid in full, or in part, by federal, state and local governments can be considerable (Table 2.4). While the average combined cost of law enforcement services and department of transportation collision scene management and maintenance, borne by the state, is approximately \$175US per deer-vehicle collision (Huijser et al., 2008), medical costs and income and sales tax losses account for 75% of the motor vehicle collision costs borne by governments.

#### **2.16 Economic Implications of Deer-Vehicle Collisions to the United States**

Although the cost of deer-vehicle collisions is estimated to be \$8US billion, the total economic implications of deer-vehicle collisions to the US is unknown. The true costs of injuries and fatalities associated with motor vehicle collisions are difficult to quantify (European Commission, 2013). Medical and rehabilitation expenses can be extremely high, and often continue for an indefinite period, particularly in the case of serious motor vehicle collision-related disabilities.

Table 2.4 Cost of motor vehicle collisions to federal, state and local governments in the United States  
(Adapted from Miller et al., 2011)

Government Cost Type	Cost Components
Public services	Police, fire and emergency medical services at the collision scene, coroner or medical examiner services for fatalities, and vocational rehabilitation and social services ofr the injured and their families.
Medical care	Emergency department, hospital, physician's office, rehabilitation, mental health, nursing home, and pharmaceutical services for injury victims paid through Medicare, Medicaid and other public medical insurance programs.
Foregone taxes	Income and sales tax revenues fall because the injured have less income and the dead are lost to the workforce.
Social safety net expenses	Social services and public assistance payments (Social Security Disability Income), welfare, food stamps, housing assistance, low income home energy assistance, and other programs that assist people when injury leaves them permanently disabled or indigent.
Property damage	Damage to roadside furniture (fences, median barriers, light standards, etc.)

The cost of prolonged medical and personal care, rehabilitation costs, the loss of a primary breadwinner, funeral costs, and the loss of income due to disability, can push a family into poverty (Hijar et al., 2003; Nantulya and Reich, 2003). Long term disability brings many intangible costs to those injured and their families (European Commission, 2013). The devastating consequences of motor vehicle collisions are far greater than can be measured and expressed in economic terms (Bačkaitis, 2000). Medical costs and lost productivity do not adequately capture the psychosocial losses associated with motor vehicle collisions, either to those injured or to their families (European Commission, 2013). Were they accurately quantifiable, the costs of psychosocial losses exceed the medical costs and productivity losses associated with premature human death. There is a high rate of psychosocial complications following motor vehicle collisions, even for minor injuries, for those injured or their families.

Economic costs are only one aspect of motor vehicle collisions (Bačkaitis, 2000). Injured motorists often suffer physical pain and emotional distress beyond that measured by financial compensation. Permanent disabilities, such as paraplegia, quadriplegia, loss of sight, or brain damage, can render an individual dependent on others for long-term economic support and physical care. More common minor injuries, to ankles, knees, and cervical spine, can result in chronic physical pain and limit a injured person's physical activities and quality of life for years. Permanent disfigurement due to contusions and lacerations can result in ongoing emotional and psychological trauma. From an individual perspective, these can be the most devastating consequences of a motor vehicle collision, regardless of any financial compensation provided through insurance, social welfare or legal channels. Long term disability can bring upon many intangible costs for those injured and their families. (European Commission, 2013).

Significant repercussions are felt by those close to motor vehicle collision victims (Bačkaitis, 2000). The provision of care for a disabled person often represents a considerable burden to families, both economically and emotionally, limiting or

precluding individual and family activities. The emotional repercussions of an individual's physical injuries can often lead to personality problems and drastically alter family dynamics and personal relationships. Motor vehicle collisions can result in a wide range of long-term psychiatric and psychosocial problems (European Commission, 2013). Sudden, unexpected and permanent separation from loved ones can cause periods of grief, anguish, guilt, fear, insecurity and withdrawal, often lasting for many years (Bačkaitis, 2000).

The Fédération Européenne des Victimes de la Route (FEVR) (1993) conducted a comprehensive European study of the physical, psychological and material damage suffered by motor vehicle collision victims and their families. The results showed 85% of the families of those disabled and 90% of the families of those killed reported a significant permanent decline in their quality of life. Over 29,000 persons are injured in deer-vehicle collisions each year in the US. Those injured in these collisions also experience psychological distress (Blanchard and Hickling, 2004). The symptoms of psychological distress include Post Traumatic Stress Disorder (PTSD) and depression. The symptoms can arise immediately after a collision, or months later. From the literature, it appears little is known about the psychological impacts of deer-vehicle collisions on the human survivors. Given deer-vehicle collisions can result in permanently crippling and disfiguring injuries, the psychological consequences on those injured must be significant.

### **2.17 The Future of Deer Populations and Deer-Vehicle Collisions in the United States**

Deer have expanded their geographic range across the US and increased in abundance in recent decades (Cote et al., 2004). Leopold et al. (1947) were the first researchers to describe the threats posed by the growing number of deer. Leopold's warnings prompted a period of concern in the 1940s and 1950s in the Midwestern US states. Although deer represent a hazard to drivers in all States, most state departments of transportation do not have a mandate for managing deer populations. This

responsibility normally lies with departments of natural resources. Unfortunately for drivers, the prospects for significant reductions in deer populations appear poor, at best. Deer management paradigms based on the jumble of ecological and political definitions of carrying capacity obscure important relationships among ecosystem elements and fail to resolve the controversy surrounding the management of deer in the US as its deer population have grown (deCalesta and Stout, 1997).

There are no easy answers or solutions for dealing with the growing deer population in the US (Warren, 1997). The deer over-abundance problem is not simply a biological or ecological one. The more challenging aspects of this problem are the social, political, legal and economic ones. The challenge of managing the deer population will become increasingly complicated as human population growth continues and urban/suburban development expands, and as social values regarding deer and their place in human environments evolve (Warren, 1997). Given increasing deer populations, and in the absence of comprehensive, effective, and large-scale deer population control, state governments will need to take steps to advise drivers in their states of the increasing potential for deer-vehicle collisions.

### **3.0 COMMUNICATING THE DEER HAZARD TO NEW DRIVERS WITH STATE DRIVER MANUALS**

*“Ignorant, unskilled and incapable drivers get into many accidents. However, records indicate that a large number of accidents by people who know how and are capable of driving properly and safely, but will not recognize potential hazards or accept the definite responsibility in the operation of a motor vehicle.” (Nevada Department of Transportation, 1969, p.4)*

#### **3.1 Introduction**

Deer represent a significant hazard to drivers in the United States (US). Their widespread distribution across the country increases the potential for drivers to encounter these wild animals on rural, urban and suburban roads and highways (Figure 3.1). One avenue for state governments to advise new drivers about deer and the hazard they pose is to include information about deer in state driving manuals. While these manuals are used to educate new drivers as a complement to state driver licensing (Eck and Williams, 1992), there appear to be no published reviews of how effective the manuals are for communicating to new drivers the hazards posed by deer or other wildlife (Figure 3.2). The purpose of the research presented in this chapter is to conduct a comprehensive, nation-wide, historical retrospective review of the state driving manuals published over the period the deer-vehicle collision phenomena in the United States evolved. The review attempted to determine if, and how, new drivers had been advised of the hazard deer pose on roads and highways. Attention was given to those US states that have experienced the highest rates of deer-vehicle collisions over the last decade.

#### **3.2 Research Background**

Driver licensing is a very significant component for ensuring highway safety (Nuckols and Clark, 1974). All 50 US states require driver license applicants

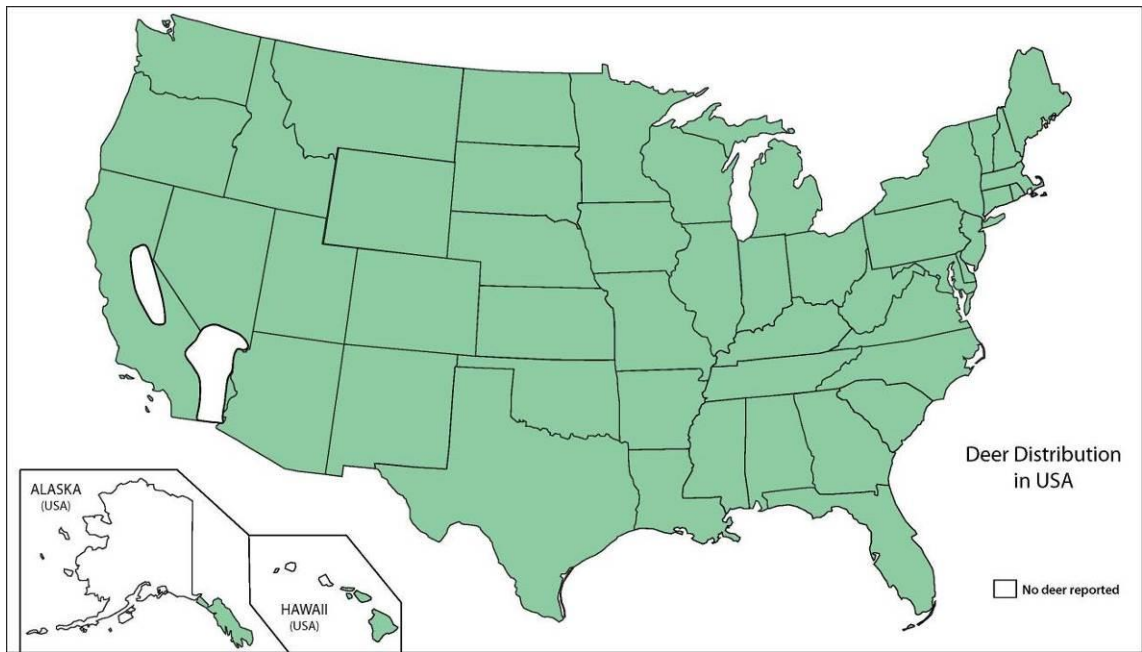


Figure 3.1 Distribution of deer in the United States (adapted from Rue (1978))

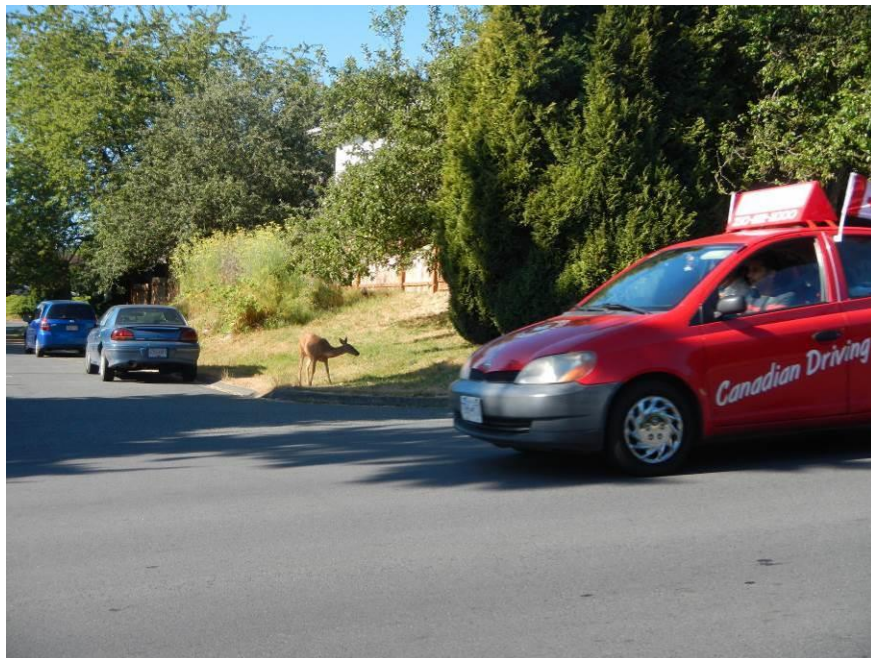


Figure 3.2 Deer and new drivers

demonstrate their readiness for the road by passing both knowledge and applied driving tests (Henk et al., 1984). For the most part, these tests assess how well the applicants have learned and mastered key concepts. Driver manuals are the principal media provided by state driver licensing agencies for communicating driving safety to new drivers (Eck and Williams, 1992). The manuals are instructional and informational publications designed to support state driver safety objectives (Stahl et al. 1995). They are typically printed, pocket-sized booklets that contain relevant information about traffic rules, laws and regulations for driving in a particular state (Eck and Williams, 1992). While these manuals vary from state to state, their fundamental objectives are the same:

1. Prepare the driver license applicant for the state driver's examination, and
2. Provide licensed drivers a reference source for driving information (Nuckols and Clark (1974).

Driver manuals represent an important source of information on state traffic regulations and driving safety (Henk et al., 1984; Stahl et al. 1995). State driver manuals provide a foundation of driving knowledge that influence a new driver's preparedness to operate a vehicle safely (Stahl et al. 1995). For many new drivers, reading and studying a state driver manual constitutes the only intensive exposure they have to traffic safety and driving rules (Henk et al., 1984; Stahl et al., 1984). As driver education in US high schools is being phased out, state driver manuals seem destined to become the only formal written source of information about driving hazards for new drivers (Sarkar et al. 1999). Despite the important role that state driver manuals play in informing and teaching the rules of the road to new drivers (Eck and Williams, 1992), only sporadic research has been undertaken that specifically focuses on the kinds of information provided to new drivers by these government publications. Nuckols (1972) conducted probably the first comprehensive review of state driver manuals available for new drivers in US states

in 1970. He examined 49 manuals and found their quality and completeness varied greatly from state to state. Many manuals had significant shortcomings, including a lack of indexes and tables of contents. While most state driver manuals provided the most complete information about driver's license information, 38 out of the 49 manuals reviewed did not advise that drivers needed to be aware of possible emergency situations. Fifty-six percent of the manuals were found to provide no information on the value of wearing seat and shoulder belts.

In their review of 50 state driver manuals, Henk et al. (1984) found their quality and completeness varied from state to state, and that most were difficult to understand. From their review of 49 state driver manuals published in early 1989, Eck and Williams (1992) commented that no two driver manuals appeared the same. There was no standardized format. Their observations echo the observations of other researchers (Nuckols, 1972; Nuckols and Clark, 1974; Henk et al., 1984). According to Nuckols (1972), Nuckols and Clark (1974) and Eck and Williams (1992), state driver manuals should have some uniformity and consistency, and should all provide an introduction to a minimum set of topics. Sarkar et al. (1999) reviewed the driver manuals of 32 states and the District of Columbia to evaluate the quality and level of information provided about the adverse interactions with pedestrians at intersections. They found that none of the state driver manuals provided statistical information or explanation on pedestrian-vehicle conflicts at intersections. There was no information provided on the most hazardous movements, nor were illustrations and/or photographs depicting the hazards provided. Sarkar et al. (1999) determined the driver manuals were inadequate and needed significant improvement. They felt, with simple graphs and photographs, driver manuals could play a significant role in guiding new drivers to avoid pedestrian-vehicle conflicts at intersections.

### **3.3 Research Methodology**

Efforts were made to collect a copy of every state driver manual ever developed for perspective new drivers of passenger vehicles by every US state driver licensing authority. Particular attention was given to the driver manuals produced from the 1950's onward, a period when the deer population in the United States began to increase rapidly. Each driver manual was examined to identify what basic information regarding the hazard deer pose for drivers was provided. A more comprehensive comparison was made of the driver manuals of the ten US states identified with the greatest likelihood of deer-vehicle collisions over the last decade, a period with the greatest number of deer-vehicle collisions recorded in the last three decades. Information shortcomings of the driver manuals were examined.

#### **3.3.1 Data Collection**

In order to examine how US state driver licensing authorities have advised new drivers of the deer hazard, a collection of over 300 state driver manuals for the period between 1912 and 2010 was assembled. Unlike the approach taken by previous researchers who restricted their analyses to current manuals (Nuckols, 1972; Nuckols and Clark, 1974; Henk et al., 1984; Eck and Williams, 1992; Stahl et al. 1995; Sarkar et al., 1999), in this instance, successive manuals spanning several decades were examined including, in a few instances, the very first driver manuals produced by a number of US states. It was not possible to obtain a copy of every state driver manual ever produced. Although millions of state driver manuals were published in the US over the last 100 years, older editions of these government publications can be difficult to locate for research purposes. Driver manuals are extremely ephemeral publications. As a consequence, non-current editions are particularly difficult to locate. The period of use and retention of driver manuals by new drivers is typically very limited. Most state driver manuals are only used for a short period of time while

perspective drivers study for state drivers license examinations. It appears the vast majority of drivers manuals are discarded soon after new drivers obtain their driver's licences. In some states, (i.e. Utah), drivers are encouraged to save their state taxes and return the driver manual when they have completed their driver knowledge examination. Driver manuals have extremely limited enduring educational value because they become immediately out of date when new editions are produced. Many driver manuals published prior to the 1960's were printed on poorer quality, newsprint-like paper, making them very susceptible to wear, deterioration and insect damage. In the warmer, more humid, regions of the United States (Louisiana, Mississippi, etc.), unprotected poorer quality paper documents tend to deteriorate quickly. Where driver manuals had been held by libraries for public use, the manuals were usually discarded soon after new editions were published. Most state government libraries tend not to have collections of old state driver manuals. For the most part, state driver manuals have not been well archived. Even the Library of Congress, the most comprehensive library in the United States, appears to have only seventeen state driver manuals in its entire collection of state government publications. For decades, some states have published new editions of driver manuals on a semi-regular basis, as changes in state driving laws and regulations occurred. In other states, the publication of driver manuals appears to have been quite a rare phenomenon, with one edition used for most of a decade. In some cases, it appears new versions of state driver manuals were published soon after state elections, as the names of governors are often prominently displayed inside or on the cover of the manuals. For undisclosed reasons, some states, primarily in the 1940's and 1950's, but as late as the 1970's and 1980's, published driver manuals without publication dates. In these cases, where possible, the approximate date of publication was estimated using the terms of office held by government officials, such as governors and motor vehicle licensing agency executives, identified in the manuals. Locating old state driver manuals was not an easy or straightforward task. The search for a representative sample of state driver manuals took approximately three years. Many

of the manuals used in this research were found on the Internet at websites such as Abebooks.com, Alibris.com, Amazon.com, Bonanza.com, and eBay.com, and their affiliates. Often the manuals were sold by individuals disposing of their own personal effects, or the personal effects from the estate of a deceased person. Consequently, at any one time, there was no consistent source of the manuals. On an almost daily basis, I would search Internet websites for state driver manuals and try to buy them. The manuals were purchased from sellers located primarily in the United States. Some manuals were purchased quite easily for a fixed-price, while other manuals were obtained through the unnerving rigours of online auctions. To complicate matters, many of the US-based Internet vendors would not ship their items outside the lower forty-eight US states. In order to work around this obstacle, I established a mail drop at a private residence in the US. I used PayPal to pay for most of the manuals. Unfortunately, some US-based vendors would not accept payments from purchasers located outside the United States. For most of the manuals I was able to purchase, I had them sent to my mail drop, where they were assembled, and then either mailed to me through the US Postal Service, or delivered to me in person in Canada. On one occasion, I traveled to the United States to pick up the manuals at my mail drop. I was also able to obtain a considerable collection of manuals from Dr. Norman A. Stahl, Professor Emeritus, College of Education, Northern Illinois University. Without Dr. Stahl's generous and significant contribution to my research, my analysis would have been severely limited.

### 3.3.2 Data analysis

Due to the relative scarceness of material predating the 1950's, the review of state driver manuals focused on the period between 1950 and 2010. This interval coincides with the period in which the majority of licensed drivers in the US obtained their driver licenses. Following the basic approach taken by earlier researchers (Nuckols, 1972; Nuckols and Clark, 1974; Henk et al., 1984; Eck and Williams,

1992; Stahl et al. 1995; and Sarkar et al., 1999), I examined the state driver manuals for elements that pertained to deer and the hazard they pose for drivers. For each manual, I focused my attention to text and illustrations that I believed would provide a new driver with the information they required to be cognisant of deer as a driving hazard. When examining each manual I specifically looked for examples of deer warning signs (Figure 3.3). These signs included those mandated for use by US states by the Manual on Uniform Traffic Control Devices (MUTCD) published by the US Department of Transportation (US Department of Transportation, 2000). The MUTCD establishes national standards for traffic control devices used by federal, state and local governments and is intended to ensure drivers are provided consistent direction by nationally consistent traffic control devices. The MUTCD W-11-3 deer warning sign is the most widely used traffic control device (Knapp and Yi, 2004). Consequently, it is the warning sign most new drivers are likely to encounter in locations where transportation authorities have identified deer to be a potential hazard (Figures 3.4, 3.5 and 3.6).

### **3.4 Results**

Deer warning signs appear not to have been included in any state driver manuals published prior to the 1950s (Figure 3.7). It appears the first time a deer warning sign was included in a state driver manual was in Nevada in 1953 (Nevada Public Service Commission (1953). Nevada continued to be the sole state to include a deer warning sign in its driver manuals until the early 1960s (Nevada State of Nevada Department of Motor Vehicles, 1963) (Figure 3.8). The graphics used in the 1953 and 1963 Nevada state publications are shown in Figure 3.9. By the 1970s, the number of states including deer warning signs in their driver manuals has increased dramatically from one in the 1960s (Figure 3.9) to 15 in the 1970s (Figure 3.10). By the 1980s, 21 states included deer warning signs in their state driver manuals (Figure 3.11) and by the 1990s 24 states did so (Figure 3.12).



Figure 3.3 MUTCD W-11-3 deer warning sign



Figure 3.4 Deer warning sign in rural Washington State



Figure 3.5 Deer warning sign in Northern Arizona



Figure 3.6 Deer warning sign in Flagstaff, Arizona

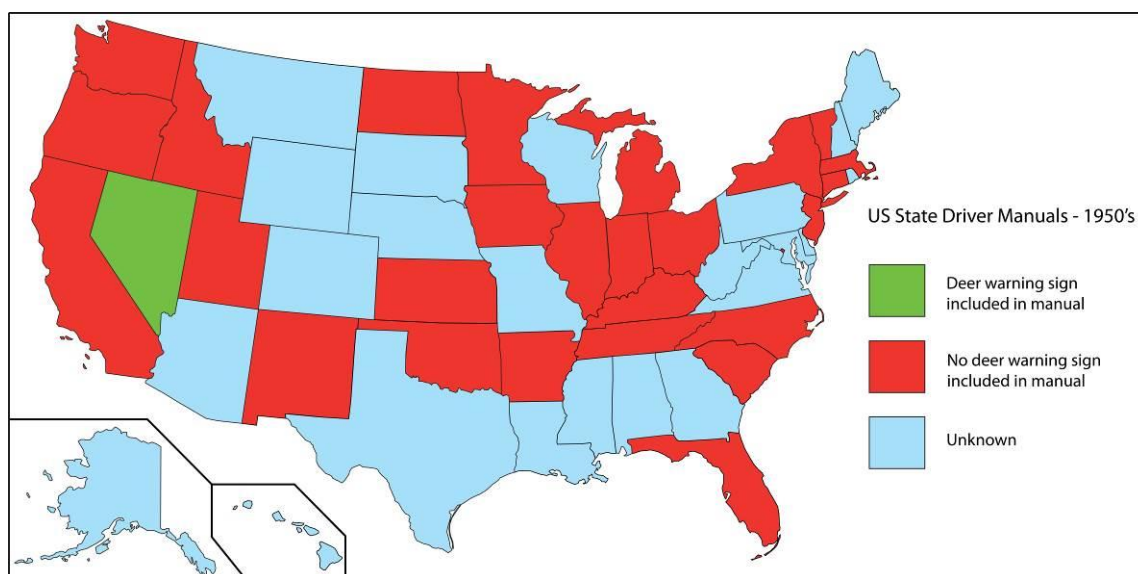


Figure 3.7 US state driver manuals (1950's)

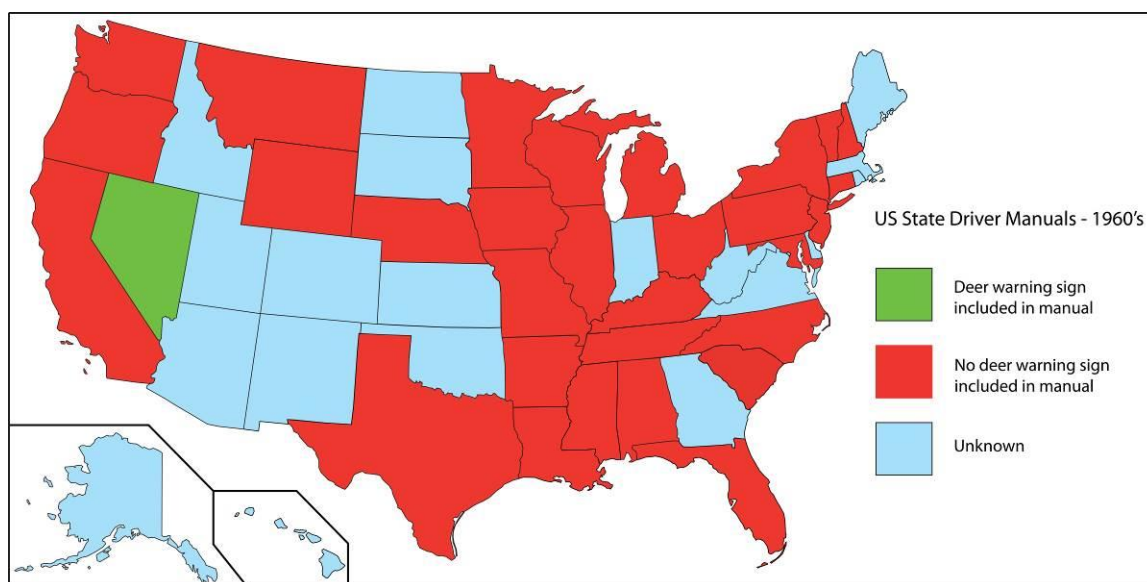


Figure 3.8 US state driver manuals (1960's)

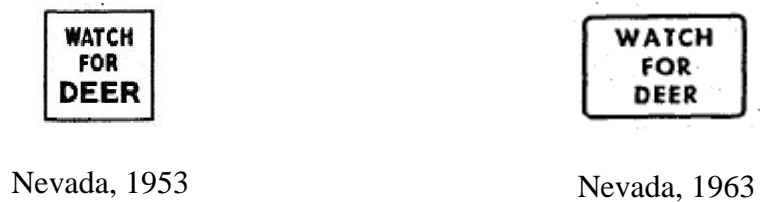


Figure 3.9 Deer warning signs used in Nevada state driver manuals (Sources: Nevada Public Service Commission (1953) and State of Nevada Department of Motor Vehicles (1963))

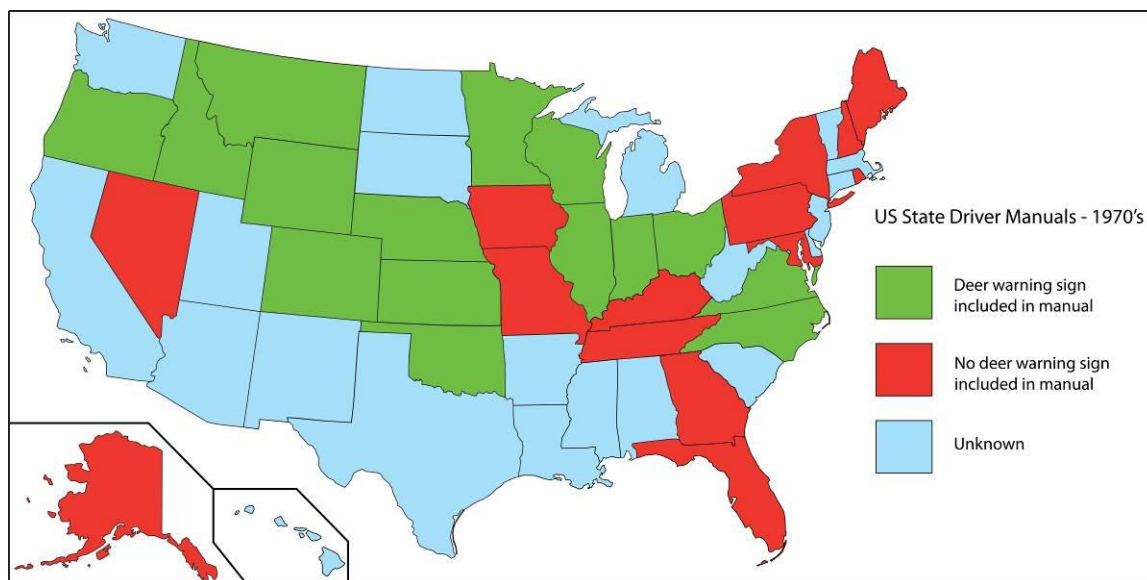


Figure 3.10 US state driver manuals (1970's)

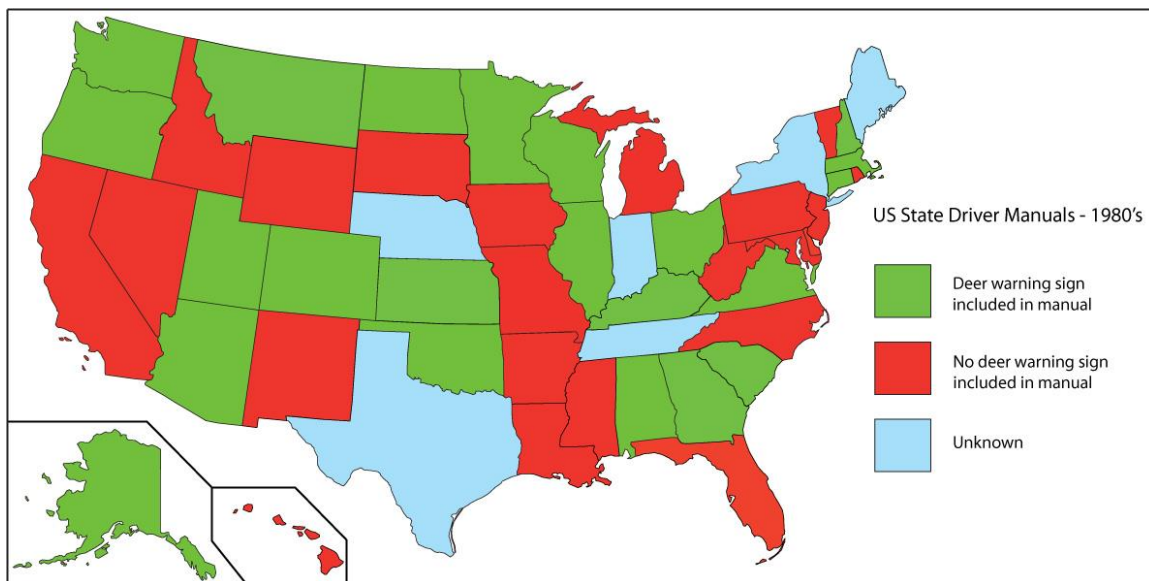


Figure 3.11 US state driver manuals (1980's)

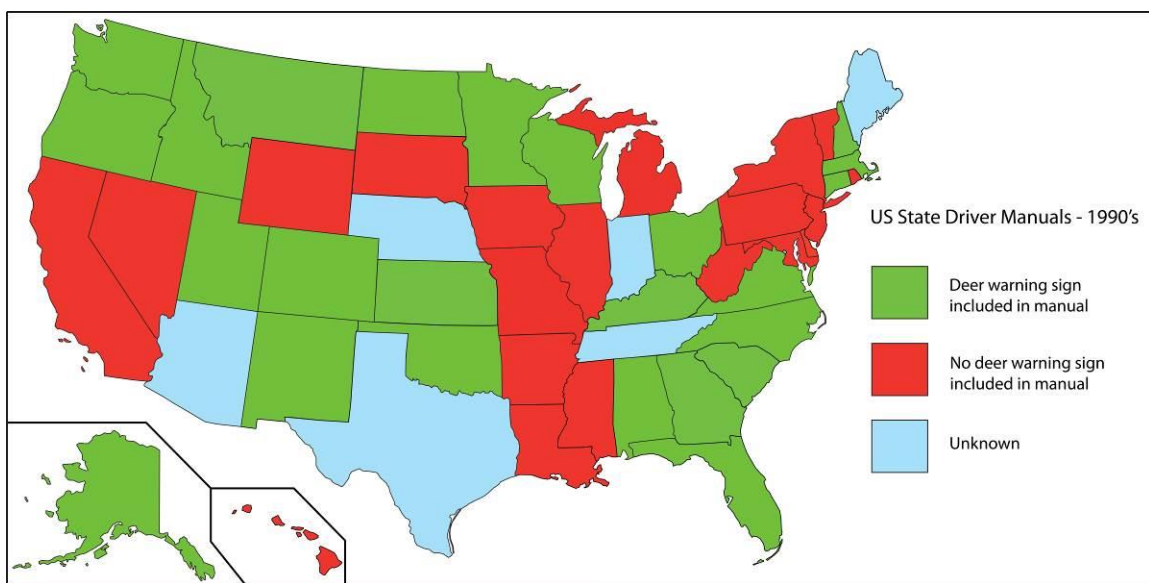


Figure 3.12 US state driver manuals (1990's)

By the 2000s, 28 of 50 US states included a deer warning sign in their driver manuals (Figure 3.13). It might be assumed the increased number of states including a deer warning sign in their driver manuals reflects increased recognition of the growing deer hazard for drivers. However, between the 1990s and the 2000s, two states, Washington and Idaho, removed deer warning signs from their state driver manuals. Furthermore, the inclusion of deer warning signs in state driver manuals does not appear completely related to the severity of the deer hazard. If one compares the states that have deer warning signs in their driver manual with those states that do not in Figure 3.13 with the estimated severity of the deer hazard in all the states shown in Figure 3.14, it is apparent some states with serious deer problems do not use their driver manuals to advise new drivers of the situation.

### **3.5 Comparison of Driver Manuals of the Ten US States with the Greatest Likelihood of Deer-Vehicle Collisions**

To determine if US states are taking steps to increase the amount of information about deer provided to new drivers, I compared the state driver manuals published in the early 2000s with those published in the early 2010s for the ten states with determined to have the greatest likelihood of deer-vehicle collisions by the State Farm Mutual Automobile Insurance Company. The state driver manuals were evaluated with respect to the following topics:

1. Deer mentioned in any format,
2. Deer warning sign example,
3. Description of deer warning signs,
4. Supplementary deer warning sign tab example,
5. Physical characteristics of deer,
6. Geographic distribution of deer,
7. Diurnal variation in deer movement,
8. Seasonal variation in deer movement,

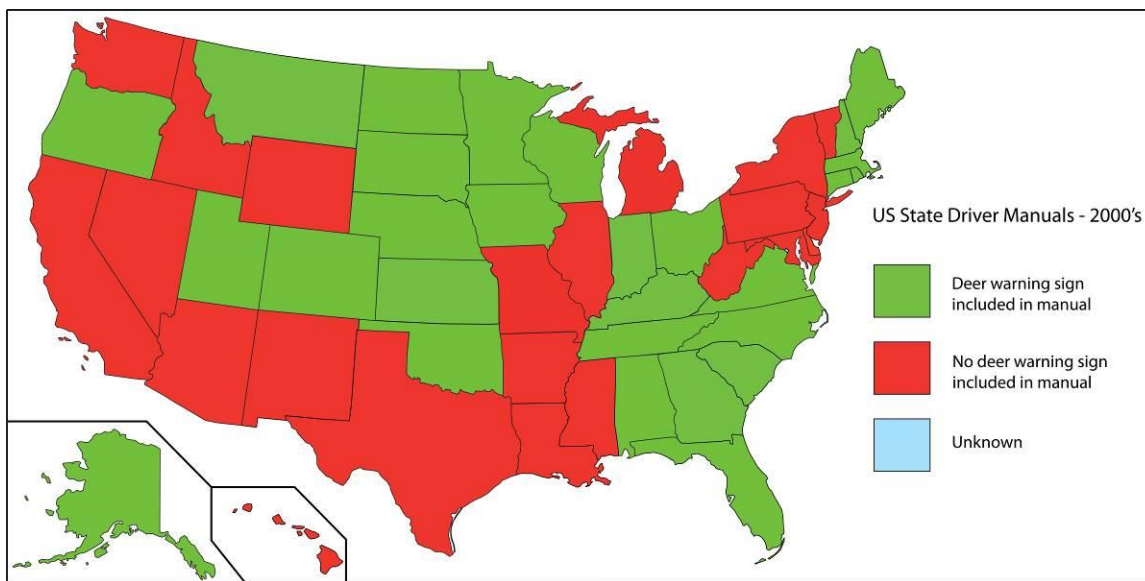


Figure 3.13 US state driver manuals (2000's)

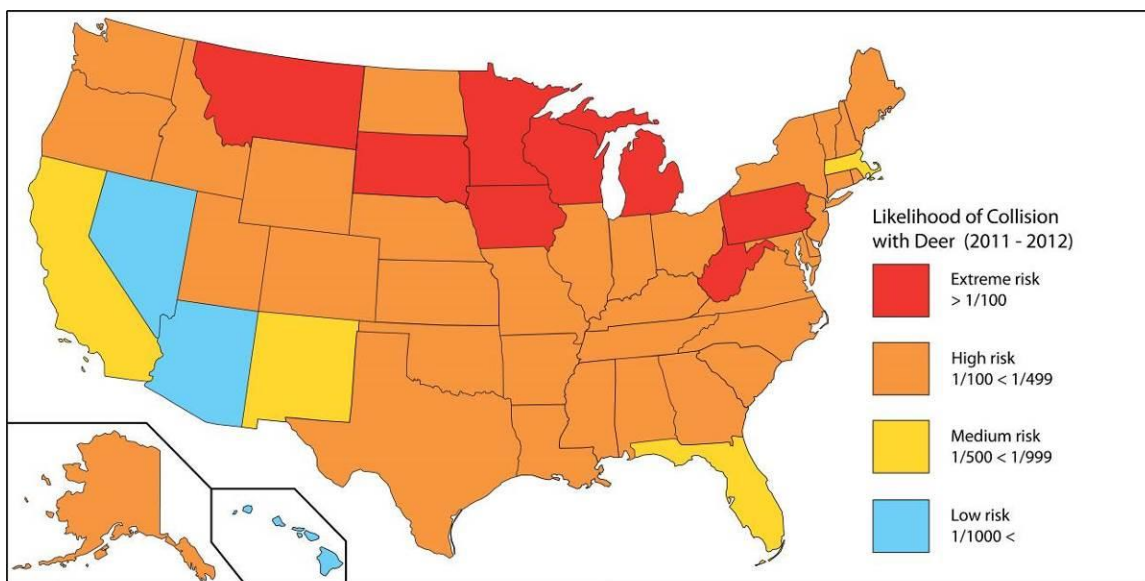


Figure 3.14 Likelihood of collision with deer in the United States (2011/2012)  
 (Data Source: State Farm Mutual Automobile Insurance Company (2012))

9. Deer behavior,
10. Consequences of deer collisions,
11. Strategies for anticipating deer,
12. Strategies for reducing the consequences of deer collisions, and
13. Post-collision advice.

These elements were selected as providing the essential information necessary for a driver to be adequately aware of deer, the hazard they represent, techniques for avoiding deer collisions and reducing the severity of collisions, and dealing with the aftermath of a collision. The results of the analysis are shown in Tables 3.1 and 3.2. The tables show, even among the states with the greatest likelihood of deer-vehicle collisions, new drivers are not being provided information in a consistent or complete manner.

### **3.6 Discussion**

It appears there has never been a consistent approach used by US states to advise new drivers of deer and the hazard they pose for driving in state driving manuals. Many state driver manuals reviewed lacked an example of the deer warning sign mandated for use in all US states by the United States Department of Transportation. Most lacked factual information about the physical characteristics of deer, or their geographic distribution and seasonal activities. The consequences of deer collisions are not portrayed in any detail as even the potential for human death and permanently crippling or disfiguring injuries is not mentioned. While some states have done a very good job of provide comprehensive information to new drivers, some states have not. Although the deer hazard for drivers has been increasing across the US, and in particular the eastern US states, over the last fifty years, even now, a large number of state driver manuals have not identified deer as a hazard of any kind to new drivers. Of particular concern are the states which have high rates of deer-vehicle collisions

Table 3.1 Driver manuals of the ten US states with the greatest likelihood of deer-vehicle collisions available in 2008

State	Arkansas	Iowa	Michigan	Montana	North Dakota	Pennsylvania	South Dakota	Virginia	West Virginia	Wisconsin
National Deer Collision Rankings (2008/2009) State Farm (2008)	6	4	2	5	9	3	7	10	1	8
Projected number of deer collisions	18,974	32,427	104,561	9,103	5,215	105,843	8,056	48,303	30,203	43,392
Likelihood of deer collision/licensed driver	1/106	1/104	1/78	1/104	1/136	1/94	1/107	1/137	1/39	1/116
State Driver Manual										
a) Publication Year	2004	2005	2004	2004	2003	2005	2005	2005	2004	2004
b) Deer-related Information										
1. Deer mentioned in any format	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes
2. Deer warning sign example	No	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes
3. Description of deer warning signs	No	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes
4. Supplementary warning sign tabs	No	No	No	Yes	No	No	No	No	No	No
5. Physical characteristics of deer	No	No	No	No	No	No	No	No	No	No
6. Geographic distribution of deer	No	Yes	No	No	No	No	Yes	No	No	Yes
7. Diurnal variation in deer movement	No	Yes	Yes	No	No	No	No	No	No	Yes
8. Seasonal variation in deer movement	No	Yes	No	No	No	No	No	No	No	Yes
9. Deer behavior	No	Yes	Yes	No	No	No	Yes	No	No	No
10. Consequences of deer collisions	No	Yes	No	No	No	No	No	No	No	Yes
11. Strategies for anticipating deer	No	Yes	Yes	No	No	No	No	No	No	Yes
12. Strategies for reducing the consequences of deer collisions	No	Yes	Yes	No	No	No	No	Yes	No	Yes
13. Post-collision advice	No	No	Yes	No	No	No	No	No	No	Yes

Table 3.2 Driver manuals of the ten US states with the greatest likelihood of deer-vehicle collisions in 2012

State	Arkansas	Iowa	Michigan	Montana	North Dakota	Pennsylvania	South Dakota	Virginia	West Virginia	Wisconsin
National Deer Collision Rankings (2011/2012) State Farm (2012)	9	3	4	6	12*	5	2	10	1	7
Projected number of deer collisions	20,281	30,117	97,856	9,576	4,586	115,571	8,863	52,369	30,203	52,525
Likelihood of deer collision/licensed driver	1/103	1/72	1/72	1/78	1/105	1/76	1/68	1/103	1/40	1/79
State Driver Manual										
a) Publication Year	2007	2011	2011	2012	2011	2012	2010	2012	2011	2012
b) Deer-related Information										
1. Deer mentioned in any format	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
2. Deer warning sign example	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes
3. Description of deer warning signs	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes
4. Supplementary warning sign tabs	No	No	No	Yes	No	No	No	No	No	No
5. Physical characteristics of deer	No	No	No	No	No	No	No	No	No	No
6. Geographic distribution of deer	No	Yes	Yes	No	No	No	Yes	No	No	Yes
7. Diurnal variation in deer movement	No	Yes	Yes	No	Yes	No	No	Yes	No	Yes
8. Seasonal variation in deer movement	No	Yes	Yes	No	No	No	No	No	No	Yes
9. Deer behavior	No	Yes	Yes	No	No	No	Yes	Yes	No	No
10. Consequences of deer collisions	No	Yes	Yes	No	Yes	No	No	Yes	No	Yes
11. Strategies for anticipating deer	No	Yes	Yes	No	Yes	No	No	No	No	Yes
12. Strategies for reducing the consequences of deer collisions	No	Yes	Yes	No	Yes	No	No	Yes	No	Yes
13. Post-collision advice	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes

that have not even shown their new drivers examples of the W-11-3 deer warning sign mandated for use by the US Department of Transportation. The state driver manuals of many states provide new drivers with no information about deer at all. In 1981, in Louisiana, the written test component of the driver examination consisted of 20 questions taken from the situations depicted in the state driver manual (Louisiana Department of Public Safety, 1981). The manual presented 54 photographs and accompanying statement about traffic rules or safe driving concepts, and 54 questions based on them. Deer, or other wildlife, were not included in the depicted situations. The need for new drivers to be able to recognize the standard deer warning sign may be a more serious problem than one might initially expect. Womack et al. (1981) tested a representative sample of Texas drivers and found their knowledge of basic traffic sign colours and shapes was lacking in the majority of the subjects.

Depending on the type of warning sign, from 41% to 76% of the drivers studied knew that warning signs were yellow, but on average, only about 25% correctly identified the diamond shape. In a later study of Texas drivers' understanding of warning signs, Hawkins et al. (1995) found that only 58% of the study subjects recognized the yellow diamond as the proper background for warning signs. Parham and Ford (1999) found that signs were among the traffic control devices most misunderstood by surveyed teenage drivers in Texas. Parham et al. (2000) recommended the Texas Driver Handbook be supplemented with a notebook for teenage drivers which included illustrations and text explaining sign shapes and sign colours. In their study of Kansas drivers, Stokes et al. (1996) found only 60% of study subjects correctly identified the yellow diamond sign as a warning sign. Only 14% of the study subjects correctly identified the school crossing sign. Stokes et al. (1996) advised the results may have overstated the general population's understanding of warning signs because drivers from the ages of 16 to 24, and over the age of 65, were underrepresented in the sample. Ferguson and Cook (1967) found only 59% of Virginia drivers they studied could correctly identify a yellow diamond sign as a warning sign. Increasing the comprehension of traffic signs partially known by new drivers is easiest by focusing on the full extent of their meaning in driver education (Kirmizioglu and

Tuydes-Yaman, 2012). Two states have taken serious steps to educate new drivers on the deer hazard. The states of Wyoming and Georgia have included accurate and detailed information about deer hazards to their new drivers. The information they provide is the most comprehensive and complete illustration of the deer hazard provided for new drivers of any US state driver manuals.

The following excerpt is from the Wyoming 2006 state driver manual:

*“Because of Wyoming’s abundant wildlife population, collisions with animals, and particularly with deer and other “big-game” animals, are real dangers on Wyoming’s rural highways.*

*Too often they have very negative consequences for both the vehicle and its occupants, as well as the animals themselves. The animals can be killed, and often are, but drivers and occupants can perish too. In addition, vehicles can be damaged beyond repair.*

*While such crashes can occur at any time of the year, they are most prevalent during the fall and spring, while animals are migrating between their summer and winter habitats.*

*Although there is no fool-proof way to avoid a vehicle-animal collision, there are steps you can take to minimize the likelihood of such a crash and lessen the severity of one if it does happen.*

*Drive cautiously and stay aware and alert by:*

- *reducing your speed and being particularly cautious in areas where “deer crossing” signs are posted;*
- *constantly scanning not only the upcoming highway as you drive but the roadside as well;*
- *using your high-beam lights as often at night as possible in order to better illuminate both the highway and the roadside;*
- *being very watchful in areas near forests and water;*
- *staying particularly alert at dusk and dawn, times when animals venture out to feed and also when your visibility is limited; and*
- *watching for the reflection of your headlights in the eyes of animals ahead.*

*When you see an animal on or near the roadway, reduce your speed and tap your brakes, to warn other drivers, and sound your horn. Of course, you can brake harder if no one is behind you, but be careful about flashing your*

*headlights because one unintended effect may be to “freeze the deer” or other animal on the roadway directly ahead.*

*If a collision seems inevitable, don’t swerve suddenly to avoid the animal; your risk of personal injury may be greater if you do. Brake as quickly as you safely can, but keep your vehicle under control and on the roadway.*

*If a crash occurs, report it to local law enforcement, particularly if the carcass of the struck animal is still on the highway and thus a danger to other vehicles.”*

Source: Wyoming Rules of the Road, The 2006 State of Wyoming Drivers License Manual, pages 30-31.)

The following passage was developed by the Georgia Department of Motor Vehicle Safety for its 2005 drivers manual:

*“Each year numerous collisions occur in Georgia due to deer. Although hunting will keep deer herds in check, the potential for an accident always exists. Understanding common habits of deer and knowing what to do when a deer runs out in front of the car can help to avoid serious accidents.*

*Automobile accident statistics from the Department of Motor Vehicle Safety indicate that though deer-automobile collisions are on the rise, they still account for less than three percent of automobile accidents reported each year.*

*It is important to remember that deer are wild animals and are very unpredictable. The deer you see calmly standing on the side of the road may bolt into the road rather than away from it when startled by a car. In areas with known deer populations, drivers should constantly scan the road and road shoulders for deer movements and sightings. Always slow down when a deer crosses the road in front of you or another car. Deer usually travel in groups and there likely is another one following closely behind. If a deer is spotted on the road or roadside at night, the driver should slow down immediately, blink their headlights and switch to low beam so as not to blind the deer. Also, short horn blasts should help scare the deer from the road.*

*Should the deer or other animal run out in front of your car, slow down as much as possible to minimize the damage of a collision. Don’t swerve to avoid a deer because you may collide with another car and cause - more damage. If you do have an accident, call the police as soon as possible. Most insurance companies will require an*

*accident report from the police before paying claims for those vehicles covered by collision insurance.*

*Deer are usually seen along the roadside during the early morning hours and late evening. Drivers should be alert for deer during these peak hours. Deer are most active in the fall months of October, November and December during the peak breeding season. Also late February and early March are critical months for deer car collisions. During this period they concentrate along road shoulders to feed on new green food available following a long hard winter.*

*There's little you can do when a deer crashes into your car of its own accord. Fortunately, many collisions are avoidable, if you take precautions, slow down and know something about their habits."*

Source: Georgia Department of Motor Vehicle Safety, 2005, page 70; reprinted as permitted by the Georgia Open Records Act, O.C.G.A. § 50-18-70.)

There are aspects of driving that have implications for drivers and the deer hazard that need to be examined. Deer represent a particularly dangerous hazard in low light conditions (dusk and dawn) and in no light conditions (night). *"About 90 percent of driving decisions are based on what you see."* (Idaho Transportation Department, 1990, p. 61). *"The grey of twilight is one of the most dangerous times of day."* (Idaho Transportation Department, 1990, p. 61). Diurnally, deer-vehicle collisions occur more frequently between 5:00 a.m. and 9:00 a.m. and between 4:00 p.m. and 12:00 a.m. (Huijser et al., 2008).

The Car/Deer Collision section of the 2002 Michigan driver manual advised new drivers, *"At night, be alert for shining eyes at the roadside"* (Michigan Department of State, 2002, p.120). In its 1990 driver manual, the Idaho Transportation Department (1990) advised new drivers to keep their eyes open for animals while driving at night. At night, the shining eyes of deer may be all a driver can identify (Figure 3.15).

### 3.6.1 Illustrations of Deer

Photographs or other graphic representations of deer were uncommon in the state driver manuals reviewed. Although the 1969 Nevada driver manual did not include a deer warning sign or any text referring to deer, the manual did include a graphic clearly depicting the dramatic difference in the conspicuity of deer along a highway during the day and at night (Figure 3.16). Virginia appears to be the only state to have included a photograph of a deer in its driver manuals (Figure 3.17). The photograph was included in the 1991 state driver manual. Both the 1969 Nevada graphic and the 1991 Virginia photograph depicted deer at night, a time when deer-vehicle collisions often occur, and when drivers have the most difficulty detecting deer (Mastro et al., 2007).



Figure 3.15 A deer by the side of a road at night

Advice on night driving is a common and constant theme in all current US state driver manuals. “No one can see as well at night as they can in the daylight.” (Louisiana Department of Public Safety and Corrections, 1990, p.36 *and things appear different that during the day.*” “Also, unfamiliar roads and unexpected situations are more likely to cause trouble.” (Edgar (1982). p. 35).

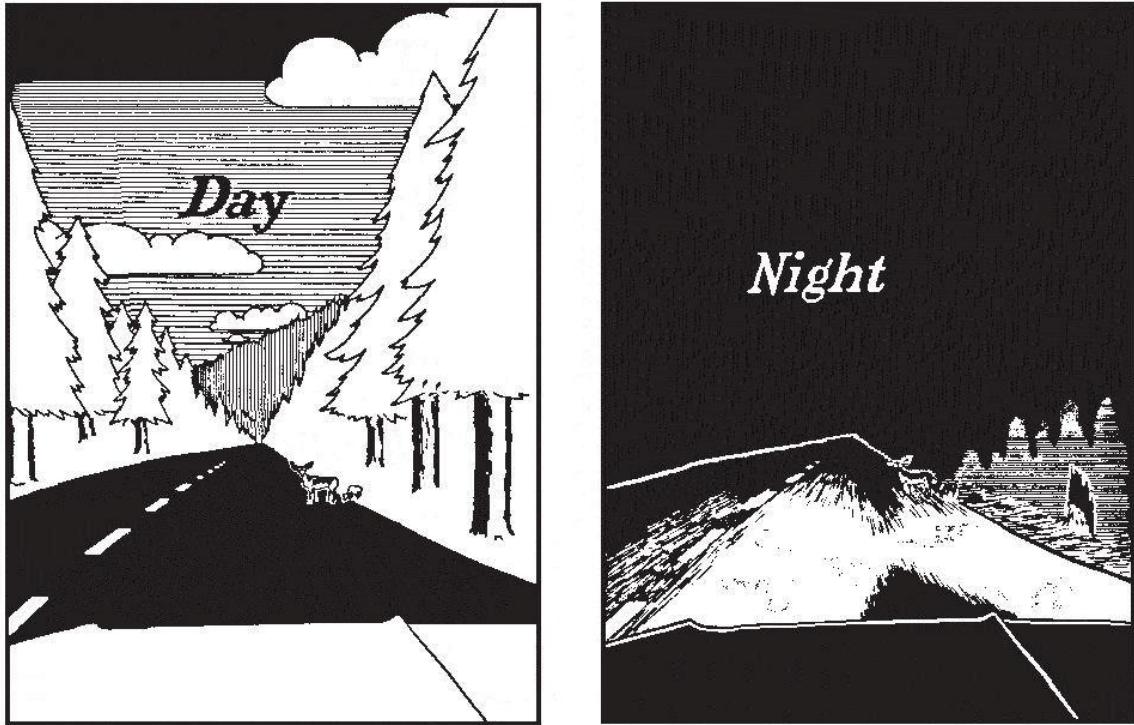


Figure 3.16 Day and night differences in visibility of deer along highways  
(Source: Nevada Driving Handbook, 1969, p. 47)



Figure 3.17 The deer at night photograph in the 1991 Virginia driver manual  
(Source: Virginia Department of Transportation (1991))

### 3.6.2 Overdriving Headlights

Visibility at night is a critical issue, especially with regards to vehicle speed. Overdriving headlights is identified as a serious problem by most state driver manuals. “*Keep your speed low enough to be able to stop in the distance you can see ahead.*” (Maryland Department of Transportation, 1981, p.39; Maryland Department of Transportation, 1990, P.39; Maryland Department of Transportation, 1998, p.44)

*“One of the most common and dangerous habits that drivers can get into at night is “overdriving” the headlights of their vehicle. You should never drive so fast that you are unable to stop within the distance which you can clearly see on the road ahead of you by the light of your vehicle’s head lamps. For most vehicles this distance is no more than 350 feet when the headlights are on high beam.”*

Source: Minnesota Department of Public Safety, 1991, p. 87.

In the “Night Driving” section of the 1990 New Hampshire driver manual advises “Under normal conditions, headlights on high beam shine about 350 feet, while headlights on low beam shine about 100 feet.” (New Hampshire Department of Safety, 1990, p. 48).

*“Legal headlights provide a minimum visibility of 150 feet; this is about the stopping distance under favorable conditions for a speed of 40 miles per hour. At night, therefore, **anyone who drives so fast that the vehicle cannot be stopped within the distance their headlights clearly show up on the road ahead is over-driving the lights.**”*

Source: Vermont Department of Motor Vehicles, 1982, p.32

*“Because you can only see as far as you lights can reach, you should always control your speed so that you can stop within the distance your lights illuminate.”*

Source: Mississippi Department of Public Safety, 1991, p. 33; Mississippi Department of Public Safety, 2001, p. 33

Johansson and Rumar (1968) found the visibility provided by low-beam headlights is not adequate for motor vehicles operation at speeds in excess of 32 km/h (20 mph). Olson et al. (1981) studied the effect of headlamps on nighttime visibility. They concluded low beams do not provide adequate visibility under many driving conditions. As early as 1947, traffic studies concluded that the majority of drivers ignore speed limits (Harkey et al., 1990).

Drivers generally do not view speeding as a safety problem, but view speed limits as guides (National Highway Traffic Safety Administration and Federal Highway Administration, 1997). In her study of randomly selected Swedish drivers, Forward (2010) found speeding in rural areas is not considered very dangerous. Herd et al. (1980) found traffic speeds are generally as high during the night as during the day. Harkey et al. (1990) found over 70% of drivers did not comply with posted speed limits on highways. They observed most drivers drive from 9.6 km/h (6 mph) to 22.4 km/h (14 mph) over the posted speed limits.

Most drivers routinely overdrive their headlights (Leibowitz et al. 1998; Olson et al., 1981). Drivers operating their motor vehicles at speeds faster than 88 km/h (55 mph) at night are overdriving their headlights (Oregon State University Transportation Research Institute, 1997). In the mid-1950's, the American Mutual Liability Insurance Company (1954) recommended drivers reduce their speed at night. The rule of thumb suggested was a reduction of speed by 20%, with a top speed of 72 km/h (45 mph).

Deer-vehicle collisions are more likely to occur when a driver fails to see a deer on the highway, or when a driver detects and identifies a deer too late to stop or take evasive action (Mastro et al., 2010). Danielson (1957) found speed affects peripheral vision. As a vehicle's speed increases, a driver's clear field of vision narrows (Figures 3.18 and 3.19). In addition, as speed increases, drivers progressively look farther ahead of their vehicles. Danielson (1957) refers to the phenomena as "speed smear". Owens and Tyrrell (1999) found steering accuracy in a nighttime driving

environment is reduced by restricted peripheral vision. Mastro et al. (2005) found most drivers at night are unable to detect a deer standing with 10 metres of the side of a road until they are within 50 metres of the deer. Visibility of low-contrast objects is very poor under typical nighttime driving conditions (Olson et al., 1981).

The implications of reduced peripheral vision is further complicated because deer are low contrast object, and low contrast objects appear to move more slowly than high contrast ones (Antis, 2003). Mastro et al. (2005) concluded that drivers travelling at speeds greater than 75 km/h at night would not be able to stop in time to avoid colliding with the deer. Mastro et al. (2005) and Sivak et al. (1994) also found that detection distances on the right side of the road was greater than on the left side.

The limitations of driver vision on the left side of vehicles at night is a serious issue when wildlife may be crossing roads and highways. Mastro et al. (2005) observed the limited left side vision phenomena but did not attribute to anything. It appears the limitation on vision on the left side of a driver's field of view at night is directly related to the illumination characteristics of vehicle headlights.

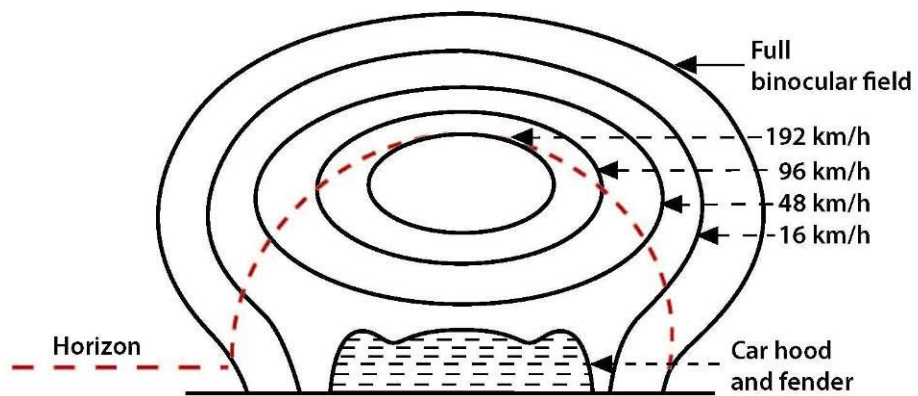


Figure 3.18 Speed smear effect on driver vision  
(Adapted from Danielson (1957))

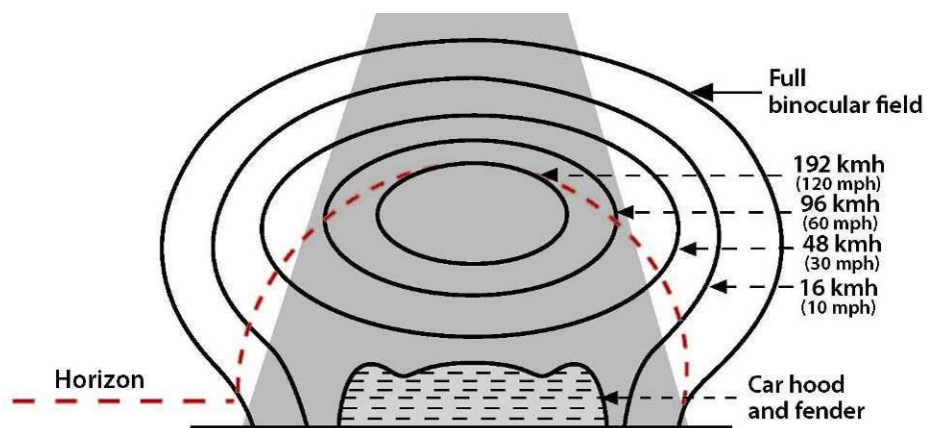


Figure 3.19 Speed smear effect on driver vision relative to a highway lane  
(Adapted from Danielson (1957))

### 3.6.3 Headlight Illumination Characteristics

Despite the advisories regarding night driving, not a single driver manual I reviewed provided any information about the illumination characteristics of the headlights drivers depend upon for visibility in low and no light conditions. Although high beam headlights provide significantly more illumination than low beam headlights, most drivers do not use high beam headlights when driving (Sullivan et al., 2004). High beam headlights do not provide evenly distributed illumination (Figure 3.20). Although high beam headlights produce greater luminous intensity than do low beam headlights, the beam pattern of high beam headlights is narrower (Shoettle et al., 2001). While headlight illumination to the left of a driver contribute to glare to oncoming vehicles, headlights must provide sufficient illumination to safely operate a vehicle while keeping glare to oncoming vehicles to an acceptable level (Rys et al., 1999). None of the state driver manuals reviewed illustrated the typical illumination pattern of headlights or advised on the safety implications of this pattern for night driving. Drivers may not be aware of the extent to which their vision is impaired when driving with headlights (Sullivan et al., 2004). As a result, many drivers may be unknowingly exposed to a “zone of vulnerability” with regards to deer approaching their vehicles from the left side of a road or highway at night (Figure 3.21). The zone of vulnerability should have some influence on the points of impact on vehicles in collisions with deer during daylight and at night. To confirm this, I examined all the records of deer-vehicle collisions reported to the Michigan State Police in 2011 for the periods Noon to 1:00 p.m. and Midnight to 1:00 a.m. I selected reports for all collisions that occurred on two lane highways with 88 km/h (55 mph) speed limits. The Midnight to 1:00 a.m collisions were limited to the collision locations where there was no artificial lighting. The impact locations were identified by Michigan State Police using the impact point numbering scheme illustrated in Figure 3.22. Tables 3.2 and 3.3 show the reported locations of the collision impacts on vehicles varied between periods of daylight and night. Impacts to the front of the vehicles increased at the two front fenders at night. At night, collisions to the vehicle front right fender and the front left fender increased. Night collisions to the front

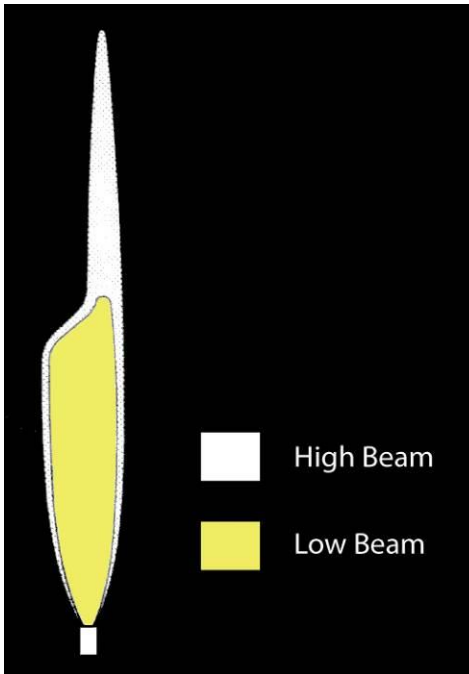


Figure 3.20 High beam and low beam illumination pattern  
(Adapted from Robert Bosch GmbH. (1993))

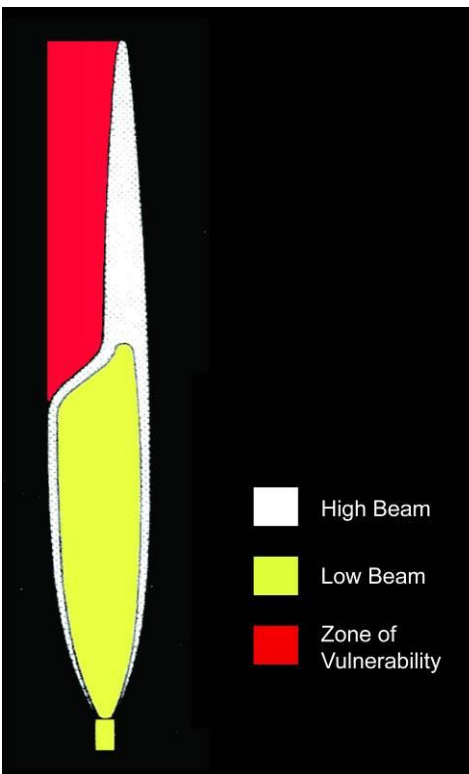


Figure 3.21 The zone of vulnerability at night

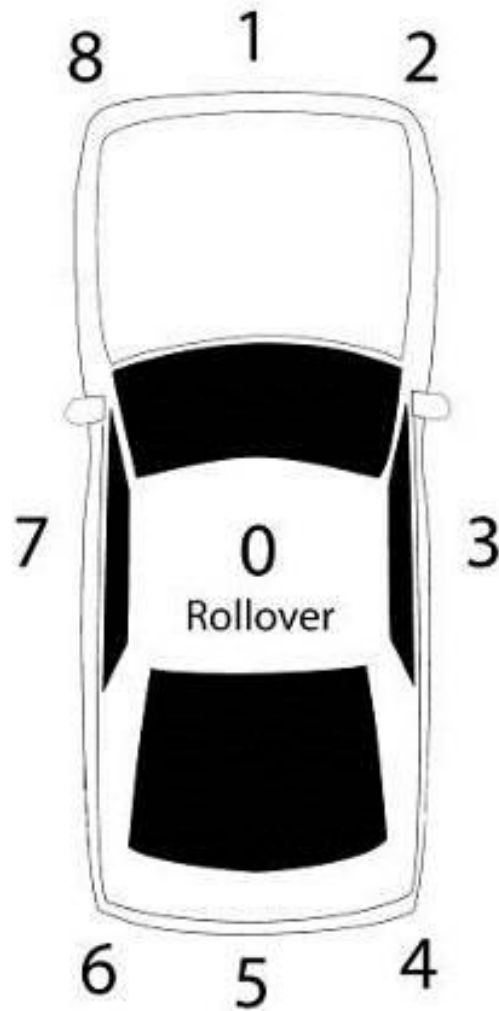


Figure 3.22 Vehicle damage location points  
(Adapted from State of Michigan UD-10 Traffic Crash Report Manual, Michigan  
Department of State Police (2010))

Table 3.3 State of Michigan deer-vehicle damage location points for collisions occurring on two lane, 88 km/h (55 mph) highways at noon and at midnight in 2011

Time of Deer-Vehicle Collision	Vehicle Damage Point									Total
	0	1	2	3	4	5	6	7	8	
Noon to 1:00 p.m. Collisions	0	28	9	5	0	1	1	6	13	63
Midnight to 1:00 a.m. Collisions	1	34	28	3	0	0	0	4	21	91

Table 3.4 State of Michigan deer-vehicle damage location points for collisions occurring on two lane, 88 km/h (55 mph) highways at noon and at midnight in 2011 by percentage

Time of Deer-Vehicle Collision	Vehicle Damage Point									Total
	0	1	2	3	4	5	6	7	8	
Noon to 1:00 p.m. Collisions (%)	0	44.4	14.3	7.9	0	1.6	1.6	0.5	20.6	100.0
Midnight to 1:00 a.m. Collisions (%)	1.1	37.4	30.8	3.3	0	0	0	4.4	23.1	100.0

center of the vehicles decreased. The changes in deer-vehicle collision impact locations suggest deer-vehicle collisions are influenced by driver visibility and warrants further study.

#### 3.6.4 The Deer Hazard at Night

None of the state driver manuals provided a comprehensive description of the factors that contribute to the deer hazard for drivers at night. The deer hazard at night poses a very complex problem to address because:

1. The majority of drivers speed at night. (Harkey et al., 1990).
2. The majority of drivers do not use high beams (Sullivan et al., 2004).
3. Low beams are not adequate for night driving (Olson et al., 1981).
4. Headlights are inadequate for peripheral vision (MacPherson, 2003)
5. Speed limits greater than 88 km/h are too high for nighttime driving with high beams. (Oregon State University Transportation Research Institute, 1997)
6. Deer are low contrast objects (Mastro et al., 2010).
7. Low contrast objects are difficult to see at night (Wood and Owens, 2005).
8. Low contrast objects appear to move slower than they actually do (Anstis, 2003).
9. Deer are active at night (Mastro et al., 2010).
10. Driver vision at night is reduced (Leibowitz and Owens, 1977; Rumar, 1990; Plainis et al., 2005; Wood et al., 2005).
11. As drivers drive at higher speeds, their vision becomes increasingly concentrated on smaller and smaller areas of focus. (Danielson, 1957)
12. Reaction time to an unexpected situation is longer (Alexander and Lunenfeld, 1986).
13. Drivers are fatigued at night and have slower response times (Vermont Department of Motor Vehicles, 1982; Sagberg, 1999).

Providing more information on the factors that collectively contribute to increase driver vulnerability to the deer hazard in state driver manuals may increase the acceptance of new drivers of the need to be particularly careful when driving at night in areas where deer are found.

### 3.6.5 Exemplar

No foolproof way has been developed to keep deer off highways and away from motor vehicles (Tennessee Department of Safety and Homeland Security, 2016). Consequently, drivers should take the steps advised by state departments of transportation to reduce their potential for deer-vehicle collisions. Collectively, a number of state driver manuals have provided valuable advice and suggestions for reducing drivers' potential for being involved in deer-related collision and reducing the potential severity of such collisions. Drawing upon the materials used in current and past state driver manuals, I have drafted an “**Avoiding Deer-vehicle Collisions**” exemplar (below) to provide direction for future state driver manual development.

#### **Exemplar: Avoiding Deer-vehicle Collisions**

##### **Preparing Your Vehicle for Driving in Deer Country**

The potential for deer-vehicle collisions, and the injuries and deaths they can cause, can be reduced by how you maintain your vehicle.

1. Windshields and windows must be clean and not be obstructed by cracks, discoloration, steam, frost, ice, or snow.
2. Do not tint windshields or coat them with reflective materials.
3. Replace worn windshield wipers and keep windshield wiper fluids topped up.
4. To reduce driving distractions, do not hang objects from rear view mirrors and keep dashboards free of clutter.
5. Windshields and windows must be clean and not be obstructed by cracks, discoloration, steam, frost, ice, or snow.



Source: Dreamstime (copyright-free)

6. Do not tint windshields or coat them with reflective materials.
7. Replace worn windshield wipers and keep windshield wiper fluids topped up.
8. To reduce driving distractions, do not hang objects from rear view mirrors and keep dashboards free of clutter.
9. At night, dim interior lighted devices and other sources of vehicle interior glare.
10. Make sure all your headlights work and are kept clean.
11. Make sure your tires are in good condition, balanced and properly inflated.
12. Make sure your brakes are in good condition, being able to stop safely is critical.
13. Keep side windows closed to help prevent deer from entering the vehicle.

### **Protecting the Driver and Passengers**

Driver awareness is the most important factor in avoiding deer-vehicle collisions. Being alert and ready for the unexpected, especially at night, is critical. Protecting yourself and your passengers is essential.

1. Do not exceed the posted speed limit.\
2. Always wear your seatbelt.
3. Do not drive after consuming alcohol or using recreational drugs.
4. Avoid driving if you have a cold, flu, fever or other medical condition that interferes with your ability to concentrate on driving.
5. If you are drowsy, stop to rest.
6. Wear up-to-date prescription glasses if needed.
7. Ensure vehicle occupants always wear their seatbelts.
8. Small children should be restrained in properly secured children's car seats.
9. Adjust headrests to meet the needs of vehicle driver and passengers.

### **Route Planning**

By selecting travel times and routes, drivers have the potential to reduce their chances of being involved in deer-vehicle collisions.

1. Avoid discretionary driving at times when deer hazards are greatest during the day (i.e. dawn, dusk and night) and during the year (i.e. Fall and Winter).
2. Avoid discretionary driving on routes that are known to have elevated deer hazard levels.

3. If possible, avoid riding a motorcycle during times when deer hazards are greatest. Motorcycle riders are the most vulnerable road users to injuries and death caused by deer-vehicle collisions.
4. If a system is used by road authorities to identify routes with extreme deer hazard levels, consider using the system to select routes with lower deer hazard levels.

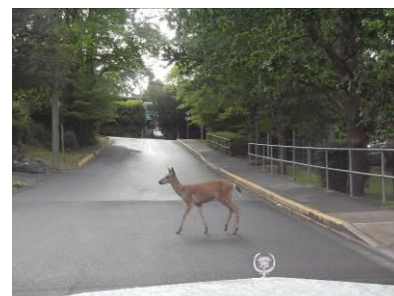


Source: Dreamstime (copyright-free)

## Driving Environment

Being aware of your driving environment is key to seeing deer.

1. Pay attention to deer crossing signs. These signs are installed in areas where deer-vehicle collisions have occurred in the past.
2. Look well ahead down the road and far off to each side.
3. Be especially watchful driving in areas near water and woods.
4. If you see one deer, there may be others nearby. Deer may travel in pairs or herds. A doe may be followed by more than one fawns.
5. In urban areas, watch for deer near golf courses and other large forested green spaces.



## Deer at Dawn, Dusk and at Night

While deer-vehicle collisions can occur at any time of day, many of the collisions occur at dawn, dusk and at night.

1. Be particularly alert at dawn and dusk. These are periods when deer venture out to feed.
2. On the open road, use high-beam headlights unless you are approaching or following another vehicle.
3. Use high-beam headlights to illuminate the road's edges.



Source: Slalom Tokyo Drift (slalomtokyodrift.com)

4. Highbeams will illuminate the eyes of deer on or near a road.
5. When you use high-beam headlights at night, you should be able to see a deer that is 60 metres away. When using the low-beam headlights, you should be able to see a deer 20 metres away.
6. Stay in the middle of the lane and leave space on both sides of your vehicle.
7. At dawn, dusk and at night, scan the sides of the road to watch for the reflection of your headlights in the eyes of deer.
8. Look for still or moving shadows of deer, created by moonlight, headlights of other vehicles, or other sources of light along the road.
9. If you see a deer on or near the road and think you have time to avoid hitting it, reduce your speed, tap your brakes to warn drivers behind you, and sound your horn.
10. Deer tend to fixate on headlights, so do not flash your headlights because this may cause the animal to freeze on the road.
11. After passing a deer, flash your headlights to warn oncoming drivers of the deer.



### At Impact

Striking a deer with your vehicle can be a very dramatic and unsettling experience. Maintaining control of your vehicle can help you protect yourself, your passengers and other road users.

1. If you are about to hit a deer, your safest action is to brake firmly, steer to maintain control and stop as safely as possible.
2. Don't swerve to avoid the deer. Your risk of personal injury may be greater if you do. Keep your vehicle under control and on the road when you hit the deer.



Source: Kenton County Police Department

### After a Deer-vehicle Collision

After a deer-vehicle collision, it is important to safeguard yourself, your passengers and other road users.

1. If you can, and it is safe to do so, pull your vehicle off the road.
2. Turn on your warning flashers to warn other drivers of your vehicle and the

collision site.

3. If the deer is inside your vehicle, leave your vehicle immediately, making sure all your passengers leave also. The sharp hooves and antlers of an frantic injured deer can cause serious injuries to you and your passengers.
4. Young children may be traumatized by the collision. Keep children away from the deer carcass.
5. Call the police to report the collision and if you and/or your passengers need medical attention.
6. Advise the police if the deer carcass is on the road or if the deer is still alive.
7. Do not approach an injured deer on the road, injured wild animals can be unpredictable.
8. From a distance, determine if the deer is dead before attempting to remove its carcass from a road. If uncertain about the deer, leave it alone. Be aware, a stunned deer can react violently if it wakes up while being dragged.
9. If the deer carcass is on the road and you can not remove it, if you have warning flares, or other warning devices, place them on the road to warn other drivers.



Source: Washington State Patrol



Source: Dreamstime (copyright-free)

### 3.7 Conclusions

To be drive safely, drivers need information about deer and the characteristics of deer behaviour, when and where deer may be encountered, and effective strategies for reducing the potential and severity of deer-vehicle collisions. As the US deer hazard is growing, and has the potential to increase even more rapidly in the future, state governments have the opportunity to provide this service by means of their driver manuals. New drivers could be provided with basic textual information, supplemented by photographs of deer and maps of locations where deer are commonly found in their state. In additions, new drivers could be given information

about how they could reduce their potential for being involved in a deer-vehicle collision and the severity of the collision should a deer-vehicle collision occur. Deer represent a growing nation-wide driving hazard in the United States. It would seem imperative new drivers be advised of the hazard. State driver manuals are often the sole source of information used by new drivers preparing for state driver licensing examinations. It would seem logical for information about deer, the hazard they pose, and driving strategies for reducing the potential for deer-vehicle collisions be included in state driver manuals. In the United States, drivers can move easily from state to state. Drivers can usually exchange driver licenses from one state for driver licences in another state without further examinations. Currently, not all states advise new drivers of the deer hazard in state driver manuals. In addition, over the last 50 years, state driver manuals have been inconsistent in providing information about the hazard. As a result, large numbers of US drivers have never been provided any formal educational information about the hazard. To ensure all new drivers in the United States are familiar with the growing deer hazard, nationally consistent and comprehensive information about the hazard should be included in all state driver manuals. Without even a rudimentary awareness of the deer hazard and knowledge of effective strategies for reducing the potential for deer-vehicle collisions, it would appear many new and old drivers in the United States are not well prepared for dealing with deer. Given the magnitude of deer-vehicle collisions in the US states, and their cost in property damage, human injuries and human deaths, it may be prudent for those responsible for producing state driver manuals to advise new drivers on the purpose and meaning of deer warning signs in context of highway situations found in their own states, as well as those found in neighbouring states. More factual and comprehensive information regarding the risks and consequences of wildlife hazards on roads and highways should be presented in a manner that communicates the hazards more graphically with maps, diagrams and photographs.

## **4.0 WARNING DRIVERS OF POTENTIAL DEER HAZARDS**

*“Being unaware of the driving environment is a common experience for most motorists.”* (Martens, 2000, p. 347)

### **4.1 Introduction**

One goal of transportation development is to design highways so drivers can adequately anticipate roadway conditions and safely adjust the speed of their vehicles (Leisch, 1971). Unless otherwise informed by a traffic control device, or some other means, drivers normally expect they can drive safely at the posted speed limit and not encounter hazards on or near the roadway (Dewar, 1993). For most drivers, being unaware of the driving environment while driving is a common experience (Martens, 2000). This chapter will examine the use of traffic warning signs in the US (US) and the need for drivers to consistently comprehend their warning messages. A historic retrospective on the development of traffic warning signs over the last 110 years will provide the context for the traffic warning signs currently in use by US state departments of transportation. The concurrent evolution of deer crossing signs will be examined. The shortcomings of static warning devices will be critiqued in the context of earlier attempts to augment wildlife warning signs. Building upon the concepts of warning sign systems used for other natural hazards, a new, and unique, dynamic wildlife hazard warning system for drivers is proposed. Implementing a simple hazard risk rating system within the scope established by the Manual on Uniform Traffic Control Devices (MUTCD), the system has the potential to significantly increase the amount of information provided to drivers in a timely manner. The system establishes a dynamic messaging format to advise drivers of the diurnal and seasonal variations of the deer hazard in the US. Examples of the proposed implementation of the new wildlife hazard warning system are provided.

## 4.2 The Use of Warning Signs to Advise Drivers of Hazards

Traffic engineers are often expected to exercise “professional judgment” in the provision of warning information to drivers (Womack et al., 1981; Dewar, 1993). Consequently, traffic warning signs are used primarily to provide drivers information about their driving environment (Johansson and Rumar, 1966; Leisch, 1971). According to the 1971 Manual of Uniform Traffic Control Devices (MUTCD), to be considered effective, traffic warning signs should meet the following five basic requirements:

- 1) fulfill a need,
- 2) command attention,
- 3) convey a clear, simple message,
- 4) command respect of drivers, and
- 5) give adequate time for proper driver response (American Association of State Highway and Transportation Officials. (1971).

The primary purpose of traffic warning signs is to describe conditions not otherwise self-evident to drivers (Womack et al., 1981; Bonneson et al., 2007) and advise drivers of potentially hazardous conditions that exist along roadways (Stokes et al., 1995). For warning signs, understandability is the most important factor for drivers, followed by conspicuity (Dewar, 1988). Warning signs provide drivers with information about road conditions in order to allow the drivers to anticipate events and encourage the drivers to adjust their driving behavior for the conditions (Stokes et al., 1995; Martens, 2000). Drivers must be able to understand the information contained in warning signs in order to respond appropriately (Stokes et al., 1995). The design and implementation of a warning sign should allow the message to be seen and understood by the majority of drivers (Dewar, 1993).

Drivers who correctly perceive hazards and evaluate higher risks tend to decrease speed (Renge, 1998). However, warning signs cannot effectively serve their intended purposes if drivers do not recognize the signs or understand what safe driving practices are required for the hazards being depicted (Stokes et al., 1995). The inability of drivers to detect hazards or identify hazardous situations is a major determinant of collision likelihood (Dewar, 1993). The use of symbol signs can present problems because many symbols are misunderstood (Hulbert and Fowler, 1980), partly because of their poor design and the failure of transportation authorities to educate drivers about their meaning (Dewar, 1993). Consequently, a driver passing a traffic sign without getting its message is often at considerable risk (Johansson and Rumar, 1966). As it is assumed the traffic sign system is an effective means of communicating to drivers, a driver who fails to see a traffic sign is considered guilty of a lapse in attention (Johansson and Rumar, 1966). However, the traffic sign system does not fulfill its intended and assumed function in a satisfactory way. Drivers overlook traffic signs more as a rule rather than an exception. During common driving conditions, the traffic sign system does not match the needs of drivers. The communication system based on traffic signs is a highly ineffective one (Johansson and Backland, 1970). In the US, the Manual of Uniform Traffic Control Devices (MUTCD) specifies the design, size and placement of warning signs (US Department of Transportation, 2000). However, no criterion has been established in the US for the level of understanding of traffic sign symbols (Dewar, 1993).

### **4.3 Positive Guidance and Driver Expectancy**

The positive guidance concept is based on the assumption that when unimpaired drivers are given appropriate, timely information about roadway hazards they will be able to avoid driving errors (Lunenfeld and Alexander, 1990). To effectively perform guidance-related tasks, drivers must be provided with sufficient information on potential hazards. A lack of information about hazards can lead to leave drivers

unprepared. One important factor that explains driver performance in relation to information they receive is expectancy (Woods, 1970; Pietrucha, 1995). From a driver's perspective, expectancy is an assumption that a set of conditions experienced in the past for a particular driving situation will be the same when that situation is encountered again. When the physical situation confirms what the driver expects, there is only a slight possibility of uncertainty (Woods, 1970). However, when the physical situation differs from the expected situation, a very complex decision making process is involved. In general, drivers do not perceive driving as a life-threatening activity (TRB, 1998). The most common perception among drivers is that collisions are rare, unpredictable events.

#### **4.4 Traffic Warning Sign Comprehension**

Drivers have learned to associate colour and the distinctive outline of traffic signs with their function (Johnson, 1965). The distinctive outlines and distinctive colours used by American Association of State Highway Officials (AASHO) are supposed to be easy to recognize by drivers with a minimum of perception time. Ironically, Hawkins et al. (1995) found many of the Texas drivers did not have a fundamental understanding of the shapes and colours used in traffic signs. Stokes et al. (1996) found warning signs are poorly understood by drivers. Womack et al. (1981) tested a representative sample of Texas drivers and found their knowledge of basic traffic sign colours and shapes was lacking in the majority of the subjects (Table 4.1).

Depending on the type of warning sign, from 41% to 76% of the drivers studied knew warning signs were yellow, but on average, only about 25% correctly identified the diamond shape. Womack et al. (1981) also found drivers greatly depend on words for understanding traffic signs. Signs such "STOP", "YIELD" and "DO NOT ENTER" posed problems for drivers when the word messages of the signs were omitted.

Table 4.1 Selected results of shape and colour survey for regulatory and warning signs  
(Source: Womack et al. (1981))

<b>Sign</b>	<b>% Correct Colour</b>	<b>% Correct Shape</b>
Stop	87	56
Yield	25	40
Speed Limit	82	87
Deer Crossing	71	39
School Crossing	76	5

The “DO NOT ENTER” sign was misinterpreted by 55% of the drivers when the sign was presented without words. In their study of Texas drivers, Hawkins et al. (1995) found only 58% of their study subjects recognized the yellow diamond as the proper background for warning signs. Similarly, Stokes et al. (1996) found that only 60% of study subjects correctly identified the yellow diamond sign as a warning sign and only 14% of the study subjects correctly identified the school crossing sign. Stokes et al. (1996) advised the results may have overstated the general population’s understanding of

warning signs because drivers from the ages of 16 to 24, and over the age of 65 were underrepresented in the sample. Ferguson and Cook (1967) found only 59% of Virginia drivers they studied could correctly identify a yellow diamond sign as a warning sign. Johansson and Rumar (1966) postulated the variations in how drivers remembered different road signs were due to the degree of urgency of the information contained in each sign based on past experiences of the drivers. The more urgent the information the sign contained, the higher the percentage of drivers remembering the sign. Johansson and Backland (1970) indicated the question of the signal value of various traffic signs for drivers is complicated and the effectiveness of low signal value traffic signs may be affected by environmental surroundings. Macdonald and Hoffmann (1991) found regardless of their conspicuity and legibility, transient-hazard warning signs for hazards rarely encountered by drivers had the lowest reported sign

information awareness levels. Signs with more importance to drivers are recalled by drivers more often than signs with less importance (Martens, 2000).

#### **4.5 Need for Improved Driver Education**

Efforts to inform drivers of the shape and colour of warning signs are needed (Womack et al., 1981). Use of supplemental information tabs for warning signs should continue (Womack et al., 1981; Stokes et al., 1995). Public information and education should be implemented to improve driver knowledge and understanding of warning signs (Womack et al., 1981; Stokes et al., 1995; Razzak and Hasan, 2010; Makinde and Opeyemi, 2012). According to Hawkins et al. (1995), the only effective way to address the lack of driver understanding was to increase the emphasis given in driver training programs to the meaning of shapes and colours in traffic signs. Revisions to the Texas state driver manual to include examples which combined sign shape and colour together were recommended. With the difficulty many drivers exhibit in correctly identifying various regulatory and warning signs, a need exists to determine the hazard posed by misunderstanding these signs (Womack et al., 1981).

Understanding of traffic control devices is very much a factor of driver education (Womack et al., 1981; Razzak and Hasan, 2010; Makinde and Opeyemi, 2012). While Al-Madani (2000) reported comprehension of traffic signs was significantly better for experienced drivers, Womack et al. (1981) found sign comprehension less attributable to level or length of driver exposure. Macdonald and Hoffmann (1991) found inexperienced drivers had greater levels of awareness of traffic sign information. Äberg (1981) found most of the drivers that noticed wildlife warning signs were inexperienced ones. Borowsky et al. (2008) reported that inexperienced drivers identified traffic signs better than experienced drivers when the signs were at unexpected locations. “One of the most effective ways to enhance the roadway communication system is to educate those to whom the communication is directed.”

(Womack et al., 1981, p. 167) Drivers appear to have the perceptual skills necessary for detecting traffic signs but do not feel they need the information being provided (Summala and Näätänen, 1974; Summala and Heitämäki, 1984). What drivers are able to do and what they choose to do are two different things. (Lonerio et al., 1995). Risk acceptance is not the same thing as collision acceptance. It is unlikely many drivers will take a risky action if they know such action will result in a collision. Poor risk perception and inability to detect hazards, coupled with overconfidence can lead to risky driving (Lonerio et al., 1995). It is easiest to increase the comprehension of traffic signs partially known by drivers by simply focusing on the full extent of their meaning in driver education (Kirmizioglu and Tuydes-Yaman, 2012). Poorly understood traffic signs should be addressed more aggressively with mass media and educational campaigns.

#### **4.6 History of Traffic Warning Signs in the United States**

The Manual on Uniform Traffic Control Devices (MUTCD), published by the US Department of Transportation, establishes national standards for traffic control devices used by federal, state and local governments (US Department of Transportation, 2000). The MUTCD standards are intended to ensure drivers are provided traffic control devices consistent in appearance and function. Throughout the US, transportation authorities use standard MUTCD mandated yellow diamond shaped warning signs to advise drivers of a wide range of potentially dangerous driving hazards. The signs are universally used in urban, suburban and rural areas. These signs may warn of fixed, permanent physical characteristics of the roadway, such as speed bumps or sharp curves, or locations where intermittent incursions onto the roadway by children or animals may be expected to occur. The ultimate goal of these warning signs is to raise driver awareness of the potential driving hazards and encourage driving practices appropriate for the hazards. Figure 4.1 illustrates the typical use of standard yellow



Speed bump warning sign



Curve warning sign



Playground warning sign



Deer crossing warning sign

Figure 4.1 Standard diamond shaped warning signs

diamond shaped warning signs. In the US, warning signs, as traffic control devices, have evolved over time as a result of efforts to standardize them by state and national organizations. In order to appreciate and understand why the deer crossing sign currently used by transportation authorities in the US exists, it is important to examine the evolution of traffic warning signs from their origins.

#### **4.7 Initial Efforts to Standardize Traffic Control Devices**

Prior to the 1920s in the US, traffic control devices for roads and highways were the subject of little interest to most people since both traffic volumes and vehicle speeds were relatively low (Hawkins, Jr., 1992a). Drivers were expected to face the challenges of driving by themselves. In most instances, traffic signs were designed, installed and maintained by auto clubs, local agencies or state departments of transportation. Little concern was given to uniformity in sign shape or colour, or consistency of use. By the mid-1920's, the number of vehicles operating in the US was increasing (Hawkins, Jr., 1992a; 1992b). Drivers were beginning to travel greater distances into unfamiliar areas on roads and highways with unknown characteristics. Municipal and state governments began to realize efficient highway systems required effective traffic control devices. Attempts were made to establish a national system of traffic control devices for the US (Hawkins, Jr., 1992a; 1992b). The need for high uniform standards was recognized early in the process (American Association of State Highway and Transportation Officials, 1971). In 1922, W.F. Rosenwald, J.T. Donaghey and A.H. Hinkle, initiated the first effort to establish uniformity in highway signs (Sessions, 1971). Their work was presented at the 1923 annual meeting of the Mississippi Valley Association of State Highway Departments (MVASHD). The MVASHD agreed on a traffic sign plan that used distinctive shapes to represent different danger conditions (Table 4.2). All signs were to have black lettering or symbols on a white background. The same sign shapes are used by

Table 4.2 Shapes and purposes of traffic signs

Shape	Purpose of Shape
Round	Used only to warn of a railroad crossing
Octagon	Used only to signify a stop
Diamond	Used to indicate ordinary conditions of danger requiring precaution at all times
Square	Used to indicate intermittent danger conditions requiring little more than ordinary care
Rectangle	Used to indicate regulatory or directional information
Cut Out	Used a distinctive shape different from the above to identify highway routes

road and highway authorities throughout the US today. In 1923, the “ordinary conditions of danger” and “intermittent danger conditions” were differentiated by use of the diamond and square signs. Ordinary conditions of danger required precaution at all times, while intermittent danger conditions required little more than “ordinary” care. Shortly after the MVASHD meeting, the Minnesota Department of Highways (MDOH) published its *Manual of Markers and Signs*.

This publication is believed to be the first manual for signing produced by a state in the US (Session, 1971). The Minnesota manual used the sign shapes and black symbols and lettering recommended by the MVASHD, but required the sign background colour to be yellow instead of white. Between 1923 and 1927, a number of organizations were working on developing a uniform national system of traffic signing (Hawkins, Jr., 1992a). In 1925, the US Secretary of Agriculture, then responsible for the Bureau of Public Roads, recommended a uniform system of signing (American Association of State Highway and Transportation Officials, 2012). The most significant work done towards this goal was by the American Association of State Highway Officials (AASHO) and the National Conference on Street and Highway Safety (NCSHS). In 1924, AASHO adopted the MVASHD plan for sign

shapes, but specified all warning signs were use black symbols and lettering on yellow background. At the same time, AASHO created a Joint Board on Interstate Highways to develop a system of numbering and marking highways of interstate nature. As part of its responsibilities, the Joint Board studied current traffic signing practices. The information collected during the study was used to develop four characteristics that could be incorporated so traffic signs would provide clear messages to drivers. The characteristics were:

- 1) distinct shape,
- 2) distinct colour,
- 3) distinct word, and
- 4) distinct symbol.

James (1924) advised that a conscientious effort should be made to emphasize and to educate the public to recognize successive degrees of hazard. The “Caution or Slow” sign was to be used where it was necessary for the driver reduce speed on account of a condition existing inherently in the road itself, such as a sharp curve, a narrow bridge, or loose surface or road construction. The “Look or Attention” sign was to be used where a general condition existed that the driver show know of, such as a school, hospital, church or other points where an unexpected increase in vehicles or pedestrians may be expected. James (1924) did not mention the need for signs to advise drivers of deer-prone locations. In 1927, AASHO published a manual for rural areas (Hawkins, Jr., 1992b; American Association of State Highway and Transportation Officials, 2012). Shortly after, NCSHS published a similar manual on traffic control devices for urban areas (Hawkins, Jr., 1992b; American Association of State Highway and Transportation Officials, 2012). Each organization independently published its own manual of standards for signs and other traffic control devices

## 4.8 AASHO Rural Sign Manual

In 1924, E.W. James, Temporary Chairman, AASHO Committee on Traffic Control and Safety, recommended AAAHO approve the following: non-luminous signs should have a light background, preferably lemon yellow, with black lettering, and be designated for purpose by distinct shape:

- 1) Round - Railroad warning sign
- 2) Octagonal - Danger or Stop sign
- 3) Diamond - Caution or Slow sign
- 4) Square - Look or Attention sign
- 5) Rectangle - Directional and Informational sign (James, 1924)

In 1925, the US Bureau of Public Roads, accepted the signing recommendations for a system of uniform signs and markers made by the Joint Board. Federal acceptance of the signing recommendations lead to publication of the first US national signing manual for rural highways in 1927 (American Association of State Highway Officials, 1927). The manual incorporated the system of standardized signs and markers adopted by AASHO in 1925. Sign designs were intended to produce uniformity of significance in the signs themselves, and make it easy for even infrequent drivers to become familiar with the signs. The design principles were based on shape, colour, symbols and uniformity of erection and application. All warning and caution signs were required to have black lettering and symbols on a yellow background. At the time, warning signs included the octagonal stop sign and the round railroad sign. Caution signs included the diamond (slow) signs and the square (caution) signs (Figure 4.2).

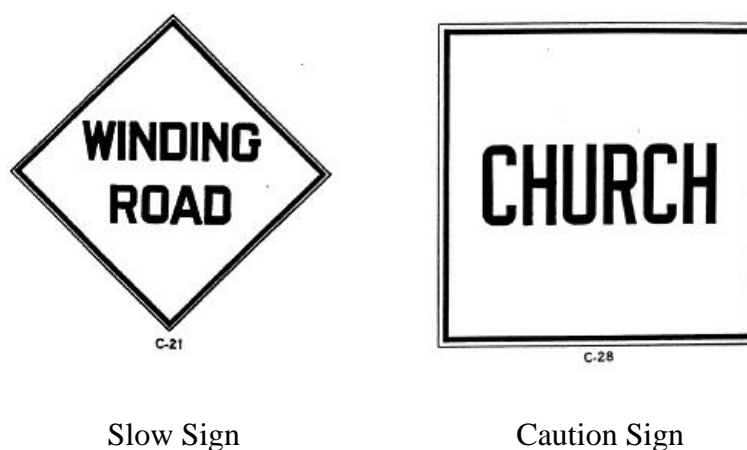


Figure 4.2 1927 AASHO Slow and Caution Signs  
 (Source: 1927 AASHO Manual and Specifications for the Manufacture, Display, and Erection of US Standard Road Markers and Signs)

The conference was called by the US Secretary of Commerce to develop the means necessary to reduce the increasing number of deaths and injuries associated with motor vehicle collisions (Hawkins, Jr. 1992a; American Association of State Highway and Transportation Officials, 2012). Recommendations made at the conference included improving signs, signals and markings, and a call for sign uniformity across all states in the country. However, no recommendations were made with regards to sign shape. I

n 1926, at the second National Conference on Street and Highway Safety, the conference accepted an offer from the American Engineering Council to conduct a national survey of traffic signs, signals and markings, and produce a recommended practice for the use of these devices. Those participating included technical representatives from US Chamber of Commerce, the National Safety Council, the Committee on Municipal Traffic Ordinances, the US Bureau of Public Roads and the Metropolitan Life Insurance Company (American Association of State Highway and

Transportation Officials, 2012). In 1929, the council submitted a draft manual on the use of traffic control devices in urban areas (American Engineering Council for the National Conference on Street and Highway Safety, 1930). After a thorough review by a number of conference committees, the Manual on Street Traffic Signs, Signals, and Markings was produced (American Association of State Highway and Transportation Officials, 2012).

In 1930, the manual was revised and updated based upon a survey of the best practices in more than 100 cities. The urban manual was the first US national standard for signals, markings and safety zones, issues not addressed in the rural manual. The signing standards of the urban manual conformed to its rural signing counterpart in virtually all respects, including sign shape and colour.

#### **4.10 The Manual on Uniform Traffic Control Devices**

Despite the successful development of signing standards, the presence of two manuals, one for urban environments and another for rural environments, created conflicts not easily resolved (Hawkins, Jr., 1992a). As a consequence, AASHO and NCSHS made efforts to combine the two manuals (Hawkins, Jr., 1992b). The Joint Committee on Uniform Traffic Control Devices (JCUTCD) was created to combine the two manuals into a single, complete, manual of traffic control devices for use in both urban and rural environments. The committee included officials from US state motor vehicle agencies, as well as representatives from the US Chamber of Commerce, the Bureau of Public Roads, American Association of State Highway Officials, Metropolitan Life Insurance Company, the Pennsylvania Railroad, the American Automobile Association and the National Safety Council (American Association of State Highway and Transportation Officials, 2012).

In 1935, the first Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) was completed and approved by AASHO and the fourth NCSHS. In November 1935, the US Secretary of Agriculture, responsible for the US Bureau of Public Roads, approved the MUTCD and the manual became a U.S standard. The 1935 Manual on Uniform Traffic Control Devices (MUTCD) was an important advancement in driver safety in the US. It established a single national system, providing a framework for consistent messaging for drivers.

#### **4.11 Efforts to Adopt International Traffic Signing Format**

In 1949, the United National Conference on Road and Motor Transport initiated the development of a worldwide uniform system of highway signs (Johnson, 1965). In 1950, an expert panel on road signs and signals was convened to consider US and European signing practices as a part of this initiative. The US worked with the panel and was interested in the initiative's overall objective. However, in 1953, the US declined to sign or ratify the protocol on a system of uniform road signs and systems for worldwide application. The two primary reasons for this action were:

*“First, all signing of roads, streets and highways in the US is the responsibility and prerogative of the various political subdivisions and not the Federal government so no single agency can commit the nation.*

*Secondly, the operation of modern controlled access facilities indicated changing conditions that would require improved and changing signing and marking concepts that would definitely be impaired by adherence to any International code.” (Johnson, 1965, p. 137)*

As late as the mid-1960's, there was no attempt by the US Federal Government to force signing practices on roads and highway operated by the States and local

governments (Johnson, 1965). In 1965, the US Federal Government was encouraging uniform signing practice and the Bureau of Public Roads had set a target date for compliance with the Manual of Uniform Traffic Control Devices for Streets and Highways (MUTCD) on all federally aided projects.

#### **4.12 Development of a Symbol-Based Sign System**

As a result of a major review initiated in 1964, new traffic signs, pavement markings and traffic signals were recommended in the Federal Highway Administration's revised 1971 Manual on Uniform Traffic Control Devices (MUTCD) (US Federal Highway Administration, 1973). The new system of traffic control devices was agreed upon by consensus of the following six organizations and agencies:

- American Association of State Highway Officials,
- Federal Highway Administration,
- Institute of Traffic Engineers,
- National Committee on Uniform Traffic Laws and Ordinances,
- National Association of Counties, and
- National League of Cities.

The US moved toward an international-type system of traffic control devices. The devices emphasized pictures and symbolic signs rather than written messages (Figure 4.3). Symbolic signs were not entirely new since curve and crossroad symbols had been in use in the US for decades. According to the US Federal Highway Administration (1973), symbols had a number of key advantages over word messages. Symbols could be understood at a glance by drivers without the need to read. Symbols could provide almost instant communication. Both sign colour and sign shape were assigned specific purposes. For example, diamond-shaped signs were to signify a warning to drivers.



















OLD	NEW	OLD	NEW
			
			
			
			
			
			

Figure 4.3 Transition of warning sign designs in 1970's  
 (Source: Virginia Division of Motor Vehicles [1975])

Yellow-coloured diamond-shaped signs were to indicate a general warning while orange-coloured ones were to convey construction and maintenance warnings. It was recognized that the new system of traffic control devices would affect every driver in the country. To accommodate transition to the new system, US states and local communities were given until 1975 to implement the new signs. As the new signs were introduced, companion word messages were to be used until drivers became accustomed to the new system.

#### **4.13 Deer Crossing Signs in the United States**

The deer crossing sign (Figure 4.4) currently used by state departments of transportation and other road authorities in the US is the result of a succession of design and philosophy changes which occurred as the Manual on Uniform Traffic Control Devices (MUTCD) evolved over the last 70 years. In the US, the MUTCD, published by the US Department of Transportation, establishes national standards for traffic control devices used by federal, state and local governments (US Department of Transportation, 2000). The MUTCD standards are intended to ensure drivers in the US are provided consistent direction by nationally standardized traffic control devices. The MUTCD W-11-3 deer crossing sign is the most widely used traffic control device by departments of transportation to reduce the potential for deer-vehicle collisions (Knapp and Yi, 2004). Consequently, it is the warning sign most new drivers are likely to encounter in locations where transportation authorities have identified deer to be a potential hazard for drivers. The deer crossing sign is not as ambiguous as a generic “ROAD HAZARD AHEAD” warning sign (Figure 4.5) or a “WATCH FOR ANIMALS” warning sign (Figure 4.6). Examining the evolution of the deer crossing sign provides perspective on the elements used in the sign in the context of all traffic warning signs currently being used in the US.



Figure 4.4 MUTCD W-11-3 Deer crossing Sign



Figure 4.5 Generic road hazard warning sign



Figure 4.6 “WATCH FOR ANIMALS” sign

#### 4.14 Evolution of the Deer Crossing Sign

Neither the 1927 Manual and specifications for the manufacture, display, and erection of US standard road markers and signs (American Association of State Highway Officials, 1927), nor the 1930 Manual on street traffic signs, signals and markings (American Engineering Council, 1930), include any types of animal crossing signs in their lists of “caution” warning signs. At the time, warning signs in both manuals were divided into three primary shape categories: The signs were octagonal-shaped, diamond-shaped and square-shaped and had black lettering and yellow backgrounds. Octagonal-shaped warning signs were used for stop signs. Diamond-shaped signs were used for “slow” signs for hazards inherent to the roadway (curves, hills, loose gravel, etc.). Square-shaped signs were used for “caution” signs for hazards not

inherent in the road itself, but which were due to contiguous or adjacent conditions which are often also intermittent (church zone, hospital zone, school zone, etc.) (American Association of State Highway Officials, 1927). “ANIMAL CROSSING” signs were first mentioned in the 1935 MUTCD’s “caution” series of warning signs. In the 1937 MUTCD, animal crossing signs, which gave warning of intermittent conditions, were supposed to be installed so they could be removed if the hazard no longer existed. “Animal crossings” were also included among the caution-type signs mentioned in the 1942 MUTCD. No graphic examples of the animal crossing signs were provided in the 1935, 1937 or 1942 editions of the MUTCD. In 1948, the square-shaped caution warning sign was eliminated. Warning signs, including animal crossing signs, were now all diamond-shaped. Although no graphic example was provided, “DEER CROSSING” was first referenced in the “Crossing Signs (W11 series)” section of the 1961 MUTCD. The sign was identified as one for hazards that may or may not be of a temporary or seasonal nature. The sign was supposed to be removed, if and when the hazardous condition terminated. The 1961 MUTCD also indicated that in many instances, it may be desirable to define the crossing by pavement markings. In 1961, there was a move toward incorporating symbols in traffic control signs. Although few new symbol signs were included in the 1961 MUTCD, this initiative set the stage for greater use of symbols in subsequent editions of the MUTCD. In 1964, the National Joint Committee (NJC) began developing the edition of the MUTCD published in 1971. In an effort to increase international uniformity, the 1971 MUTCD included a large number of symbols in signs. Although word signs were allowed as an alternative, most of the new symbol signs were developed to replace existing word signs. Since a number of completely new symbol signs were introduced, the meaning of these signs was explained with supplementary educational plaques (Hawkins, 1992c). A deer crossing sign with a leaping stag symbol was introduced in the “Other Crossing Signs (W11 Series)” section of the 1971 MUTCD. The graphic was presented with a “DEER XING” educational plaque (Figure 4.7).



Figure 4.7 Deer crossing sign with symbol and educational plaque  
(Source: National Joint Committee on Uniform Traffic Control Devices and  
American Association of State Highway Officials (1971))

Use of the sign may be justified to warn of an unexpected hazard. If the unexpected hazard was seasonal or temporary, the signs should be removed if, and when, the hazardous conditions are terminated, or cease to exist. A deer crossing sign with a leaping stag symbol, but without a “DEER XING” educational plaque was included in the “Advance Crossing Signs (W11 Series) of the 1978 MUTCD (Figure 4.8). The advance crossing sign was to be used to alert drivers to unexpected entries into the roadway by deer. Deer crossings may be relatively confined in nature, or may occur randomly over a substantial distance of roadway. Where deer crossing is confined to a single location, the deer crossing sign could be supplemented with an auxiliary distance sign specifying the distance to the crossing. Where deer crossings occur randomly, an auxiliary distance sign specifying the length of highway section upon which the potential deer hazard exists may be used. If the section of roadway where the potential deer hazard exists is quite long, additional signs may be located at intervals, with appropriate adjustments in the auxiliary distance signs. If the deer hazard is seasonal or temporary, the signs could be removed when the hazard was no longer present. Since the symbol-based deer crossing sign was adopted in the 1978

MUTCD, it has remained the national standard in the US. The evolution of the deer crossing sign is illustrated in Figure 4.9.



Figure 4.8 Deer crossing sign with symbol  
(Source: Federal Highway Administration (1978))



Figure 4.9 Evolution of the deer crossing sign in US

#### 4.15 Standard Deer Crossing Signs

Deer crossing signs are the oldest and most common form of deer-vehicle collision mitigation (Wood and Wolfe, 1988; Knapp and Yi, 2004). The standard MUTCD deer crossing sign is used in almost all US states (Sullivan and Messmer, 2003; Knapp and Yi, 2004). The static deer crossing signs are the devices most commonly used to advise drivers of known deer-vehicle collision locations or where potential deer hazards are believed to exist. The general objective of deer crossing signs is to warn drivers of a deer crossing danger and, hopefully, encourage an appropriate

reaction, such as increased driver focus and/or speed reduction (Knapp and Yi, 2004). Most signs are permanently installed, passive signs in fixed locations, with the same text or symbol message appearing at all times of the day and in all seasons of the year. Unfortunately, drivers are believed to become complacent about the significance or the meaning of conventional, static, diamond-shaped warning signs (Pojar et al., 1975; Putman, 1997; Sullivan and Messmer, 2003; Sullivan et al., 2004; Vest and Stamatiadis, 2005; Stanley et al., 2006). Drivers are suspected of misinterpreting or disregarding warning signs, thus reducing the effectiveness of warning signs for reducing vehicle speeds (Vest and Stamatiadis, 2005). Warning signs lose credibility for drivers if the hazard indicated by the warning sign is not immediately perceptible (Macdonald and Hoffmann, 1991). Very little is known about the effects of wildlife warning signs on driver behaviour (Åberg, 1981; Al-Kaisy, 2006). However, Åberg (1981) found only about 40% of drivers studied in Sweden noticed wildlife warning signs while driving. In their reviews of deer crossing signs, Knapp (2004) and Mastro et al. (2008) found no studies into the effectiveness of standard deer crossing signs for reducing deer-vehicle collisions.

Found and Boyce (2011) found installing new deer crossing signs at deer-vehicle collision-prone “hot spots” significantly reduced collisions at those locations in the year following the installation of the signs. Sullivan et al. (2004) advise deer crossing signs lose their effectiveness relatively quickly. Deer crossing signs, whether permanent or temporary, are not considered a cost-effective approach for reducing deer-vehicle collisions by state wildlife agencies and state departments of transportation Sullivan and Messmer (2003). Permanent deer crossing signs are used so frequently in the US that drivers habituate to them (Hughes et al., 1996). The continued use of permanent deer crossing signs is considered a token effort by state departments of transportation to reduce liability (Hughes et al., 1996). Although traffic warning signs are used to warn drivers for many different types of hazards, very little is known about the effects of the signs on driver behaviour (Åberg, 1981).

Skolving (1987) observed no valid measurements of the effectiveness of wildlife warning signs in Sweden had been conducted, and commented this was mainly because such studies are both difficult and time consuming to do. Johansson and Backland (1970) found wildlife crossing signs are remembered by slightly more than 60% of drivers passing such signs.

Skolving (1987) found only one third of surveyed Swedish drivers observed wildlife warning signs. Sullivan and Messmer (2003) reported that most US state wildlife resource agencies and state departments of transportation believe drivers do not observe and respond to wildlife warning signs. For traffic warning signs to be effective, the most important aspect relating to modifying driver behavior, is driver readiness to respond (Martens, 2000). Pojar et al. (1975) examined vehicle speed adjustments made by drivers who had just passed deer-crossing signs. They found only marginal reductions in speed could be attributed to the signs. Skolving (1987) found temporary wildlife warning signs had no clear effect and speed reduction was minimal (Table 4.3). Gordon et al. (2004) found vehicle speeds were only minimally reduced after vehicles passed static deer warning signs.

Table 4.3 Vehicle speed before and after temporary moose warning sign  
(Adapted from Skolving (1987))

<b>Speed Limit (kmph)</b>	<b>Average Speed Before Warning Sign (kmh)</b>	<b>Average Speed After Warning Sign (kmh)</b>	<b>% Average Speed Reduction</b>	<b>Time of Day</b>
90	97	96	1.0	Daylight
90	89	86	3.4	Dark

#### **4.16 Augmented Wildlife Warning Signs**

Warning signs augmented with features designed to attract driver attention have an increased potential to influence driver behavior (Stanley et al., 2006). Vest and Stamatiadis (2005) found that, when warning signs were augmented with flags and lights, speed reductions were less where hazards were not obvious to drivers than where hazards were more obvious or more clearly communicated by the warning signs. There have been few field studies on the effectiveness of augmented static wildlife warning signs. Pojar et al. (1975) and Reed and Woodward (1981) found attempts to augment deer crossing signs did not result in fewer deer-vehicle collisions. Temporary deer crossing signs with flashing lights were rated as “non-to-moderately” cost effective at reducing deer-vehicle collisions by state wildlife agencies and state departments of transportation (Sullivan and Messmer, 2003). Sullivan et al. (2004) found a 70% reduction in deer-vehicle collisions using temporary flashing deer crossing signs during seasonal migrations of mule deer. In Colorado, Pojar et al. (1975) found that while drivers reduced vehicle speeds in response to a lighted, animated deer crossing sign, the number of deer-vehicle collisions was not reduced. Sullivan et al. (2004) found the use of temporary, enhanced wildlife warning signs where highways transected mule deer migration corridors at five locations in Idaho, Nevada and Utah, resulted in a 50% reduction in deer-vehicle collisions. They also observed reduced vehicle speeds, but the degree of speed reduction diminished over time. Gordon et al. (2004) found drivers on US Highway 30 in western Wyoming reduced their vehicle speeds an average of 6.9 km/h at night in response to deer crossing signs with warning lights. They found when a deer decoy was visible to approaching drivers in combination with deer crossing signs and the flashing lights, vehicle speeds decreased by up to 20%. While Gordon et al. (2004) believed reducing vehicle speeds by 6 to 7 km/h may not have a significantly reduce deer vehicle collisions, the reducing the speed of impact should reduce the severity of a collision, possible leading to lower vehicle damage costs and

fewer human injuries and fatalities. When comparing the influence of activated and unactivated deer crossing signs, Gordon et al. (2004) found automobile drivers reduced their vehicle speeds significantly in response to warning signs augmented with flashing lights (Table 4.4).

Table 4.4 Day and night reductions in automobile speeds resulting from activated and unactivated deer crossing signs  
(Data source: Gordon et al., 2004)

<b>System</b>	<b>Time of Day</b>	<b>Speed Reduction (km/h)</b>
Activated	Day	3.0
Unactivated	Day	1.2
Activated	Night	6.0
Unactivated	Night	2.5

Stanley et al. (2006) observed driver responses to a series of conventional, static, diamond-shaped deer crossing signs augmented with flashing lights and variable message signs (VMS) in a simulated driving environment. They found augmented deer crossing signs decrease vehicle speed and increase the onset of braking distance. Although a deer crossing sign was used in the Stanley et al. (2006) study, the sign used was not specifically identified as a “deer” warning sign. In addition, the VMS text message used to augment the deer crossing sign was “ANIMAL CROSSING NEXT 20 MILES BE ALERT”. Stanley et al. (2006) associated the generic concept of “animal” in the VMS text message with a warning sign specifically depicting a deer. Although, it may be a matter of semantics, the inconsistency of the text message and the symbol may have contributed in confusion for some drivers. Hardy et al. (2006) investigated the effectiveness of seasonal animal movement advisories in southwestern Montana. They found messages on portable dynamic message signs (DMSs) had a more significant impact on average vehicle speed than messages on

permanent DMSs. Hardy et al. (2006) found animal advisory messages posted on DMSs during dark conditions resulted in lower vehicle speeds than when the DMSs posted no messages. They surmised given it is in the dark and dusk or dawn conditions when most animal vehicle collision occur, the use of animal advisory messages at these times may lead to fewer animal vehicle collisions. Hardy et al. (2006) also speculated drivers respond more positively to DMS animal advisory messages when the messages provided a warning for a more immediate portion of the highway (i.e., “NEXT 2 MILES” versus “NEXT 20 MILES”).

Drivers may respond more consistently to specific shorter-range advisories rather than longer-range advisories. A driver’s ability to avoid an animal vehicle collision may be determined within a fraction of a second and the distance their vehicle travels during that period (Hardy et al., 2006). Providing an animal advisory message during periods when most animal vehicle collisions are most likely to occur, may provide drivers with the critical time necessary to safely avoid a collision. In a traffic warning sign study involving Swedish drivers, Johansson and Backland (1970) found the sign depicting an antlered wild animal was only observed by 33.6% of their study subjects. It appeared the wildlife sign may have been one of relatively low signal value for Swedish drivers. Hardy et al. (2006) recommended enhanced warning signs should be used only where animal movements or animal vehicle collisions are concentrated when animal movements and animal vehicle collisions peak. This peak occurs typically at night during the fall months.

#### **4.17 Wildlife Warning Systems**

The primary goal of the wildlife warning systems is to make drivers more aware of the presence of wildlife along highways (Dai et al., 2009). Greater awareness of wildlife should encourage drivers to slow down so they have more time to react

effectively to wildlife, and potentially reduce the likelihood of a deer-vehicle collision or reduce the severity of the collision (Figure 4.10).



Figure 4.10 Deer crossing sign with flashing lights  
(Source: Dai et al. (2009))

Dodd and Gagnon (2010) found drivers on Arizona State Route 260 reduced their vehicle speeds significantly when they encountering warning signs with lights activated by an animal detection system (Figure 4.11). They observed vehicle speeds decreased 15 to 19% when the warning sign lights were activated. For the two years after the warning signs and animal detection system were installed, a reduction of 97.2% in large wildlife-related collisions was recorded. Huijser et al. (2010) noted the increased driver alertness Dodd and Gagnon (2010) reported is likely to have accompanied the lower vehicle speed and that the increased driver alertness was needed to be maintained only for a very short section of road section.

Huijser et al. (2010) suggested substantial reductions in wildlife-vehicle collisions could not be expected for longer sections of road, if time or location specific warning signs were not installed to raise driver alertness. The wildlife detection systems trials conducted in the US over the last decade have used extremely expensive technology relative to the cost of a standard deer crossing sign and a flashing light. The system used by Dai et al. (2009) in Wyoming cost approximately \$1US million to install.



Figure 4.11 Elk crossing sign with flashing lights  
(Source: Gagnon (2013). Used with permission.)

#### 4.18 Shortcomings of the MUTCD Deer Crossing Sign

In the US, transportation agencies typically install deer crossing signs near the site of a deer-motor vehicle collision, or along corridors where deer-motor vehicle collisions have occurred over time (Knapp and Yi, 2004). Deer crossing signs provide drivers a warning about the potential for deer to be on or near a roadway. Use of deer crossing signs assumes that drivers recognize the sign, understand the identified hazard, and know how to respond to the hazard should it be present. As currently used by US state departments of transportation, the MUTCD deer crossing sign is a static warning device that does not communicate the dynamic nature of the deer hazard. When installed by themselves, deer crossing signs provide drivers no spatial or temporal context for a deer hazard, or its potential magnitude. However, in some cases, spatial information may be provided with a tab indicating the length of road or highway subject to deer hazards. Static deer crossing signs are used so frequently at locations where deer are present only occasionally that the signs have limited utility for drivers (Putman, 1997, Sullivan and Messmer, 2003). Deer collisions occur more often at

specific periods during the day, and more often at specific periods during the year. Deer-vehicle collisions exhibit diurnal characteristics. In general, deer-vehicle collisions occur more frequently between 5:00 a.m. and 9:00 a.m. and between 4:00 p.m. and 12:00 a.m. in the US (Huijser et al., 2008). In Michigan, more deer-vehicle collisions occur during periods of darkness than during periods of light (Table 4.5). Deer-vehicle collisions also occur more frequently during periods of darkness or reduced light that coincide with peaks in traffic (Table 4.6). Across the US, deer-vehicle collisions occur more frequently in the spring and fall (Huijser et al., 2008). In Ohio, most deer-vehicle collisions occur between May and June, and October and January (Ohio Department of Public Safety, 2012) (Table 4.7).

Table 4.5 Light conditions in Michigan deer-vehicle collisions in 2012  
(Data source: 2012 Michigan Traffic Crash Facts)

<b>Light Condition</b>	<b>Deer-vehicle Collisions</b>	<b>% of Total</b>
Daylight	11,311	23.1
Dawn	4,427	9.0
Dusk	2,354	4.8
Dark – Lighted	1,744	3.6
Dark – Unlighted	28,321	57.9
Other/Unknown	761	1.6
Total	48,918	100.0

Table 4.6 Time of Michigan deer-vehicle collisions in 2012  
(Adapted from 2012 Michigan Traffic Crash Facts)

<b>Time of Collision</b>	<b>Deer-vehicle Collisions</b>	<b>% of Total</b>
Midnight – 2:59 a.m.	3,363	6.9
3:00 a.m. – 5:59 a.m.	4,745	9.7
6:00 a.m. – 8:59 a.m.	11,113	22.7
9:00 a.m. – 11:59 a.m.	2,538	5.2
Noon – 2:59 p.m.	1,906	3.9
3:00 p.m. – 5:59 p.m.	3,748	7.7
6:00 p.m. – 8:59 p.m.	12,259	25.1
9:00 p.m. – 11:59 p.m.	9,232	18.9
Total	48,904	100.0

Table 4.7 Monthly distribution of deer collisions in Ohio in 2011  
(Source: Ohio Traffic Crash Facts. Ohio Department of Public Safety.(2012))

<b>Month</b>	<b>Deer-vehicle Collisions</b>	<b>% of Total</b>
January	1,683	7.4
February	1,210	5.3
March	1,238	5.4
April	1,176	5.2
May	1,751	7.7
June	1,530	6.7
July	833	3.7
August	740	3.3
September	1,062	4.7
October	3,169	13.9
November	5,481	24.1
December	2,860	12.6
<b>Total</b>	<b>22,733</b>	<b>100.0</b>

#### **4.19 Roadway-based Natural Hazard Warning**

Natural hazard warning systems are not uncommon in the US, Canada and Australia. For decades, the National Forest Service of the US has been using a universal forest fire warning system (Cohen and Deeming, 1985). The warning system uses a very simple, colour-coded scale to provide a dynamic warning message. Forest fire warning signs are commonly installed along roads and highways in forested areas (Figures 4.12 and 4.13). As the potential for forests fires changes over time, the hazard levels indicated on these signs are adjusted accordingly (Cohen and Deeming, 1985). Weather, fuels, and topography provide the inputs necessary to predict fire weather, fire occurrence, and fire behaviour. In Australia, fire danger rating signs are located next to roads and highway to advise the public of bushfire potential (Figure 4.14). As a result, these fire warning signs provide a dynamic message with regards to changing fire hazard levels. In some cases, where the fire hazard is extreme, the warning signs may be periodically augmented with other messages pertaining to temporary forest use restrictions established to reduce the potential of the fire hazard

risk. In the US and Canada, forest closures are not uncommon when forest fire hazards are extreme.



Figure 4.12 Forest fire danger warning sign used in the US (Arizona)



Figure 4.13 Forest fire danger warning sign used in Canada (British Columbia)



Figure 4.14 Fire danger rating sign in Wanneroo, Australia  
(Source: Wanneroo Volunteer Fire Brigade, Used With Permission)

The fire hazard rating systems used in the US, Canada and Australia provide simple and easily understood methods of communicating the potential severity of natural hazards to the public. Although members of the public may not know, or appreciate, the amount of information and analysis required to support these systems, they should be able to associate the colour scheme, from green to red, with the corresponding hazard severity rating, low to extreme. One aspect of the US, Canadian and Australian fire danger rating systems that I believe contributes to the public's understanding of the hazard context is the relationship of the natural environment and

the hazard rating. If physically placed in the environment for which the warning system is intended, the warning signs can be viewed with visual cues supporting the warning rating.

#### **4.20 The Wildlife Hazard Rating System® (WildHAZ®)**

In the US, static wildlife warning signs are the devices most commonly used by state transportation agencies to advise drivers of known wildlife-vehicle collision locations or where potential wildlife hazards are believed to exist. Research has shown wildlife-related motor vehicle collisions are not random events but exhibit spatial and temporal patterns. James (1924) advised a conscientious effort was necessary to use traffic warning signs to educate drivers to recognize successive degrees of driving hazards. However, as currently employed, the wildlife warning signs used by transportation agencies provide limited information to drivers about the dynamics of wildlife hazards. The shortcomings of this situation are compounded as many drivers apparently do not notice wildlife warning signs. Figure 4.15 illustrates how as the potential fire danger changes, the environment surrounding the warning sign also changes. From a low fire danger rating in a snowy environment to an extreme fire danger rating in a very dry environment, the visual cues should help reinforce the fire danger rating message being given to the public.

Combining a colour code scheme and hazard severity rating system, I developed the WildHAZ®, the Wildlife Hazard Rating System® (Figure 4.16). The WildHAZ® system uses elements of the colour code schemes and textual components similar to the Australian, Canadian and US fire danger rating systems. The WildHAZ® system colour-coded hazard rating scale indicates the degree of potential wildlife hazard. Motor vehicle-related wildlife mortality data collected by state resource agencies or state departments of transportation, and/or wildlife-related motor vehicle collision data collected by police departments is used to determine the hazard severity rating.

From a driving safety perspective, the WildHAZ® is a new and unique sign system designed to complement conventional static wildlife warning signs and increase the



Low hazard



Moderate hazard



High hazard



Extreme hazard

Figure 4.15 Forest fire danger warning signs in context of environment



Figure 4.16 Wildlife Hazard Rating System<sup>®</sup>

amount of information conventional static wildlife warning signs provide drivers. The WildHAZ<sup>®</sup> system is designed to advise drivers of the potential severity of the deer hazard as the severity varies over time.

#### **4.21 Augmenting Static Deer Crossing Signs with the WILDHAZ<sup>®</sup> SYSTEM**

In the past, efforts have been made to augment deer crossing signs to increase their effect on advising drivers of potential deer hazards (Pojar et al., 1975; Reed and Woodward, 1981; Sullivan and Messmer, 2003; Hardy et al., 2006; Stanley et al., 2006; Dodd and Gagnon, 2010). In the US, the MUTCD allows for the augmentation of traffic warning signs with flags, flashing lights and coloured and/or patterned borders, to increase the effectiveness of the signs. Examples of similar sign augmentation are illustrated in Figure 4.17. The WildHAZ<sup>®</sup> system adopts elements of the coloured-border augmentation permitted by the MUTCD.

#### **4.22 Temporal Relationship of Speed and Deer Hazards**

In the absence of effective education about driving hazards, prior experiences with driving hazards, or recognizing driving hazards when they are present, a traffic warning sign in isolation may convey little information as to the context of the hazard that the hazard represents to drivers. An example of this is illustrated by comparing



Fluorescent squares



Flags



Coloured border



Flashing lights and patterned border

Figure 4.17 Augmented traffic signs

applications of the school zone warning signs in Figure 4.18. One school zone warning sign is presented without reference to when the school zone is likely to be a hazardous location for drivers. The second school zone warning sign is presented with specific reference to what days and time periods the school zone is most likely to be a hazardous location for drivers, and what the speed limit in the school zone is. Figure 4.19 illustrates the use of a school warning sign augmented with a time-specific, regulatory speed sign. If a warning sign is to convey a message about a hazard to drivers, providing timely information about the hazard and directions to reduce the potential of the hazard should help driver deal with the hazard more effectively. If drivers are educated about the WildHAZ® system and the significance of its colour code scheme for potential deer hazard severity, the WildHAZ® system can provide timely advisories to drivers without the need for supplementary message signs.

#### **4.23 Implementation of the WILDHAZ® system**

Implementation of the WildHAZ® system should not be difficult. Upon adoption of the WildHAZ® system, existing wildlife warning signs would need to be replaced or retrofitted within a period of time. The replacement and retrofitting could be staged to reduce cost. Due to the presence of deer crossing signs already installed along roads and highways, drivers should be aware of deer crossing signs. The WildHAZ® system colour code scheme should be familiar to drivers in areas where forest fire warning signs are installed. Figures 4.20 to 4.22 illustrate how the WildHAZ® system could be implemented by a transportation department. The implementation of WildHAZ® would be by means of the changeable warning sign colour borders, possibly augmented with variable speed advisory or regulatory signs.



Figures 4.18 Applications of school zone warning signs



Figure 4.19 School zone signs augmented with regulatory speed signs

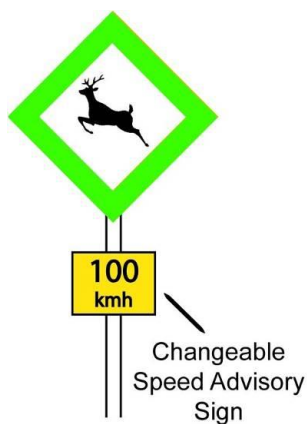


Figure 4.20 Low deer hazard sign with changeable speed advisory sign

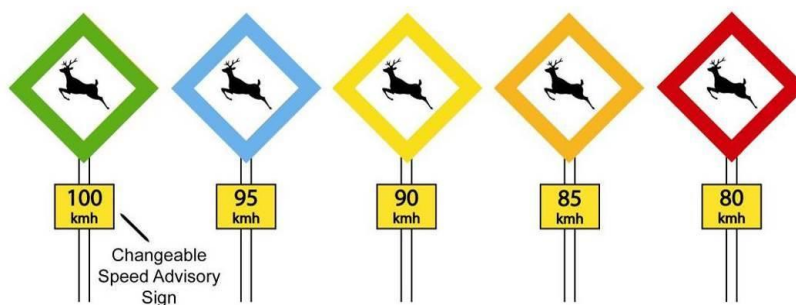


Figure 4.21 WildHAZ® system with changeable speed advisory signs

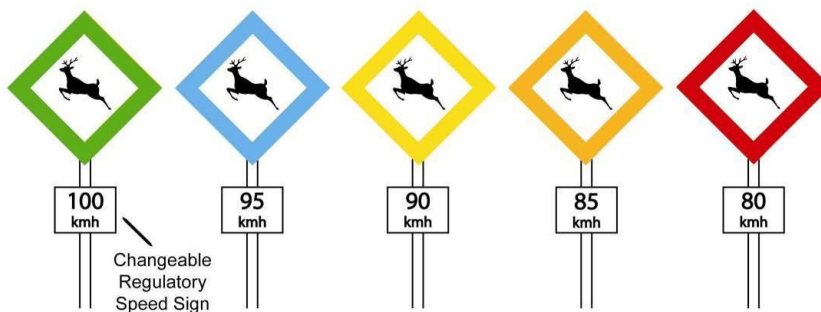


Figure 4.22 WildHAZ® system with changeable regulatory speed signs

For more than 45 years, variable speed limits and warning signs have been used in Europe to match environmental conditions (Coleman et al., 1995). As the warning sign borders change colour from green through to red, drivers would know the potential deer hazard severity was also changing. Where drivers are not actively searching for information, sign content, in terms of the significance the message has, seems to play a crucial role in modifying driver behavior (Martens, 2000).

Advising drivers when most deer-vehicle collisions are most likely to occur, may provide drivers with the critical time necessary to safely avoid a collision (Hardy et al., 2006). Without changeable speed advisory signs or changeable regulatory speed signs augmenting the deer crossing signs, drivers would be expected to modify their driving in a manner they themselves determined was appropriate. With the speed advisory signs or changeable regulatory speed signs, drivers would be guided more directly with either advisory speeds or mandatory speeds.

An example of a traffic warning sign that provides a temporal component is the supplementary sign which often accompanies school crossing signs (Figure 4.18). Drivers respond more positively when advisory speed signs are set based on valid parameters. It is important to uniformly apply advisory speed limits consistent with driver expectations in order to improve driving safety (Bonneson et al., 2007).

#### **4.24 An example application of the WILDLHAZ®**

To enable the WildlHaz® system to provide drivers with as much timely information about potential deer hazards as possible, its colour scheme should be guided by deer-vehicle collision times and dates recorded in preceding years by state resource agencies, state departments of transportation, and/or by state or local law enforcement agencies. An illustration of this would be the use of deer-vehicle collision data

collected by the Michigan State Police. Table 4.8 shows the deer-vehicle collision statistics for the state of Michigan for the period 2004 to 2012.

If one classifies the collision rates by hour according to the ranges of hourly collisions shown in Table 4.9, one can generate the colour code scheme for the entire state shown in Table 4.10. By applying this approach, one can use the WildHAZ® system to augment deer crossing signs to reflect the dynamic variation in deer-vehicle collision potential that occurs over the course of a year. If changeable advisory or regulatory speed limit signs are incorporated with the WildHAZ® system, speed limits could be automatically modified as deer-vehicle collision potentials change. An economical engineering option is the provision of information to drivers through the use signs and new technologies such as automated warning signs (ITE, 1999). A number of scenarios are depicted in Figures 4.23 to 4.25.

Table 4.8 Proposed WildHAZ® colour code scheme for the State of Michigan

<b>Deer-vehicle Collision Range (State-wide Collisions/Hour)</b>	<b>Colour Code</b>
Less than 500	Green
501 to 1000	Blue
1001 to 2000	Yellow
2001 to 5000	Orange
Greater than 5000	Red

Table 4.9 Total hourly deer-vehicle collisions in Michigan (2004 to 2012) from Michigan Crash Data

Month	12:00 AM - 1:00 AM	1:00 AM - 2:00 AM	2:00 AM - 3:00 AM	3:00 AM - 4:00 AM	4:00 AM - 5:00 AM	5:00 AM - 6:00 AM	6:00 AM - 7:00 AM	7:00 AM - 8:00 AM	8:00 AM - 9:00 AM	9:00 AM - 10:00 AM	10:00 AM - 11:00 AM	11:00 AM - 12:00 PM
January	1175	1030	850	837	1150	2358	3528	4062	1039	433	360	381
February	961	708	615	571	814	1549	2793	2581	649	314	333	287
March	899	740	573	546	755	1561	3349	3449	959	526	443	394
April	825	662	548	517	717	1451	4031	2175	875	562	485	429
May	1245	1154	825	828	957	3152	3683	2133	1266	912	793	690
June	1421	1342	1013	907	1088	4102	2848	2056	1407	1048	1013	983
July	1048	906	705	586	731	2403	2260	1305	944	745	741	662
August	671	542	418	410	532	1282	3065	1619	873	552	505	455
September	1082	840	720	687	988	1806	3978	4386	1478	758	592	459
October	2269	1916	1608	1615	2260	4091	6657	10322	3578	1447	1018	812
November	2207	1785	1521	1443	2043	4055	7176	7662	2802	1584	1447	1321
December	1449	1155	940	901	1346	2563	3677	3852	1046	567	571	474
Month	12:00 PM - 1:00 PM	1:00 PM - 2:00 PM	2:00 PM - 3:00 PM	3:00 PM - 4:00 PM	4:00 PM - 5:00 PM	5:00 PM - 6:00 PM	6:00 PM - 7:00 PM	7:00 PM - 8:00 PM	8:00 PM - 9:00 PM	9:00 PM - 10:00 PM	10:00 PM - 11:00 PM	11:00 PM - 12:00 AM
January	385	331	355	383	514	2108	7962	4794	2630	2211	2178	1924
February	278	252	290	285	349	648	3463	4938	2451	1597	1375	1311
March	403	342	375	457	526	650	1209	4066	4515	2747	1620	1282
April	425	373	408	423	462	573	534	945	3151	4380	1736	1301
May	654	611	588	660	617	687	621	781	2018	6754	3507	1666
June	896	814	827	805	854	793	728	865	1461	4881	5933	2400
July	664	592	567	617	585	611	587	636	1065	3266	3870	1717
August	456	445	423	440	459	494	522	692	1773	3412	1524	980
September	408	411	387	427	472	622	892	2206	5483	3025	1890	1759
October	740	601	630	726	739	1363	3064	9967	7980	5188	4077	3397
November	1108	976	969	1190	1816	9786	15898	10024	7060	5516	4599	3518
December	458	454	447	492	832	6221	9792	5256	3379	3029	2843	2435

Table 4.10 Proposed WildHAZ® system hourly colour code scheme for Michigan

Month	12:00 AM - 1:00 AM	1:00 AM - 2:00 AM	2:00 AM - 3:00 AM	3:00 AM - 4:00 AM	4:00 AM - 5:00 AM	5:00 AM - 6:00 AM	6:00 AM - 7:00 AM	7:00 AM - 8:00 AM	8:00 AM - 9:00 AM	9:00 AM - 10:00 AM	10:00 AM - 11:00 AM	11:00 AM - 12:00 PM
January	Yellow	Yellow	Blue	Blue	Yellow	Orange	Orange	Orange	Yellow	Green	Green	Green
February	Blue	Blue	Blue	Blue	Blue	Yellow	Orange	Orange	Blue	Green	Green	Green
March	Blue	Blue	Blue	Blue	Blue	Yellow	Orange	Orange	Blue	Blue	Green	Green
April	Blue	Blue	Blue	Blue	Blue	Yellow	Orange	Orange	Blue	Blue	Green	Green
May	Yellow	Yellow	Blue	Blue	Blue	Orange	Orange	Orange	Yellow	Blue	Blue	Blue
June	Yellow	Blue	Yellow	Blue	Yellow	Orange	Orange	Orange	Yellow	Yellow	Yellow	Blue
July	Yellow	Blue	Blue	Blue	Blue	Orange	Orange	Yellow	Blue	Blue	Blue	Blue
August	Blue	Blue	Green	Green	Blue	Yellow	Orange	Yellow	Blue	Blue	Blue	Green
September	Yellow	Blue	Blue	Blue	Blue	Yellow	Orange	Orange	Yellow	Blue	Blue	Green
October	Orange	Yellow	Yellow	Yellow	Orange	Orange	Red	Red	Orange	Yellow	Yellow	Blue
November	Orange	Yellow	Yellow	Yellow	Orange	Orange	Red	Red	Orange	Yellow	Yellow	Yellow
December	Yellow	Blue	Blue	Blue	Yellow	Orange	Orange	Orange	Yellow	Blue	Blue	Green
Month	12:00 PM - 1:00 PM	1:00 PM - 2:00 PM	2:00 PM - 3:00 PM	3:00 PM - 4:00 PM	4:00 PM - 5:00 PM	5:00 PM - 6:00 PM	6:00 PM - 7:00 PM	7:00 PM - 8:00 PM	8:00 PM - 9:00 PM	9:00 PM - 10:00 PM	10:00 PM - 11:00 PM	11:00 PM - 12:00 AM
January	Green	Green	Green	Green	Green	Orange	Red	Orange	Orange	Orange	Orange	Yellow
February	Green	Green	Green	Green	Green	Blue	Orange	Orange	Yellow	Yellow	Yellow	Yellow
March	Green	Green	Green	Green	Blue	Blue	Yellow	Orange	Orange	Orange	Yellow	Yellow
April	Green	Green	Green	Blue	Blue	Blue	Blue	Orange	Orange	Orange	Yellow	Yellow
May	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Orange	Red	Orange	Yellow	Yellow
June	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Yellow	Orange	Orange	Red	Orange
July	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Yellow	Orange	Orange	Orange	Yellow
August	Green	Green	Green	Green	Green	Green	Blue	Blue	Yellow	Orange	Yellow	Blue
September	Green	Green	Green	Green	Green	Blue	Blue	Orange	Red	Orange	Yellow	Yellow
October	Blue	Blue	Blue	Blue	Blue	Yellow	Orange	Red	Red	Red	Orange	Orange
November	Yellow	Blue	Blue	Yellow	Yellow	Red	Red	Red	Red	Red	Orange	Orange
December	Green	Green	Green	Green	Blue	Red	Red	Red	Orange	Orange	Orange	Orange



Standard deer crossing sign



Augmented deer crossing sign at a low hazard period



Augmented deer crossing sign at a low hazard period with advisory speed tab



Augmented deer crossing sign at a low hazard period with regulatory speed tab

Figure 4.23 Application of the WildHAZ® system at a low hazard period



Standard deer crossing sign



Augmented deer crossing sign at a high hazard period



Augmented deer crossing sign at a high hazard period with advisory speed tab



Augmented deer crossing sign at a high hazard period with regulatory speed tab

Figure 4.24 Application of the WildHAZ® system at a high hazard period



Standard deer crossing sign



Augmented deer crossing sign at an extreme hazard period



Augmented deer crossing sign at an extreme low hazard period with advisory speed tab



Augmented deer crossing sign at an extreme hazard period with regulatory speed tab

Figure 4.25 Application of the WildHAZ® system at an extreme hazard period

#### 4.25 Preliminary Evaluation of the WildHAZ® System

After developing the WildHAZ® system, it was brought to my attention that a significant number of male drivers have Red-Blind/Protanopia vision, and may be blind to the colour red. Approximately 2% of male drivers have a colour vision problem that makes red appear to be black (Allen, 2001). A large number of senior drivers also have diminished colour vision, in particular for the red end of the visual spectrum (Whillans, 1993). Traffic signals in most countries are not suited to colour blind drivers (Daltoniana, 1988). Compared to drivers with normal vision, red-blind drivers do not have as much recognition or braking distance at stop lights. Since the colour red was chosen as the colour to indicate the highest hazard potential in the WildHAZ® system, I felt it was critical to explore alternatives to address this issue.

Colour-blind drivers should have at least an equal safety margin in recognizing traffic signs (Whillans, 1993). Drawing upon resources for the colour-blind (Colblindor, [www.color-blindness.com](http://www.color-blindness.com)), I was able to simulate the vision of Red-Blind/Protanopia individuals to determine how the WildHAZ system might look to them. The red element of the WildHAZ® system did not appear to provide any degree of uniqueness or urgency for a Red-Blind/Protanopia individual that it may for a non-Red-Blind/Protanopia individual.

The Colour Blind Committee recommends all red coloured traffic signs be augmented with white bars (Allen, 2001). To accommodate the needs of drivers who have Red-Blind/Protanopia vision, the original WildHAZ® system should be modified before being tested in a field situation. If one compares the images in Figures 4.26 and 4.27, it is apparent drivers who have Red-Blind/Protanopia vision may not be able to readily distinguish the “Low” and “Extreme” ratings. I modified the red component of the system to include white elements, thus clearly differentiating it from the other colour components of the system. By adding white bars to the red border of the “Extreme” rating, the contrast of this element relative to the “Low” rating can be increased significantly.



Figure 4.26 Wildlife Hazard Rating System® (Normal colour vision)



Figure 4.27 Wildlife Hazard Rating System® (Red-blind/protanopia vision)

Figures 4.28 and 4.29 illustrate the effects of this modification for drivers who have Red-Blind/Protanopia vision. It appears this modification may also increase the potential value of the WildHAZ® system for all drivers. I considered modifying the other colour components of the WildHAZ® system. However, I believed increasing the complexity of the other components might increase the visual distraction of the system for many drivers. Steele et al. (2013) found complex visual driving environments can confuse drivers. Increasing the complexity of the WildHAZ® could compromise the warning potential of the system for a majority of drivers. To better understand how the modified WildHAZ® system might be perceived by drivers, I asked a number of colleagues, friends and family members to provide objective evaluations of the system. To facilitate these evaluations, I designed and built a fully functional, ½ scale manual prototype of the system (Figure 4.30).



Figure 4.28 Wildlife Hazard Rating System® (Normal colour vision)



Figure 4.29 Wildlife Hazard Rating System® (Red-blind/protanopia vision)



Figure 4.30 Half-scale manual WildHAZ® system prototype

The prototype was constructed of the same type of materials that road authorities use for conventional wildlife warning signs. I also produced graphics materials to illustrate the different hazard level warnings of the WildHAZ® system (Figure 4.31). The WildHAZ® system was well received by the target audiences. The concept of a colour-coded hazard rating system for communicating the varying degree of wildlife hazards was understood by all. However, concerns were raised about the use of the colour green relative to “low” potential hazard risk. Green is a colour everyone associated with a “no hazard” condition, similar to the green “go” light in green-yellow-red colour sequence used for intersection control lights (Figure 4.32). Given the population dynamics of wildlife and their movement patterns, a “no hazard” situation with regards to potential wildlife-vehicle collisions may never completely exist, unless the hazard species in question became extinct.



Figure 4.31 Hazard colour codes of WildHAZ® system prototype at night

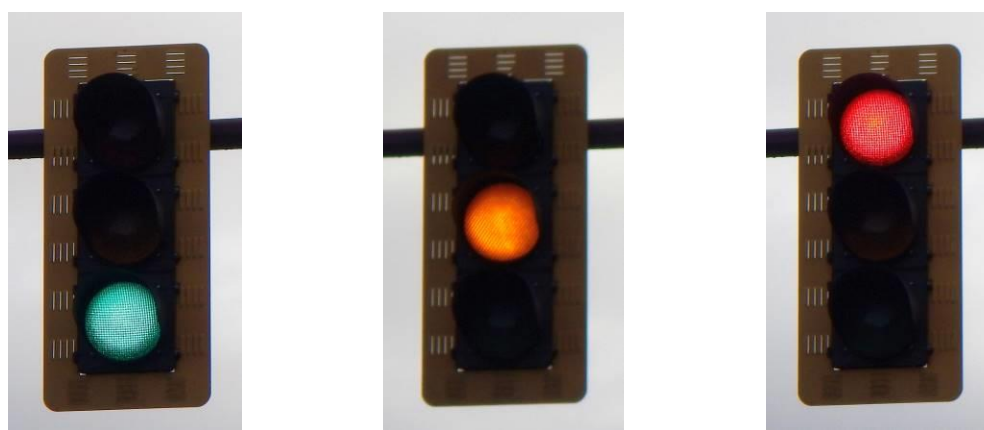


Figure 4.32 Colour sequence of traffic control signal

#### **4.26 Driver Awareness of the WildHAZ® System**

Unless drivers see deer in the vicinity of deer crossing signs, it is unlikely drivers will associate the WildHAZ® ratings to the potential deer hazard as strongly as they might associate potential forest fire hazard ratings to a natural environment that appears very susceptible to fire. If adopted and implemented by US states, details about the WildHAZ® system should be included in state driver manuals to advise new drivers of the system. The WildHAZ® system should also be advertised in the media to advise all existing drivers of the new traffic hazard warning system.

#### **4.27 Testing the WildHAZ® System**

Despite the logic behind the risk hazard rating colour code of the WildHAZ® system and the use of state-collected wildlife collision data to support colour code use decisions, it is anticipated there may be resistance to the implementation of the system by some road authorities. Knowing the effectiveness of traffic warning signs for driver safety is important for road authorities to assess the feasibility of using conventional signs and determine whether alternative warning devices are required to increase driver safety (Al-Kaisy et al. 2008). Without a comprehensive, statistically sound evaluation of the WildHAZ® system that proves the system's ability to modify driver behaviour to improve driver safety, the WildHAZ® system may be viewed as a novelty by road safety professionals. Road authorities need to be assured any proposed innovation in road safety is thoroughly vetted by road safety professionals and proven effective (Pullen-Seufert and Hall, 2008). There have been numerous attempts to attract driver's attention through the use of unique and unusual traffic warning signs (Florida Section (District 10) of the Institute of Transportation Engineers, undated). These types of warning signs, with messages warning of children at play or domestic animals crossings, are usually installed as a result of emotional and political pressure. Unfortunately, the novelty effect of these warning signs wears off quickly and the signs no longer attract the attention of regular passing drivers. In addition, the warning signs are targets for vandals and souvenir hunters.

Unique message warning signs have no legal meaning or established precedent for use in basic traffic safety engineering. The signs are not approved by the US Manual on Uniform Traffic Control Devices (City of Wichita Traffic Engineering, 2008). The use of such signs is discouraged because of both a lack of proven effectiveness and potential legal liability (Florida Section (District 10) of the Institute of Transportation Engineers, undated). The warning signs provide no guidance to drivers in terms of a safe speed (City of Wichita Traffic Engineering, 2008). There is no evidence special traffic warning signs reduce driver speeds or collision rates (CTC and Associates, 2007). There is also no legal basis for determining what a driver should do when they encounter a unique traffic warning sign (City of Wichita Traffic Engineering, 2008).

Unique traffic warning signs may undermine the effectiveness of conventional traffic warning signs (City of Wichita Traffic Engineering, 2008). Consequently, augmenting conventional wildlife warning signs with the WildHAZ® system may lead some drivers to believe the message provided by non-augmented conventional wildlife warning signs is less important, or worse, not important at all. Some state departments of transportation have exacting specifications with regards to the production of wildlife warning signs (Figures 4.33 and 4.34). However, from the literature, it appears no road authorities have corresponding exacting standards with regards to the required measured effectiveness of these signs. In addition, the MUTCD does not provide guidance or research indicating what types of traffic warning signs are not effective (CTC and Associates LLC, 2010). The effectiveness of warning signs and warning messages for their target audiences is not frequently tested (Laughery, Sr. and Smith, 2006). Conventional wildlife warning signs are common on many roads and highways throughout the US (Gkritza et al., 2010). However, limited research has been conducted to evaluate the effectiveness of these signs in reducing wildlife-vehicle collisions (Knapp et al., 2004). The most common technique for evaluating traffic signs is the paper-and-pencil method (De Ceunynck et al., 2015).

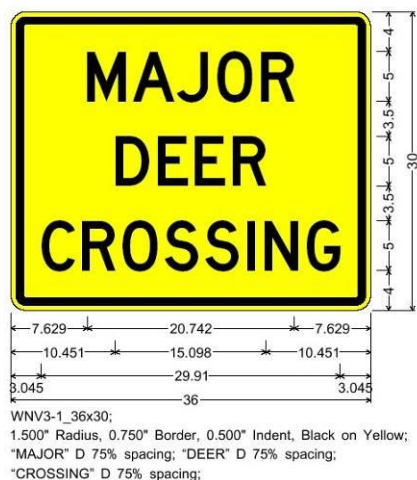
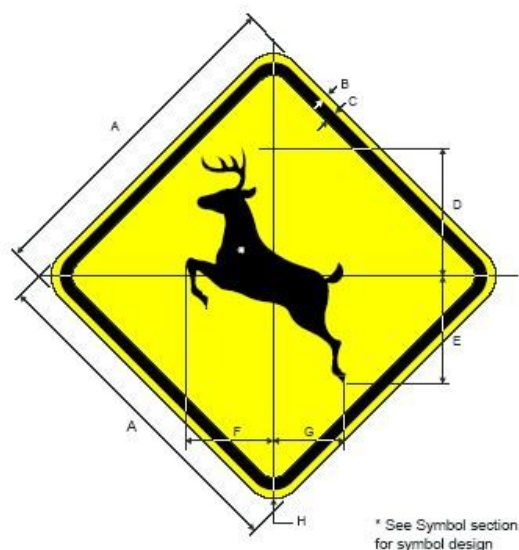


Figure 4.33 Major deer crossing sign specifications  
 (Source: Nevada Department of Transportation (2009))



W11-3  
 (Deer)

A	B	C	D	E	F	G	H
24	.375	.625	10.625	7.875	6.5	5.875	1.5
30	.5	.75	13.5	10	8.25	7.5	1.875
36	.625	.875	16.25	12	9.875	9	2.25
48	.75	1.25	21.25	15.75	13	11.75	3

COLORS: LEGEND - BLACK  
 BACKGROUND - YELLOW (RETROREFLECTIVE)

Figure 4.34 Deer crossing sign specifications  
 (Source: Texas Department of Transportation (2012))

From the literature, it appears there is no standardized methodology for determining the effectiveness of conventional wildlife warning signs. Traffic warning sign effectiveness appears to be more a matter of perception and opinion than based on evidence (CTC and Associates LLC, 2010).

#### **4.28 Example of a Poorly Evaluated Traffic Safety Device**

Before a road authority can accept new traffic safety technology for a widespread application, it is essential a robust analysis be undertaken to determine if the technology is effective in changing driver behaviour, and whether or not traffic safety benefits are achieved (Hay, 2011). For example, the Insurance Institute of Highway Safety (1993) considered wildlife reflectors as the most promising system for preventing deer-vehicle collisions. However, the value of wildlife reflectors as a traffic safety device was poorly evaluated when the devices were first introduced to the US (Ramp and Croft, 2006). As a consequence, the effectiveness of the device has been subject to considerable controversy and dispute by its advocates and detractors (Putman et al., 2004). Robust evaluation of wildlife reflector effectiveness has been lacking (Ramp and Croft, 2006). The lack of an authoritative, properly designed and executed, comprehensive, multi-year study of wildlife reflectors at the onset of their use has overshadowed the use of the devices by road authorities in the US. The theory behind wildlife reflectors is that the devices modify wildlife behaviour at the roadside in such a way that wildlife-vehicle collisions are reduced (U.S. Roads, 1997). In accordance with specific manufacturer's installation instructions, the reflectors are carefully located along roadsides (Figure 4.35).

At night, by means of their coloured reflective surfaces, the devices reflect light from approaching motor vehicle headlights (Woodham, 1991). The reflected light is presumably seen by roadside wildlife, which then apparently stop moving at the roadside. Any reductions in the number of wildlife-vehicle collisions is typically attributed to the change in wildlife movement behaviour caused by the reflectors. There seems little doubt however that if, even under ideal conditions, wildlife

reflectors have some effectiveness for a period after installation, this effect wanes over time, due to deterioration of the reflectors themselves and due to wildlife habituation/learning (Putman et al., 2004).



Figure 4.35 Wildlife reflector installed by a highway

While the theory behind wildlife reflectors may be plausible, considerable research has shown these devices do not influence wildlife behaviour, in particular deer, nor do the devices reduce the incidents of wildlife-vehicle collisions (D'Angelo et al. 2004). Studies of wildlife warning reflectors have used a variety of testing methods of various levels of scientific validity (D'Angelo et al. 2004). Unfortunately, this has led to an extremely limited understanding of reflector effectiveness. Most reflector evaluations have been based on counts of deer-vehicle collisions:

- 1) Within test sections pre- and post- reflector installation (Ingebrigtsen and Ludwig, 1986), or

- 2) When reflectors were covered versus uncovered with the same test section (Schafer and Penland, 1985; Armstrong, 1992), or
- 3) Within reflectorized test sections and adjacent non-reflectorized control sections (Reeve and Anderson, 1993).

These approaches fail to consider changes in deer populations, seasonal deer movements, or traffic patterns (D'Angelo et al. 2004). Studies based on counts of deer carcasses found along roadways to determine reflector effectiveness rarely use data quality controls of test sections or driver surveys to account for deer-vehicle collisions that resulted in injured deer wandering from the roadside. While Pafko and Kovach (1996) used anecdotal trends in deer-vehicle collision data for pre- and post-reflector installation and concluded collisions declined in rural areas, they did not conduct statistical analysis of the collision data. Beyond the differences in experimental design, comparisons of the results of the various reflector studies are compromised by the variety of reflector models tested and the distinct spectral properties of those devices. The use of wildlife reflectors has been discontinued in many US States (Figure 4.36).

#### **4.29 Discussion**

The MUTCD deer crossing sign currently used by state departments of transportation in the US evolved over the last 80 years. The deer crossing sign changed from a square shape with text to a diamond shape with a deer silhouette. The evolution of the deer crossing sign culminated in the mid-1970s, decades before the deer hazard for drivers in the US reached epidemic proportions. The MUTCD deer crossing sign is a static device used to warn drivers of a growing, dynamic hazard. Earlier research has shown that, as a static warning device, the MUTCD deer crossing sign has limited utility for drivers. Studies have shown that augmenting the MUTCD deer crossing sign with flashing lights and changeable messages can be effective in increasing driver awareness of potential deer hazards.



Figure 4.36 Decommissioned wildlife reflector installation

Lacking in both the standard MUTCD deer crossing sign and the augmented versions is a dynamic element that incorporates the diurnal and seasonal attributes of the deer hazard for drivers.

To address this deficiency, I developed the Wildlife Hazard Rating System® (WildHAZ®). WildHAZ® is a new and unique wildlife warning system that incorporates the accepted elements of existing warning systems for other natural hazards to provide drivers information about the degrees of the potential deer hazard they may face while driving. The WildHAZ® system evaluates vehicle-related deer mortality data collected by state resource agencies or state departments of transportation, and/or deer-related motor vehicle collision data collected by state or local law enforcement agencies to determine the spatial and temporal potential for wildlife hazards along roads and highways. A simple colour-coded hazard rating scale has been developed to indicate the degree of the potential deer hazard.

The WildHAZ® system offers state departments of transportation, and other road authorities a system of communicating the deer hazard to drivers that reflects the dynamic nature of the deer hazard. The WildHAZ® uses elements and concepts of traffic warning sign augmentation already approved for use in the US by the MUTCD. Increased awareness of deer should encourage drivers to slow down so they have more time to react effectively to deer, and potentially reduce the likelihood of a deer-vehicle collision or reduce the severity of the collision (Dai et al., 2009).

While some drivers may chose not to modify their driving behaviour when provided with ratings on deer hazards, other drivers may do so. Those drivers who become more cognisant of deer and reduce their speeds should reduce the likelihood and/or severity of deer-vehicle collisions. The success of implementing the WildHAZ® system would require the replacement or retrofitting of existing wildlife warning signage within a period of time. Retrofitting existing signs with coloured borders could be accomplished with simple frames screwed to the existing signs. Speed advisory tabs could be attached to the existing signs posts.

For the WildHAZ® system to be most effective in the US, it would have to be implemented universally and consistently across all US states. A standard rating system would need to be developed and adopted by all US states. In 1965, A.E. Johnson, Executive Secretary, AASHO, advised it was essential traffic signs meant the same thing to drivers in every part of the US. A driver education campaign would be required in order for the WildHAZ® system to establish any degree of effectiveness. Drivers would need to know what the elements of the WildHAZ® system represent and why they are used.

In order for new drivers to become aware of the WildHAZ® system, state drivers manuals would need to include a description of the signing system and the examples of signage that could be encountered. Driving instructors would need to be advised of the WildHAZ® system and provided supporting materials so they could effectively teach new drivers about the new signing system. A public awareness campaign,

utilizing the visual attributes of television and print media, would be required in order for current drivers to become aware of the new signing system. Brochures would be mailed to all licensed drivers and posted on state transportation agency websites and insurance company websites.

If implemented at the individual state level, the WildHAZ® system offers state departments of transportation an approach to augment their existing deer crossing sign inventory and reduce the potential for deer-vehicle collisions based on local deer-vehicle collision histories. If implemented across the US, the WildHAZ® system would provide a uniform and consistent approach to advising drivers of the deer hazard potential as the hazard varies spatially and temporally nationwide.

## **5.0 WILDLIFE HAZARD WARNING SYSTEM® SURVEY**

### **5.1 Introduction**

The Wildlife Hazard Warning System® would represent a paradigm shift for road authorities with respect to the current use of static wildlife warning signs for temporally and spatially dynamic wildlife hazards. Before the system could be considered for implementation, road authorities would need assurance drivers understand the system and that drivers will respond appropriately. In order to determine the potential of the Wildlife Hazard Warning System® to effectively advise drivers of changing risk levels and influence driver behaviour, the system needed to be evaluated by drivers. To accomplish this, a web-based questionnaire survey was developed and drivers were invited to participate. The survey is considered a first step in the longer process of validating the potential effectiveness of the Wildlife Hazard Warning System®.

### **5.2 Objectives**

The two primary objectives of the Wildlife Hazard Warning System® questionnaire survey were:

1. To determine if drivers understand the basic premise of the system, and
2. To determine if drivers would respond to the system in a manner that would reduce their potential for a wildlife-vehicle collision and/or reduce the potential severity of a wildlife-vehicle collision.

### **5.3 Methodology**

The web-based questionnaire survey involved three basic steps:

1. Survey development;
2. Survey participant recruitment; and
3. Survey deployment

### **5.3.1 Survey Development**

A twenty-question survey with 19 multiple choice questions and one open-ended response question was developed. The open-ended question was to provide the survey participants with the opportunity to give comments or suggestions about the Wildlife Hazard Warning System®. The survey was designed to be anonymous, so no identifying information (i.e. name, address, telephone number, email address, etc.) was required or requested from the participants. Survey questions were designed to collect:

1. demographic information about the survey participants,
2. information regarding the survey participants' knowledge and past experience with deer and deer warning signs,
3. information about the survey participants' comprehension of the Wildlife Hazard Warning System® and how they would respond to the system.

Since the survey was primarily intended for drivers living in Canada and the US, two versions of the survey were created to address differences between the two countries (Appendices 5-A and 5-B). The two versions of the survey reflected national differences in the spelling of words, linear measurement systems, and the names of political geographic areas. The Canadian version of the survey used the words "colour", "kilometres", "centre" and "province", while the US version used the words "color", "miles", "center" and "state". Linear measurements were kept consistent between the two surveys by using equivalent Metric and US units (i.e. 8 kilometres for the Canadian version and 5 miles for the US version). For the Canadian version

of the survey, provinces and territories were listed as location of residence options while for the US version, a list of states was provided.

The draft version of the survey was circulated for review. As a result of the suggestions received, the survey was modified to improve demographic information collection and the Wildlife Hazard Warning System® was modified to increase its comprehension by red/green blind individuals (Figures 5.1 and 5.2).



Figure 5.1 Original Wildlife Hazard Warning System®



Figure 5.2 Modified Wildlife Hazard Warning System®

Prior to recruiting participants for the survey, all versions of the survey and all participant recruitment materials and participant consent forms (Appendices 5-C and 5-D) were submitted for review and approval by the University of Victoria Human Research Ethics Board (HREB). In order to proceed with the survey, compliance with all HREB regulations was necessary.

The survey was designed for persons aged 19 years and older. This step was taken specifically to avoid HREB requirements for surveying minors. In order to survey a

person under 19 years of age, the HREB requires written permission from that individual's parents or guardians be obtained before the individual can participate in a survey. Persons 19 years and older are considered competent adults by the HREB. Surveying persons under 19 years of age would have significantly complicated a web-based survey that both used email for participant recruitment and guaranteed survey participants complete anonymity. After modifying the original survey and invitation emails to comply with HREB review requirements, the survey materials were approved by the HREB (Appendix 5-E).

### **5.3.2 Survey Participant Recruitment**

The survey target group was drivers who were 19 years of age or older. Potential survey participants were recruited via email invitations. In order to email survey invitations to potential survey participants, it was necessary to obtain their names and email addresses. Researchers face obstacles to sampling if access to a population list is restricted (Palys, 1992; Black, 1999). Driver contact information is collected by state and provincial vehicle driver licensing agencies and public and private automobile insurance companies. However, such personal information is subject to extremely strict privacy controls and not readily available to individuals outside those agencies and companies.

A sampling frame is a tool used to gain access a population (Knuttila, 2008). There are two basic types of sampling frames: area frames and list frames (Statistics Canada, 2001). An area frame is a list of geographic areas that provide indirect access to individuals (such as provinces in a country). A list frame is simply a list of names and addresses of potential survey participants that provide direct access to individuals (i.e. a list of players on a football team) (Knuttila, 2008). The sampling frame chosen for a survey will impact the selected survey population (Statistics Canada, 2001; Knuttila, 2008). Sometimes, when sampling frames such as provincial

and state driver records, are not available a sampling frame will need to be created (Knuttila, 2008).

Research studies may employ more than one sampling strategy (Patton, 1990). A study can be strengthened through the combination of methodologies (Patton, 1990; Tashakkori and Teddlie, 1998). Taking this into consideration, the sample frame for the survey was a combination of:

1. friends, colleagues and acquaintances, and
2. persons who I did not know, but whose contact information was publicly available.

Contact information for those persons I did not know was obtained from the websites of the following types of organizations:

1. Automobile associations,
2. Bus and taxi companies,
3. Car clubs,
4. Computer software companies,
5. Conservation associations,
6. Driving schools,
7. Education institutes,
8. Environmental groups
9. Federal, state/provincial and municipal governments,
10. Fish and wildlife associations,
11. Government agencies,
12. Manufacturing companies,
13. Media outlets (TV, radio, and newspapers),
14. Medical and dental offices,

15. Outdoor recreational associations,
16. Private and public insurance companies,
17. Religious organizations,
18. School bus authorities,
19. Seniors care facilities,
20. Seniors organizations,
21. Trucking associations,
22. Trucking companies.
23. Veterans organizations,
24. Volunteer fire departments, and
25. Wildlife rehabilitators.

Recruitment of potential survey participants was limited to a single email invitation. This approach was used to avoid the possible negative effects of bothering or harassing people. There is a strong belief among survey researchers that reluctant respondents, those who require vigorous persuasion, tend to provide responses of lower quality (Grove, 1987). Sapsford (2007) suggests people may become alienated with a survey after multiple contacts. After multiple requests, improving survey response rates by vigorous follow-ups may lead to a more comprehensive data set with poorer quality data (Grove, 1987).

Survey participant encouragement takes a variety of forms, from offering monetary incentives to emphasizing people's contributions to a worthwhile project (Gray and Guppy, 2003). It appears recruiting survey participants is challenging. Major retailers in Canada regularly offer their customers the chance to win prizes ranging from several hundred dollars to \$1,500 if the customers participate in "brief" web-based surveys (Figures 5.3 and 5.4). Offering large cash prizes to potential survey participants was beyond the scope of unfunded research. In addition, offering any incentive to participate, beyond modest reimbursement for time and out-of-pocket

expenses (i.e. parking, bus fare, etc), would be unethical. Consequently, potential survey participants were not offered any payment or any chance to win a prize if they participated in the survey.

### **5.3.3 Survey Deployment**

The Canadian and US versions of the survey were presented to survey participants via the Internet using FluidSurveys. Web-based surveys enable researchers to access groups and individuals who would be difficult, if not impossible, to reach, through other channels (Wright, 2005). They are fast, flexible and low cost (Cook et al. 2000; Monroe and Adams, 2012). Web-based surveys also have the potential to save researchers time through both rapid access to large numbers of potential survey participants and immediate preliminary analysis of collected data (Llieva et al., 2002).

### **5.3.4 FluidSurveys Survey**

FluidSurveys was a web survey tool hosted in Canada. The tool could be used to create and manage surveys and responses. Information collected with FluidSurveys was stored in Canada. The FluidSurveys service at University of Victoria was provided to support teaching, learning, research, and administration. The University of Victoria offered access for current faculty, staff and students for a 1-year trial, ending July 1, 2017. The use of the FluidSurveys service by graduate students was completely voluntary. The FluidSurveys services used for the survey were provided by the University of Victoria free of charge. Free use of the FluidSurveys service and the University of Victoria email service eliminated all direct costs of conducting the survey on the Internet.

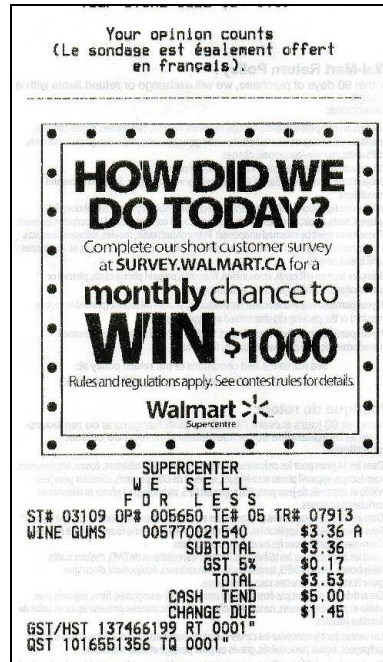


Figure 5.3 Walmart® survey participant recruitment incentive

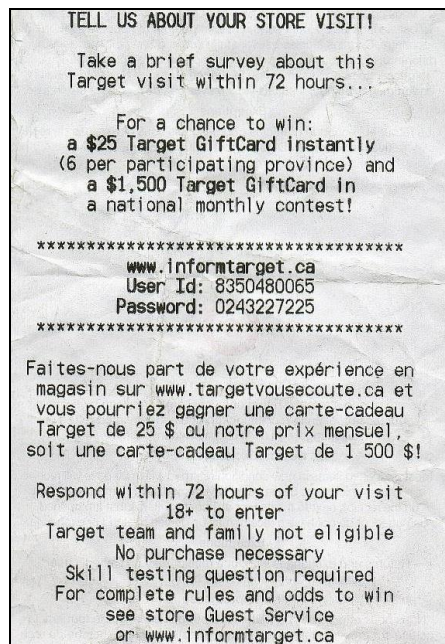


Figure 5.4 Target® survey participant recruitment incentives

The survey went live on FluidSurveys on June 28, 2016. Immediately after, survey participant recruitment commenced. The choice of sampling techniques is a complex one and depends on research objectives and the constraints (i.e. cost, time, etc.), and the type of phenomena one is studying (Palys, 1992). Web-based surveys, which typically involve email requests with web-survey links, are popular for collecting conducting surveys (Monroe and Adams, 2012). Survey invitation emails were sent to 43 friends, colleagues and associates, and 435 persons who I did not know, but whose contact information was publicly available on the Internet. The survey invitation emails included a request to survey participants to forward the email to others.

This approach to survey participant recruitment is called “snowball sampling” (Abrahamson, 1983; Palys, 1992, Snijders, 1992; Tashakkori and Teddlie, 1998; Black, 1999; Atkinson and Flint, 2001; Knuttila, 2008; Bryman et al., 2009). Snowball sampling is a non-probability method of sampling based on identifying initial survey participants who meet the criteria for inclusion in a study and asking them to forward to forward survey invitations to others they may know who meet the criteria. If the aim of a study is primarily explorative, qualitative and descriptive, snowball sampling offers advantages over other sampling methods (Atkinson and Flint, 2001; Statistics Canada, 2003).

Researchers can face serious data collection limitations when sampling if access to a population list is restricted. (Palys, 1992; Black, 1999). Snowball sampling is typically used because it is the best, or only, alternative that can be used in a situation (Abrahamson, 1983; Palys, 1992; Black, 1999; Dorofeev and Grant, 2006; Knuttila, 2008). Snowball sampling is useful when a researcher is trying to reach populations that are inaccessible or hard to find (Palys, 1992; Knuttila, 2008). With snowball sampling, the best approach is to recruit sample participants, as much as possible,

from independent sources (Snijders, 1992). Sampling bias may occur with snowball sampling if initial survey participants have disproportionate influence on subsequent survey participant recruitment (Snijders, 1992). Larger snowball sample sizes may reduce sampling bias (Atkinson and Flint, 2001). Where the initial sample is uncorrelated with direct and indirect ties, snowball sampling may have the potential to approximate random sampling (Snijders, 1992). As a survey method, snowball sampling has been found to be economical, efficient and effective (Atkinson and Flint, 2001; Statistics Canada, 2003). Completed surveys were collected from June 28, 2016 to July 28, 2016. Given this survey period, snowball sampling provided the greatest potential for recruiting as many survey participants as possible in the shortest time possible. At the conclusion of the survey period, the result was deleted from the FluidSurveys website.

## **5.4 Results**

According to FluidSurveys statistics, the web-based survey was accessed 554 times between June 28 and July 28, 2016. A total of 527 survey forms were collected. This was greater than the number of email invitations sent to potential survey participants. For unknown reasons, 24 of the 527 surveys had only the first twelve questions completed. These respondents were omitted from the analysis leaving 503 respondents. The survey participants were almost equally divided by gender. Survey participants ranged in age from 19 to 75 and older. The results of the survey follow.

### 5.4.1 Survey Participant Demographics

#### 5.4.1.2 Gender

Survey participants were almost equally split between male and female (Table 5.1). Less than 1% of the survey participants selected “Other” to indicate their gender.

Table 5.1 Gender of Survey Participants

Survey participant gender	Number of Survey Participants	% of Responding Survey Participants
Male	247	49.1
Female	250	49.7
Other	3	0.6
No response	3	0.6
Total	503	100.0

## 5.4.1.3 Age

Survey participants ranged in age from 19 to 75 and older (Table 5.2). The distribution of age between males and females is shown in Table 5.3.

Table 5.2 Age of Survey Participants

Age	Number of Survey Participants	% of Responding Survey Participants
19 years	1	0.2
20 - 24 years	14	2.8
25 - 29 years	25	5.0
30 - 34 years	30	6.0
35 - 39 years	38	7.6
40 - 44 years	44	8.7
45 - 49 years	54	10.7
50 - 54 years	80	15.9
55 - 59 years	73	14.5
60 - 64 years	67	13.3
65 - 69 years	41	8.2
70 - 74 years	20	4.0
75+ years	13	2.6
No response	3	0.6
Total	503	100.0

Table 5.3 Age of Survey Participants by Gender

Age Range	Males	% of Males	Females	% of Females	Other	% of Other	No Gender Reported	% of No Gender Reported
19 years	1	0.4	0	0	0	0.0	0	0.0
20 - 24 years	4	1.6	10	4	0	0.0	0	0.0
25 - 29 years	8	3.2	17	6.8	0	0.0	0	0.0
30 - 34 years	13	5.3	17	6.8	0	0.0	0	0.0
35 - 39 years	15	6.1	23	9.2	0	0.0	0	0.0
40 - 44 years	22	8.9	22	8.8	0	0.0	0	0.0
45 - 49 years	21	8.5	31	12.4	2	66.7	0	0.0
50 - 54 years	44	17.8	34	13.6	0	0.0	2	66.7
55 - 59 years	43	17.4	29	11.6	1	33.3	0	0.0
60 - 64 years	35	14.2	32	12.8	0	0.0	0	0.0
65 - 69 years	20	8.1	21	8.4	0	0.0	0	0.0
70 - 74 years	10	4.0	9	3.6	0	0.0	1	33.3
75+ years	10	4.0	3	1.2	0	0.0	0	0.0
No Response	1	0.4	2	0.8	0	0.0	0	0.0
Total	247	100.0	250	100	3	100.0	3	100.0

#### 5.4.1.4 Participant Country

Although the survey was designed primarily for Canadian and US drivers, drivers from other countries also participated. Canadian drivers represented 69.2% of the survey participants while US drivers represented 24.1% of the survey participants. Drivers from fourteen other countries represented the remaining 6.7% of the survey participants.

Table 5.4 Participant Country

Country	Number of Participants	% of Participants
Australia	3	0.6
Canada	367	69.2
China	1	0.2
France	2	0.4
Germany	3	0.6
Italy	2	0.4
Japan	7	1.4
Lithuania	1	0.2
Netherlands	2	0.4
Portugal	1	0.2
Russian Federation	1	0.2
South Africa	1	0.2
Sweden	6	1.2
Switzerland	4	0.8
United States	121	24.1
Total	503	100.0

#### 5.4.1.4 Participant Location by US States and Canadian Provinces and Territories

Drivers from nine Canadian provinces and one Canadian territory participated in the survey (Table 5.5). Of the three Canadian provinces with the most survey participants, drivers from British Columbia, Ontario and Alberta represented 66.1%, 21.0% and 7.8% of the Canadian survey participants, respectively. Drivers from 24 U.S. states and the District of Columbia participated in the survey (Table 5.6). Of the three U.S. states with the most survey participants, drivers from New York, Washington and Montana represented 43.0%, 6.6% and 5.0% of the U.S. survey participants, respectively.

Table 5.5 Participant Location by Canadian Provinces and Territories

Canadian Province or Territory	Number of Participants	% of Canadian Participants
Alberta	27	7.8
British Columbia	230	66.1
Manitoba	1	0.3
New Brunswick	5	1.4
Newfoundland and Labrador	4	1.1
Nova Scotia	1	0.3
Ontario	73	21.0
Quebec	1	0.3
Saskatchewan	3	0.9
Yukon	3	0.9
Total	348	100.0

Table 5.6 Survey Participant by US Participant States and Territories

U.S. State or Territory	Number of Participants	% of US Participants
Alaska	4	3.3
Arizona	4	3.3
California	5	4.1
Colorado	7	5.8
Connecticut	1	0.8
District of Columbia	2	1.7
Florida	3	2.5
Georgia	1	0.8
Idaho	4	3.3
Illinois	1	0.8
Indiana	2	1.7
Iowa	1	0.8
Massachusetts	2	1.7
Minnesota	2	1.7
Mississippi	1	0.8
Montana	6	5.0
New York	52	43.0
Oregon	4	3.3
Pennsylvania	2	1.7
South Carolina	1	0.8
South Dakota	1	0.8
Texas	3	2.5
Utah	3	2.5
Washington	8	6.6
Wyoming	1	0.8
Total	121	100.0

#### 5.4.1.5 Type of Survey Participant's Community

The survey participants reported living in communities, ranging from acreages and farms in rural areas, to large urban centres with populations of 100,000 or greater (Table 5.7).

### 5.7 Type of Community

Type of Community	Number of Survey Participants	% of Survey Participants
Rural area (acreage, farm, etc.)	86	17.1
Small population centre (population between 1,000 and 29,999)	122	24.3
Medium population centre (population between 30,000 and 99,999)	93	18.5
Large urban population centre (population of 100,000 or more)	201	40.0
No response	1	0.2
Total	503	100.0

#### 5.4.2 Survey Participant Driving Characteristics

The majority of survey participants reported having their driver licenses for 20 or more years (Table 5.8). Driving for pleasure was a component for 89.9% of the survey participants driving, while driving to and from work was a component of 67.7% of the survey participants (Table 5.9) Driving to and from school represented a component of driving for only 8.6% of the survey participants (Table 5.9). Over 70% of the survey participants reported driving less than 40 km per day (Table 5.10). Less than 4% of the survey participants reported driving 160 km or more per day (Table 5.10).

Table 5. 8 Length of Time with a Drivers License

Length of time with a drivers license	Number of Survey Participants	% of Responding Survey Participants
1 to 5 years	8	1.6
5 to 10 years	29	5.8
10 to 20 years	64	12.7
20 to 40 years	243	48.3
More than 40 years	158	31.4
No response	1	0.2
Total	503	100.0

Table 5. 9 Type of Driving

Driving Type	Number of Survey Participants	% of Responding Survey Participants
For work	18	3.6
To and from school	1	0.2
To and from school/For work	1	0.2
To and from work	21	4.2
To and from work/For work	7	1.4
For pleasure	104	20.7
For pleasure/For work	51	10.1
For pleasure/To and from school	2	0.4
For pleasure/To and from school/For work	1	0.2
For pleasure/To and from work	122	24.3
For pleasure/To and from work/For work	138	27.4
For pleasure/To and from work/To and from school	9	1.8
For pleasure/To and from work/To and from school/For work	25	5.0
No response	3	0.6
Total	503	100.0

Table 5.10 Daily Driving Distance

Daily Driving Distance	Number of Responses	% of Responding Survey Participants
Less than 8 km (5 miles)	152	30.2
Between 8 and 16 km (5 and 10 miles)	93	18.5
Between 16 and 40 km (10 and 25 miles)	125	24.9
Between 40 and 80 km (25 and 50 miles)	62	12.3
Between 80 and 160 km (50 and 100 miles)	47	9.3
Between 160 and 400 km (100 and 250 miles)	15	3.0
Over 400 km (250 miles)	1	0.2
Don't know	6	1.2
No response	2	0.4
Total	503	100.0

### 5.4.3 Survey Participant Experiences with Deer and Deer Warning Signs

When asked if they had seen deer on or near a road or highway (Figure 5.5), 98.2% of the responding survey participants reported they had (Table 5.11). When asked if they had had a collision with a deer (Figure 5.6), 25.8% of the responding survey participants reported they had (Table 5.12). When asked to identify a deer crossing sign (Figure 5.7), 98.4% of the responding survey participants correctly identified the deer crossing sign (Table 5.13).



Figure 5.5 Deer crossing road



Figure 5.6 Deer-vehicle collision



Figure 5.7 Deer crossing sign

Table 5.11 Experience seeing a deer on or near a road or highway

Experience seeing a deer on or near a road or highway	Number of Responses	% of Responding Survey Participants
Yes	494	98.2
No	9	1.8
Total	503	100.0

Table 5.11 Experience with a deer-vehicle collision

Experience with a deer-vehicle collision	Number of Responses	% of Responding Survey Participants
Yes	130	25.8
No	373	74.2
Total	503	100.0

Table 5.11 Deer warning sign comprehension

Sign Type	Number of Responses	% of Responding Survey Participants
Bear crossing	0	0.0
Deer Crossing	495	98.4
Moose Crossing	5	1.0
Don't know	2	0.4
No response	1	0.2
Total	503	100.0

When asked to look at two photographs of similar suburban highways scenes with deer crossing signs (Figures 5.8 and 5.9) and indicate which driving situation had the greatest potential hazard for drivers, using the deer crossing signs as their only reference, the results were mixed (Table 5.12). The greatest number of responding survey participants indicated they could not tell which driving situation had the greatest potential deer hazard from the deer crossing signs only.



Figure 5.8 Suburban highway in Flagstaff, Arizona



Figure 5.9 Suburban highway in Colwood, British Columbia

Table 5.12 Deer warning sign comprehension

<b>Using the deer crossing sign as your ONLY reference, which driving situation shown in the pictures below has the greatest potential deer hazard for drivers?</b>	<b>Number of Responses</b>	<b>% of Responding Survey Participants</b>
Picture 1	127	25.2
Picture 2	131	26.0
Can not tell	245	48.7
Total	503	100.0

#### **5.4.5 Comprehension of the Wildlife Hazard Warning System®**

After being introduced to the Wildlife Hazard Warning System®, survey participants were asked to answer questions about their comprehension of the system when applied to driving environments. When asked which driving situation had the lower deer hazard level (Figures 5.10 and 5.11), 93.8% of the responding survey participants correctly distinguished between the “Low” hazard warning sign and the “Extreme” hazard warning sign (Table 5.13). When asked which driving situation had the higher deer hazard level (Figures 5.12 and 5.13), 87.1% of the responding survey participants correctly distinguished between the “Moderate” hazard warning sign and the “Very High” hazard warning sign (Table 5.14).



Figure 5.10 “Low” Hazard



Figure 5.11 “Extreme” Hazard



Figure 5.12 “Moderate” Hazard



Figure 5.13 “Very High” Hazard

Table 5.13 Comprehending the Wildlife Hazard Warning System®

Using the Wildlife Hazard Warning System as your only guide, which driving situation shown in the pictures below do you think has the LOWER deer hazard level?	Number of Responses	% of Responding Survey Participants
Picture 1	472	93.8
Picture 2	20	4.0
Don't know	9	1.8
No response	2	0.4
Total	503	100.0

Table 5.14 Comparing “Moderate” and “Very High” hazard signs

Using the Wildlife Hazard Warning System as your only guide, which driving situation shown in the pictures below do you think has the HIGHER deer hazard level?	Number of Responses	% of Responses
Picture 1	36	7.2
Picture 2	438	87.1
Don't know	26	5.2
No response	3	0.6
Total	503	100.0

#### 5.4.6 Driving Behaviour Responses to the Wildlife Hazard Warning System®

When asked how they would respond to a “Low” deer hazard warning sign (Figure 5.14), a “Very High” deer hazard warning sign (Figure 5.15), and an “Extreme” deer hazard warning sign (Figure 5.16), the survey participants reported they would modify their driving behaviour as hazard ratings increased (Table 5.15). Almost 100.0% of the survey participants reported they would modify their driving behaviour in ways that would reduce their potential for a deer-vehicle collision (i.e. watch for deer) or reduce the potential severity of a deer-vehicle collision (i.e. slow down)..



Figure 5.14 “Low” Hazard



Figure 5.14 “Very High” Hazard



Figure 5.16 “Extreme” Hazard

Table 5.15 Comparison of self-reported driving behaviour responses

<b>Driving Response</b>	<b>% of Responses for Low Deer Hazard Warning Sign (503 Responding Survey Participants)</b>	<b>% of Responses for Very High Deer Hazard Warning Sign (502 Responding Survey Participants)</b>	<b>% of Responses for Extreme Deer Hazard Warning Sign (501 Responding Survey Participants)</b>
Slow down	0.8	1.2	0.6
Watch for deer	19.1	10.7	4.2
Slow down and watch for deer	10.3	64.1	84.1
Speed up	0.2	0.0	0.0
Speed up and watch for deer	0.4	0.2	0.0
Keep driving the same speed	5.2	0.6	0.0
Keep driving the same speed and watch for deer	64.0	23.2	11.2
No response	0.000	0.002	0.004
Total	100.0	100.0	100.0

#### **5.4.7 Survey Participants' Comments on the Wildlife Hazard Warning System®**

When asked if the Wildlife Hazard Warning System® would help them know how severe the deer hazard is for drivers, 92.0% of the responding survey participants reported the system would (Table 5.16). Only 3.0% of the responding survey participants reported the system would not help them know how severe the deer hazard for drivers is. When asked if they would like to see a system like Wildlife Hazard Warning System® used on roads in their state, province or territory, 79.5% of the responding survey participants reported they would like a system like the Wildlife Hazard Warning System® (Table 5.17). While 7.8% of the responding survey

participants reported they would not like a system like the Wildlife Hazard Warning System®, 11.9% of the responding survey participants reported they did not know.

Table 5.16 Usefulness of Wildlife Hazard Warning System®

If you are driving down an unfamiliar road or highway, in another state, province or territory, would the Wildlife Hazard Warning System help you know how severe the deer hazard is?	Number of Responses	% of Responses
Yes	462	92.0
No	15	3.0
Don't know	25	5.0
No response	1	0.002
Total	503	100.0

Table 5.17 Desire for Wildlife Hazard Warning System®

Would you like to see a system like the Wildlife Hazard Warning System used on roads in your province or territory to warn drivers of deer hazard levels?	Number of Responses	% of Responses
Yes	400	79.5
No	39	7.8
Don't know	60	11.9
No response	4	0.8
Total	503	100.0

#### 5.4.7 Survey Participant Comments Summary

Two hundred and ninety-seven of the 503 participants provided written comments. The comments provided by 59.0% of the survey's participants gave great insight into the participants' opinions about the system and how they felt the system could be improved. The comments were overwhelmingly positive. Ninety-five survey

participants, 32.0% of the participants who gave written comments, used words such as “Good”, “Great”, “Like” and “Terrific” to describe the WildHAZ® system. Overall, the majority of survey participants gave valuable objective and constructive criticism. Only four participants (1.3%) of the 297 participants who provided written comments gave completely negative ones. These comments were: “Makes no sense.”, “Seems silly.”, “I don’t support this approach.” and “We don’t need more signs.” The major issues identified in the written comments are summarized in the Table 5.18.

Table 5.18 Major issues with Wildlife Hazard Warning System®

Comment topic	Number of participant written comments	% of participant written comments
Need fewer colour classes	78	26.3%
Question use of the colour blue	13	4.4%
Need system to be dynamic	12	4.0%
Suggest use of blinking lights	10	3.4%
Need for driver education	9	3.0%
Need to add wording tabs	8	2.7%
Cost of implementing system	3	1.0%

#### 5.4.7.1 Need fewer colour classes

Of the seventy-eight survey respondents that indicated the Wildlife Hazard Warning System should use fewer colour codes, sixty-three provided their opinions on the number of colour codes they thought would be appropriate (Table 5.19 ).

Table 5.19 Colour code preferences from survey respondent comments

Number of Colour Codes	Number of participant written comments	% of participant written comments
1	1	1.6
2	4	6.3
2 – 3	3	4.8
3	45	71.4
3 – 4	3	4.8
4	7	11.1
Total	63	100.0

The risk hazard levels that were suggested were:

#### One Level

- Extreme

#### Two Levels

- Low / Extreme

#### Three Levels

- Low / Moderate / High
- Low / Moderate / Extreme
- Low / High / Extreme
- Low / Very High / Extreme

#### Four Levels

- Low / Moderate / High / Extreme
- Low / High / Very High / Extreme

## 5.5 Discussion

The results of the survey suggest all drivers would take steps such as watching for wildlife and slowing down, if they were provided with wildlife hazard risk levels.

The results of the survey indicate the following:

1. The majority of drivers surveyed appear to understand the Wildlife Hazard Warning System®; and
2. The majority of drivers surveyed reported that they would modify their driving behaviour in response to the Wildlife Hazard Warning System® in ways that could reduce their potential for wildlife-vehicle collisions and/or the severity of those collisions.

A vast majority of the survey participants indicated the Wildlife Hazard Warning System® would help them know the risk hazard level posed by wildlife on unfamiliar roads and highways. In addition, a vast majority of the survey participants reported they would like to see a system like the Wildlife Hazard Warning System® used on roads and highways where they live.

Although the Wildlife Hazard Warning System® was understood by the vast majority of the survey participants, the variation in the results suggests both the number of hazard levels used by the Wildlife Hazard Warning System® and the text (Low, Moderate, etc.) for messaging the hazard levels need further examination. The use of the colours green and blue to “Low” and “Moderate” hazard levels was also questioned by some survey participants. Concern about potential confusion due to lack of driver familiarity with the colour blue was also raised. The issues of colour, the number of hazard levels and warning message text should be evaluated for consensus by driver focus groups.

As with any research endeavor, it is important to identify the limitations with regards to their validity. The issues of particular note are:

1. Sampling technique
2. Response rate
3. Sample size
4. Representativeness of survey participants
5. Sampling bias
6. Prior deer-vehicle collision bias
7. Self-reporting

### **5.5.1 Sampling Technique**

In non-probability sampling, such as snowball sampling, the objective is to select typical or representative subjects (Abrahamson, 1983). While the representativeness of a probability sample is expected as a consequence of the selection procedure, and a probable degree of accuracy can be calculated, the probable accuracy of a non-probability sample cannot be directly calculated (Statistics Canada, 2001). Although snowball sampling is an accepted approach for non-probability sampling of hard to identify individuals in a population, the technique has shortcomings with respect to the analysis of sampling results (Snijders, 1992). According to Statistics Canada (2003), the disadvantages of non-probability sampling, like snowball sampling are:

- 1) To make inferences about the population, strong assumptions about the representativeness of the sample are required; and
- 2) Reliable estimates and estimates of sampling error cannot be computed because it is impossible to determine the probability that an individual in the population is selected for the sample.

Non-probability sampling involves the selection of a sample from a population using arbitrary criteria (Statistics Canada, 2001). In snowball sampling, since each survey participant can contribute to the recruitment of other survey participants, the sample mushrooms as the study continues (Tashakkori and Teddlie, 1998). No assurance can be given that each individual in a population has a chance of being selected, thus making it impossible to estimate sampling variability or to identify any possible sampling bias criteria (Statistics Canada, 2001). In non-probability sampling, data reliability cannot be measured (Statistics Canada, 2001). The only way to estimate data quality is by comparing some of the survey results with information available about the population (Tashakkori and Teddlie, 1998; Sapsford, 2007). While probability sampling is frequently far from perfect, the average difference in data quality between probability sampling and non-probability sampling may be becoming less marked (Dorofeev and Grant, 2006). According to Bryman et al. (2009) the results of a snowball study must be very tentatively generalized because unknown biases of the initial study participants in their selection of subsequent study participants may distort the process at any stage (Abrahamson, 1983). Snowball samples may be biased by social interactions and so over-emphasize the representation of cohesive social networks (Atkinson and Flint, 2001). Larger snowball samples sizes may reduce sampling bias (Atkinson and Flint, 2001). Provided that the nature of the non-probability sampling technique is clearly defined, determining if the results of the sampling are representative of the population is subject to evaluation (Sapsford, 2007). To consider the validity of the survey results, the representativeness of the drivers who participated in the survey needed to be examined.

### **5.5.2 Response Rate**

The response rate is typically calculated as the ratio of successful sampling to the total eligible sample (Abrahamson, 1983). Lack of response to a survey by potential

participants in a sample is referred to as non-response bias (Fincham, 2008). There are three major reasons for non-response:

1. Some people refuse to participate in surveys;
2. Some people can never be contacted; and
3. Some people may be ineligible to participate in a survey

Non-response bias is a serious factor that can affect both the reliability and validity of survey findings. If a survey achieves only a 20% response rate, the non-response bias is 80%. There is no generally agreed-upon criterion for evaluating the adequacy of response rates (Abrahamson, 1983). One major concern for web-based surveys is their low response rates (Miller and Smith, 1983; Archer, 2003; Wiseman, 2003). Response rates for web-based surveys have tended to range from moderate to poor (Fricker and Schonlau, 2002).

A major challenge for academic researchers using web-based surveys is distinguishing themselves from the plethora of commercial and entertainment surveys found on the Internet (Fricker and Schonlau, 2002). Response rates may be lowered when potential survey participants are concerned with Internet security and the receipt of spam emails (Sills and Song, 2002). Response rates as low as 2% have been reported (Petchenik and Watermolen, 2011). Responses rates to email invitations to participate in surveys tend to be low, partly because some people assume the email is spam (Knuttila, 2008). People using the Internet are also becoming increasingly wary about opening emails from unknown sources because of the fear of viruses (Gray and Guppy, 2003). Despite most efforts, some potential survey participants will never respond (Tashakkori and Teddlie, 1998). For my research, the low response rate from potential US survey participants may have resulted from a response bias due to the non-US origin of my email invitations. Confirming this suspicion would be difficult. Following up on those contacted but

who have not participated in a survey is not possible if the survey is anonymous (Sapsford, 2007). Quantifying the response rate of invited participants in this survey is complicated by the “snowballing” component of the survey invitations. Participants were asked to forward the invitation email to others. An invited participant, who did not or could not complete the survey, could forward the invitation email to many others who subsequently completed the survey. In addition, multiple points of contact for each survey participant were possible. These included direct personal email, redirected personal email via snowballing, and survey access details distributed by survey participants via listserv distributions and Facebook links. Since survey response rates may only approximate 25% to 30% without follow-up email and reinforcements (Yun and Trumbo, 2000), the survey response rate exceeded the norm.

### **5.5.3 Sample Size**

Obtaining an adequate sample is one of the most fundamental tasks for creating credible research (Marshall et al., 2013). While a sample size of one hundred is typically considered the minimum number (Singleton and Straits, 1999; Bryman et al., 2009), I was able to recruit 527 survey participants. In both quantitative and qualitative research, it is usually not possible to study the totality of a population of individuals (Tashakkori and Teddlie, 1998). However, there are no universally agreed upon rules for sample size in qualitative surveys (Patton, 1990). “Sample size depends on what you want to know, the purpose of the inquiry, what’s at stake, what will be useful, what will have credibility, and what can be done with available time and resources” (Patton, 1990: page 184). Determining an appropriate sample size is not straightforward (Statistics Canada, 2001; Bryman et al., 2009). The quest for the perfect sample size is typically constrained by the practical considerations of time and budget (Statistics Canada, 2001; Bryman et al., 2009). There is a trade-off between cost and quality in surveying (Dorofeev and Grant, 2006). Achieving a balance

between available resources and desired sample size is not a trivial challenge (Black, 1999). Data collection limits are often practical and situational: research funding is limited, time is limited, ethics committees impose restrictions, or research access is compromised (Gibbs et al., 2007). The survey response rate was well beyond the minimum number cited in the literature. Thirty samples is regarded as minimally adequate for statistical data analysis (Singleton and Straits, 1999). For the most part, sample size is subject to peer review, consensual validation and judgement (Patton, 1990). The survey sample size avoided the pitfalls of small sample size. Email invitations to participate in web-based surveys have been criticized as an invasion of privacy and labeled as unwanted spam or obnoxious emails (Gray and Guppy, 2003). In snowball sampling, trust may be developed as referrals are made by peers or acquaintances rather than random contacts by means of traditional probability sampling methods (Atkinson and Flint, 2001). Cook et al. (2000) found the number of contacts, personalized contacts and pre-contacts were factors most associated with higher response rates in web-based surveys.

#### **5.5.4 Representativeness of Survey Participants**

Drivers represent a very heterogeneous population. They can be either male, female or transgender, and range from less than 16 years of age to over 85 years of age. Drivers may drive for pleasure, or for work, or for commuting to and from work and/or school, or for a combination of these purposes. They may drive infrequently or regularly, and travel an extremely wide range of distances. Given the mobility driving provides, drivers can live in a diverse range of locations, where roads and/or highways provide access for motor vehicles. Upon the completion of a survey, it is important to determine the representativeness of the sample (Gray and Guppy, 2003). Where possible, it is advisable to compare samples with population statistics published by government agencies (Statistics Canada, 2001; Sapsford, 2007). The more representative a sample is of a population, the greater the probability research findings are valid for the population (Tashakkori and Teddlie, 1998). Although Black

(1999) states there is no way of knowing if a snowball sample is representative of a population, enough government information about drivers in Canada and the U.S. is publicly available to evaluate the sample I obtained.

#### **5.5.4.1 Gender and Age**

Distributions derived from a survey sample must be compared to known distributions of the population to determine the representativeness of the sample (Gray and Guppy, 2003). The sample in this instance appears reasonably representative of the driver population in Canada and the US with regards to gender. The overall survey sample was 49.6% male and 49.8% female. In Canada, 51.5% of drivers are male and 48.5% are female (Transport Canada, 2014). In the US, 50.3% of drivers are male while 49.7% are female (Federal Highway Administration, 2016). The Canadian survey participants more closely represented the driver population in Canada with 50.1% being male and 49.3% being female. Table 5.20 show the differences between the gender distribution of the survey participants with the gender distribution of drivers in the US and Canada. In the survey, both males and females under 45 years of age were under-represented while, except for females 65 years of age and older, males and females 45 years of age and older were over-represented. No single age group dominated the survey sample. Table 5.20 show the differences between the gender distribution of the Canadian survey participants with the gender distribution of drivers in Canada. No single age group dominated the Canadian portion of the survey sample.

Table. 5.20 Comparison of Survey Participant Gender Distribution to US/Canadian Driver Gender Distribution

<b>Driver Age</b>	<b>US/Canada Combined Male %*</b>	<b>Survey Male (US/Canada Combined) %</b>	<b>US/Canada Combined Female %*</b>	<b>Survey Female (US/Canada Combined) %</b>
20–24	8.9	1.8	8.6	4.3
25–34	20.3	9.3	19.8	13.2
35–44	22.7	11.6	22.7	17.1
45–54	19.9	26.2	20.0	26.1
55–64	13.2	33.8	13.2	25.2
65 +	15.0	17.3	15.7	14.1
<b>Total</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>

\* Sources: Transport Canada (2016) and US Federal Highway Administration (2016)

Table 5.21 Comparison of survey participant age distribution to Canadian driver age distributions

<b>Driver Age</b>	<b>Canada Male %*</b>	<b>Survey Male (Canada) %</b>	<b>Canada Female %</b>	<b>Survey Female (Canada) %*</b>
20–24	8.3	0.5	8.2	4.3
25–34	17.8	7.2	18.2	13.2
35–44	17.9	11.8	18.5	17.1
45–54	20.1	32.3	20.4	26.1
55–64	18.0	32.8	18.0	25.2
65 +	17.9	15.4	16.8	14.1
<b>Total</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>

\* Source: Transport Canada (2016)

The survey participants were relatively well distributed between rural communities and large urban population centres. The survey participants represented a wide range of driving types (for pleasure, to work, for work, to school, etc.) and daily driving distances. Although snowball sampling, a non-probability sampling technique, was

used to recruit survey participants, it appears the sample obtained is relatively representative of the population.

### **5.5.5 Sampling Bias**

Sampling bias results when groups of people are omitted from sampling. In the United States, the poor, more socially isolated, more transient, younger and male members of society tend to be missed in population surveys (Groves, 1987). The large-scale movement to telephone surveys in the 1980's eliminated those potential survey participants who could not be reached by telephone (Groves, 1987). A similar situation exists for web-based surveys with regards to those potential survey participants who do not have access to the Internet. Those who do not participate in a survey may have different attitudes and behaviours of those who participate (Sapsford, 2007). The potential sources of sampling bias identified in the survey are:

1. Language;
2. Computer hardware and software;
3. Internet access;
4. Other Internet-based avenues of contact;
5. Participant age;
6. Prior deer-vehicle collision experience; and
7. Self-reporting

#### **5.5.5.1 Language**

The survey was only conducted in English. In large-scale surveys, some survey participants may not be able to read or write well (Tashakkori and Teddlie, 1998).

For persons for whom English is not their first language, it may have been difficult for them to participate in an English language-only survey (Sapsford, 2007). It is assumed that such drivers would not have participated in the survey.

In 2011, approximately 7.2 million Canadians reported French as their mother tongue (Statistics Canada, 2011). In addition, approximately 0.9 million Canadians reported other languages as their mother tongues (Statistics Canada, 2011). It is conceivable some of these 8.1 million Canadians drive, but do not understand English well enough to have participated in the survey. In the US, approximately 25.1 million individuals are considered “Limited English Proficient” (LEP) (Zong and Batalova, 2015). The LEP portion of the total US population was 8.5 percent in 2013. An unknown number of LEP drivers in the U.S. may not have been able to participate in the survey.

#### 5.5.5.2 Computer hardware and software

One of the challenges of using web-based surveying methods is the extent of sampling bias caused by less than complete Internet access for all elements of a population (Gray and Guppy, 2003). Sampling from publicly accessible lists made available by business, industry, professional, and institutional organizations may provide adequate coverage so sampling bias can be minimized (Gray and Guppy, 2003). People use a variety of computer hardware, web browsers and user preferences (Gray and Guppy, 2003). The survey was designed for persons using conventional laptop and desktop computers with colour screens and monitors. Depending on the type of display, the appearance of a web-based questionnaire may vary significantly (Gray and Guppy, 2003). Given the scale of the graphics used in the survey, this compromised the ability of persons whose Internet use is limited to smart phones and tablets to participate in the survey. In some cases, poorly displayed graphics and colours may affect survey completions (Gray and Guppy, 2003). If

future surveys regarding the Wildlife Hazard Warning System® or other systems are to be undertaken, the surveys should be designed to be accommodate smart phone and tablet users too.

#### 5.5.5.3 Internet access

Another limitation of the survey was its dependence on the Internet. Invitations to individuals to participate in the surveys were only sent out by email. The mandated use of only publicly accessible contact information for recruiting survey participants further limited survey coverage. Persons with no publicly accessible email addresses could not be contacted. In addition, the surveys could only be completed using the Internet. It is assumed, individuals who do not use the Internet would not have participated in the surveys. In the US, 87.4% of the population uses the Internet (World Internet, 2016). In 2015, approximately 40.6 million individuals in the US did not use the Internet. In Canada, 92.5% of the population uses the Internet (World Internet, 2016). In 2015, approximately 2.7 million Canadians did not use the Internet. Information about the number of US and Canadian drivers that do not use the Internet was not available. However, it is assumed some portion of the approximately 43.3 million individuals in the US and Canada who do not use the Internet are drivers.

#### 5.5.5.4 Other Internet-based avenues of contact

Recruitment of survey participants was limited to the use of email invitations. However, use of Internet-based social media avenues of communication, such as Twitter and Facebook, may have made it possible to reach more potential survey participants. In the United States, approximately 192 million people use Facebook (Miniwatts Marketing Group, 2016). Concurrently, approximately 21 million Canadians use Facebook (Miniwatts Marketing Group, 2016). There may be drivers,

among the U.S. and Canadian Facebook users, that would have participated in the survey had participant recruitment been done using Facebook. Given the large number of U.S. and Canadian Facebook users, research into increasing driver participation in traffic safety surveys by using social media as a recruitment tool should be done.

#### 5.5.5.5 Participant age

Although persons under 19 years of age are able to obtain driver licenses in all US states and territories, and all Canadian provinces and territories, they were not included in the survey. This step was taken specifically to avoid University of Victoria Human Research Ethics Board (HREB) requirements for surveying minors. In order to survey a person under 19 years of age, the HREB requires written permission from that individual's parents or guardians for the individual to participate. This requirement would have significantly complicated a web-based survey that both used email for participant recruitment and guaranteed survey participants' anonymity.

By not including persons under 19 years of age, approximately 5.6 million drivers in the U.S. were excluded from being potential participants in the survey (FHWA, 2015). If the proportion of drivers under 19 years of age in Canada is similar to that found in the US, then an estimated 0.8 million drivers in Canada were also excluded from being potential participants in the survey (Transport Canada, 2016). Although these drivers represent approximately only 2.6% of US drivers and 3.2% of Canadian drivers, it is possible these drivers may have influenced the outcome of the survey by some degree. Accessing drivers under 19 years of age for their opinions on the Wildlife Hazard Warning System® and wildlife hazards should be considered before developing any informational materials about the system for drivers.

#### 5.5.5.6 Prior deer-vehicle collision experience

Over 25% of the participants in the survey indicated they had experienced a collision with a deer. This number exceeded expectations. However, if only one driver in 100 has a collision with a deer each year, it is possible that collectively as many as 40% of drivers could have had at least one deer-vehicle collision over a 40 year driving period.

The experience of drivers having had a deer-vehicle collision may have biased the results of the survey. Hindelang et al. (1999) found the highest number of deer-vehicle collisions in rural Michigan involved drivers between the ages of 30 and 39. This age range corresponded to the largest group of registered drivers. They also found that drivers between 15 and 19 were involved in disproportionately more deer-vehicle collisions for the number of registered drivers in their age group. In their analysis of driver age and incidence of deer-vehicle collisions in three Michigan counties, Riley and Marcoux (2006) found the proportion of the collisions peaked for drivers from 45 to 59 years of age, and that male drivers were more likely than female drivers to be involved in these collisions. Drivers with prior deer-vehicle collisions may have been more inclined to participate in a survey on a wildlife hazard warning system than drivers who had never had a deer-vehicle collision. This potential phenomena warrants further investigation. One approach could be to randomly select potential survey participants from motor vehicle insurance company records and then compare the survey response rates between drivers who had prior deer-vehicle collisions and drivers who did not.

#### 5.5.5.7 Self-reporting

Self-reporting is the most frequent source of data in quantitative and qualitative research (Tashakkori and Teddlie, 1998). In self-reporting, individuals are asked to

report on their feeling, beliefs, attitudes and other attributes. Self-reporting may result in “response sets” when survey participants exhibit the tendency to respond in a certain manner (Tashakkori and Teddlie, 1998). Honesty of responses can affect survey data quality (Fricker and Schonlau, 2002). Survey participants may provide answers that do not reflect their true feelings, beliefs and tendencies. With respect to how drivers may actually response to the Wildlife Hazard Warning System, observational studies in the field can validate self-reported behavioural responses (Tashakkori and Teddlie, 1998).

## **5.6 Conclusions**

Although self-reported by survey participants, the results suggest all drivers would take steps such as watching for wildlife and slowing down, if provided with wildlife hazard risk levels. Increased driver attention to wildlife and reduced vehicle speeds could lead to fewer wildlife-vehicle collisions and/or reduced wildlife-vehicle collision severity. The results of the survey indicate the following:

1. The majority of drivers surveyed appear to understand the Wildlife Hazard Warning System®; and
2. The majority of drivers surveyed would modify their driving behaviour in response to the Wildlife Hazard Warning System® in ways that could reduce their potential for wildlife-vehicle collisions and/or the severity of those collisions.

Determining the actual impact of the Wildlife Hazard Warning System® on driver behaviour (vehicle speed) and wildlife-vehicle collisions (frequency and severity) would require extensive, long-term field studies. Given the opinions expressed by the survey participants regarding the colour hazard coding scheme used by the system, focus groups should be used to determine the how the system should be configured

before any field studies are initiated. Since the majority of drivers surveyed indicated they would like a system like Wildlife Hazard Warning System® to be used on roads and highways where they drive, moving forward with focus groups and field studies should be considered by road authorities.

The success of the survey exceeded all expectations. The 503 respondents were far more than the minimum sample size cited in the literature. The overwhelming positive feedback received from survey participants about the Wildlife Hazard Warning System® was constructive. The results of the survey indicate most survey participants comprehend the colour-coded elements of the Wildlife Hazard Warning System® and most survey participants report they would modify their driving behaviour in ways that should contribute to fewer wildlife-vehicle collisions and/or less severe ones. In addition, most responding survey participants indicated, when driving on unfamiliar roads and highways, they would like to see the Wildlife Hazard Warning System® used to advise them of wildlife hazard levels.

Written feedback from the survey participants indicated some issues regarding how many hazard levels should be used for the Wildlife Hazard Warning System® and what colours should be used for those hazard levels. Before the Wildlife Hazard Warning System® can be presented to road authorities for their consideration, future research is required to determine what colour-coded hazard level configuration of the Wildlife Hazard Warning System® would best suit the expectations and needs of drivers. Driver focus groups may be the best next approach needed to identify and understand driver expectations and needs with regards to possible Wildlife Hazard Warning System® modifications. Extensive, multi-year field testing of the Wildlife Hazard Warning System® will be the only way to determine if the survey participants' self-reported driving behaviour changes are truly representative of what they will actually happen.

## **6.0 TESTING AND EVALUATING THE WILDHAZ® SYSTEM**

*“Generally speaking, a road sign provides road users with information about road conditions in order to allow them to anticipate events and sometimes encourages them to adjust their behaviour appropriately.” (Martens, 2000, p. 347)*

### **6.1 Introduction**

The WildHAZ® system represents a paradigm shift with respect to the use of conventional wildlife warning signs by road authorities. The system increases the amount of information provided by road authorities to drivers about a temporally and spatially dynamic driving hazard. Drivers are given a degree of information about a hazard with spatial and temporal properties largely known by road authorities but that the road authorities are not able to disseminate to drivers by means of conventional static warning signs. The results of the survey suggest the majority of drivers would comprehend the WildHAZ® system and would modify their driving behavior in a manner that should reduce their potential for a wildlife-related vehicle collision and/or reduce the potential severity of such an accident. Determining if use of the WildHAZ® system results in traffic safety improvements will require verification using methodology accepted by road authorities. This chapter reviews the approaches road authorities have used to validate the effectiveness of road safety initiatives. A comprehensive three-stage approach is proposed to test and evaluate the WildHAZ® system. The stages involve focus groups, driving simulations and field tests. Data generated from simulated field tests are evaluated using analysis of variance (ANOVA) and post hoc tests. The costs of conducting the focus groups, driving simulations and field tests the WildHAZ® system are estimated.

## 6.2 Need to Test the WildHAZ® System

Road authorities have relatively little sound knowledge on the safety implications of their design and operational decisions, and much needs to be done to improve both the state of highway safety research and the state of highway safety practice (Persaud, 2001). Therefore, it is essential the WildHAZ® system be thoroughly tested and assessed before any consideration is given to implement the system on a large scale. Traffic safety programs are too important to allow guesswork to guide program decisions (Council et al., 1980). The consequences of a traffic safety test can be significant (Lyles et al., 2012). If the results of a poorly designed test of an ineffective system show the system to be effective, the negative consequences can be substantial (Williams, 2007). Large investments in the system may be made, at the expense of other road safety improvements, and to the detriment of drivers (Council et al., 1980; Williams, 2007; Lyles et al., 2012). A worse scenario could develop, if the system actually decreases driver safety (Williams, 2007). Conversely, if the results a poorly designed test of an effective system show the system to be ineffective, an opportunity to protect drivers may be unnecessarily forfeited (Council et al., 1980). With less than adequately vetted research, road authorities may make road safety investments in non-effective systems, or miss opportunities to consider effective systems (Lyles et al., 2012).

According to Wogalter and Vigilante (2006), the development of a warning system should:

- 1) Consider the sensory and mental capabilities of the target audience.
- 2) Consider the environment in which the target audience will see the warning.
- 3) Consider the actions the target audience is expected to perform upon seeing the warning.
- 4) Evaluate the effectiveness of the system:

- a. Test a representative sample of the target audience.
  - b. Locate the system when and where the warning is needed.
  - c. Test the warning system using methods that measure the desired behaviour of the target audience.
- 5) Modify the system when insufficient effectiveness is found.

### **6.3 Three-Stage Testing and Evaluation Approach for the WildHAZ® System**

From the literature, it appears there is no standardized methodology for determining the effectiveness of conventional traffic warning signs. “*No studies have evaluated the effectiveness of standard deer warning signs in increasing driver awareness of deer, in reducing driving speeds, or in reducing DVCs.*” (Hedlund et al., 2003, page 4.) Knapp et al. (2004) found no literature that specifically considered or quantified the DVC reduction and/or vehicle speed reduction impacts of typical deer crossing signs. In its safety research literature search, the Minnesota Department of Transportation Research Service Section (2014) found no documentation of wildlife-vehicle collision reductions associated with conventional static wildlife warning signs. Based on these findings these researchers, I propose the WildHAZ® system be tested and evaluated using a three-stage approach consisting of: (1) focus groups; (2) driving simulation; and (3) field testing. Progression through each stage would be increasingly more complicated, time-consuming and costly. Assessment at the conclusion of each stage would provide an opportunity to improve the WildHAZ® system prior to further investment of the time and funds necessary for the next evaluation stage.

A review of the literature suggests no wildlife warning sign has previously been subjected to such a comprehensive, three-stage evaluation approach. To simplify the testing, attention would be focused on deer warning signs. Deer represent are the most common wildlife hazard for drivers in Canada and the US.

### 6.3.1 Focus groups

Focus group discussions provide an established method to obtain information from drivers (US Federal Highway Administration, 2005). Focus groups are usually small-group discussions (8-10 people) in which a moderator takes participant through a series of questions about a given topic, with the flexibility to explore feelings and attitudes (US Department of Transportation, 2014). Focus groups have been used for many years in commercial marketing to help determine how prospective buyers of consumer products respond to various product concepts, prototypes, and advertising strategies. For social marketing, focus groups enable in-depth probing of public conceptions, knowledge, ideas, motivation, and attitudes. Although focus groups do not provide the statistically reliable data possible from surveys, these groups can serve as a good source of general information and ideas. This is true primarily for two reasons: (1) focus group participants are usually selected because they have something in common, rather than randomly, as in surveys and, (2) the questions asked to focus groups can vary greatly, rather than the same questions being asked in the same way of everyone, as in surveys.

Discussions provide an opportunity to probe participant responses and introduce new ideas in a flexible manner (US Department of Transportation, 2014). In addition, focus groups provide continual feedback and exchange between the interviewer and the participants. The opportunity for self-correction provides more robust and accurate responses. If a participant's answer or response is unclear or ambiguous, the interviewer can rephrase the question and gather desired insights accordingly. If new ideas emerge during a focus group, the interviewer has the opportunity to investigate them in more depth. Since focus groups typically represent small samples sizes, they are not representative of the total population (US Federal Highway Administration, 2005). Since focus group research relies on nondirective, semi-structured interviews, the stimulus situation is not the same for every respondent. As a result, focus group

studies should not be viewed as definitive (US Federal Highway Administration, 2005). Quantitative research is also necessary to arrive at in depth conclusions.

The need for the WildHAZ® system to be useful and relevant to the average driver requires an understanding of the knowledge of these drivers and their needs with respect to potential wildlife hazards. Carefully pretesting the system would provide the opportunity to ensure its traffic safety message effectively reaches drivers (Williams, 2007). Dewar (1988) surveyed traffic sign experts of national traffic control device committees and practicing traffic engineers from Australia, New Zealand, Canada, and the US, to determine the importance of the criteria necessary for the design and evaluation of traffic warning sign symbols. The survey participants rated understandability as the most important factor, followed by conspicuity. The survey participants considered learnability least important. Rating reaction time, legibility distance, and glance legibility were considered equally important, but more important than learnability. Undoubtedly, the opinions of experts and professionals are very important with regards to driver safety. However, Laughery, Sr. and Smith (2006) suggest what may be obvious to the experts and professional working in a particular field, may not be for the target audience. Ideally, professionals and laymen should be included in the evaluation of traffic signs because they can provide feedback from different perspectives (De Ceunynck et al., 2015).

#### 6.3.1.1 Examples of focus groups in traffic safety research

Drawing upon databases containing driving records and insurance claims for all drivers in British Columbia, Vavrik (1997) assembled 100 young male drivers aged from 16 to 21. These drivers were divided into two groups of fifty. The first group was comprised of high-risk drivers randomly selected from the population of drivers who had at least two or more at-fault collisions in their last two years of driving. The second group was comprised of low-risk drivers randomly selected from a driver

population with no collisions over the same time period. The high-risk group had higher risk-taking and lower harm-avoidance scores compared to the low-risk group. The finding of the study may have important implications for designing remedial driving programs (Vavrik, 1997).

Drawing upon Australian citizens holding a current driving licence, Glendon (2005) used nineteen males and twenty-five females, aged from 17 to 24 years, in six focus groups. Group discussions were recorded and information provided by the participants was analysed for themes and subthemes. Glendon (2005) concluded significant data can be obtained from relatively small focus groups using qualitative analysis.

Nasvadi and Vavrik (2007) used focus groups to study 884 older drivers who attended the 55 Alive/Mature Driving Program. The aim of their study was to determine if collision rates of aging drivers could be reduced with remedial driver education. The results of the focus groups suggested older men use fewer strategies to cope with their declining driving skills. Steele et al. (2013) used focus groups to evaluate the use of flashing arrows, flashing lights, signs and changeable message signs for improving driver and worker safety at nighttime highway operations. Steele et al. (2013) found complex visual driving environments can confuse drivers. They found drivers tend to be overwhelmed when an excessive number of illuminated devices in a localized area at night. Consequently, drivers can take longer to process cognitively, resulting in slower reaction times.

#### 5.3.1.2 Proposed WildHAZ® system focus groups

The objective of WildHAZ® system focus groups would be to identify driver attitudes and behaviours related to conventional wildlife warning signs and to assess the likely impacts of implementing WildHAZ® on highways for driver safety. A

minimum of twelve focus groups should be used to evaluate the WildHAZ® system. These groups would be segmented by sex, age, and previous wildlife-vehicle collision experience (Table 6.1). Segmenting focus group participants by demographics is commonly done in traffic safety studies (Wang et al., 2007; Ullman et al., 2008). Depending on their sex, age and driving experiences, drivers may have different perspectives on wildlife hazards. Sex, age and ethnicity have been used as criteria for determining driver exposure to hazards and developing educational materials for drivers. Savolainen and Ghosh (2008) found younger drivers and females in Michigan were more likely to be injured in deer-vehicle collisions. Focus groups have been used to examine generational perspectives on teen and older drivers in rural and urban communities in Minnesota (Manser et al., 2008); the differences between women and men to traffic safety messages (Morris et al., 1994); accident risk and traffic safety among immigrants in Norway (Assum and Nordbakke, 2013); drinking and driving among younger drivers in the US (Polychron, 2011); developing traffic safety educational materials for Spanish-speaking audiences (Educational Development Center, Inc., 2006); and improving traffic safety culture in Iowa (Baird et al., 2011).

Having a number of focus groups specifically limited to younger drivers and females may also provide an opportunity to determine why these groups of drivers are liable to experience more severe wildlife-vehicle collisions (Savolainen and Ghosh, 2008). Focus groups consisting of older drivers may provide an opportunity to determine the needs of aging drivers with respect to the growing wildlife-vehicle collision phenomenon. The focus groups would provide insight into the experiences of drivers who have been involved in wildlife-vehicle collisions, and insight into what drivers who have never experienced a wildlife-vehicle collision may be doing to reduce their potential for such collisions. To focus on the most vulnerable drivers in wildlife collisions, the selection of focus group participants would be limited to those who primarily drive passenger vehicles only. Drivers who primarily operate vans, pickup

trucks, SUVs or large commercial/industrial vehicles would be excluded from the study. The moderator of the WildHAZ® system focus groups would guide the participants through a number of pre-determined steps designed to extract driver opinions on hazard-related issues and solicit suggestions for improving the hazard potential communication of conventional traffic warning signs.

**Table 6.1 Proposed focus groups for WildHAZ® system**

<b>Focus Group</b>	<b>Gender</b>	<b>Age Range</b>	<b>History of wildlife-vehicle collisions</b>	<b>Operate passenger vehicle only</b>
1	Females	<25	Yes	Yes
2	Females	25 to 54	Yes	Yes
3	Females	55+	Yes	Yes
4	Females	<25	No	Yes
5	Females	25 to 54	No	Yes
6	Females	55+	No	Yes
7	Males	<25	Yes	Yes
8	Males	25 to 54	Yes	Yes
9	Males	55+	Yes	Yes
10	Males	<25	No	Yes
11	Males	25 to 54	No	Yes
12	Males	55+	No	Yes

In particular, the moderator would facilitate the focus group participants to:

1. examine standard traffic warning signs and what they mean to drivers,
2. examine the use of colours for warning the public of potential hazards,
3. examine concepts of hazard warning systems (i.e. forest fire danger),
4. examine the wildlife hazard issue for drivers,
5. examine effectiveness of conventional wildlife warning signs for drivers,
6. review the WildHAZ® system,
7. examine the potential for the WildHAZ® system for augmenting conventional wildlife warning signs, and

8. provide advice on improving the WildHAZ® system for drivers.

As suggested by Pullen-Seufert and Hall (2008), at this point, the feedback collected from the focus groups would be used to direct any modifications to the WildHAZ® system that could be implemented in the driving simulation stage to improve the system's effectiveness. The primary objective would be to maximize the hazard warning potential of the WildHAZ® system prior to incorporating the system into the driving simulation stage.

#### **6.4 Driving Simulation**

A driving simulator is a system that provides a controlled, coherent, multi-sensory environment for a driver to perceive and control virtual vehicle movements (Figure 6.1) (Kemeny and Paneria, 2003). In driving simulation studies, participants are seated in a mock-up and navigate through a virtual road environment projected on a screen (De Ceunynck et al., 2015). Simple simulators have a fixed mock-up and use one or more computer screens for scenario visualization. More sophisticated simulators use a mock-up mounted on a moving base platform and provide virtual projection on large screens, typically ranging from 180° to 360° (Fisher et al., 2011a). The projected road environment can be virtually simulated or real-life video footage (De Ceunynck et al., 2015).

Driving simulators have been used for traffic safety research since the late 1950's (Blana, 1996). The devices enable researchers to develop driving scenarios that provide a safe, realistic and consistent environment in which to assess driver behaviour (Reed et al., 2011). Driving simulators provide a valid tool for assessing a variety of driving performance measures, such as speed, brake onset, divided attention and risky driving behaviour (Mullen et al., 2011). They offer a safe and relatively low-cost alternative to on-road instrumented vehicle research (Blana, 1996;

Kemeny and Panerai, 2003; Bach et al., 2008; Rudin-Brown et al., 2009). For researchers, using a driving simulator to study driver behaviour is less expensive and less time consuming than setting up a test track and observing drivers using real vehicles (Bach et al., 2008). Driving simulators provide an inherently safe environment for driving research because there is no danger to the driver under critical driving conditions (Blana, 1996; Mullen et al., 2011) or when testing innovative devices (Blana, 1996). Rudin-Brown et al. (2009) recommended the use of driving simulation as a first step in the evaluation of novel road safety interventions. Data recorded during driving simulations can be separated into vehicle control measures and visual behaviour measures. Vehicle control measures include information on vehicle speed, the way in which a driver brakes and the movement of the vehicle within a lane. The measures of visual behaviour allow the assessment of the duration and frequency with which drivers look at the traffic control signs they encounter when driving, and their distance from each sign when they choose to look at it. These measures help researchers to identify the information drivers use to make decisions when approaching potentially hazardous driving environments, and to determine what information drivers tend to ignore.

#### 6.4.1 Near-ideal laboratory-based driving study environment

Driving simulators offer the promise of conducting driver behaviour studies with the realism of the natural world, but with the control of a laboratory environment (Kearney and Grechkin, 2011). However, driving simulators can never replicate real world driving in all its complexity (Blana, 1996; Fisher et al., 2011b). There will always be the issue of validity as to the extent driving behaviour in a driving simulator corresponds to that in real life.



Figure 6.1 VRX driving simulator

Driving simulators do not always provide an accurate picture of on-road driving behaviour (Mullen et al., 2011). Bach et al. (2008) believe the key to creating a realistic driving simulation is to provide the driver a challenging and unpredictable driving environment. Albeit digitally rendered, or digitally augmented, driving simulations represent a near-ideal, laboratory-based driving environment for researchers to study drivers. While drivers on public roads and highways operate anonymously, driving simulation subjects can be selected by specific age, sex and driving history criteria. Consequently, researchers can observe the responses of specific driver types and differentiate response patterns between the driver types.

While the models of vehicles driven on public roads and highways can vary dramatically, specific vehicles can be selected for driving simulations. Using a single model of vehicle for driving simulations should reduce variations that might result from using a mix of different vehicle model types. When the presence of other

vehicles is eliminated, driving simulations provide an environment where traffic congestion does not occur and free flow traffic conditions can be guaranteed. As a result, study subjects in driving simulations are not influenced by traffic in any way. The absence of other vehicles allows study subjects to drive as they might without any influence from other drivers (Reed et al., 2011).

#### 6.4.1.1 Examples of driving simulation in traffic safety research

Reed et al. (2011) observed 81 licenced drivers to determine their behaviour when driving through temporary traffic management sites. No particular inclusion or exclusion criteria were followed during participant recruitment. Reed et al. (2011) took steps to include different experience levels and driving styles of drivers. Their study subjects were divided into “younger” drivers, those 17 to 44 years of age, and “older” drivers, those 45 years of age and older, and further segmented into male and female subgroups. Reed et al. (2011) had their study subjects drive a 42 kilometre test route for approximately 30 minutes.

Bella (2005) found driving simulation is a valid method to evaluate drivers' behaviour in work zones. Bella (2005) compared actual vehicle speeds recorded on highways near work zones with the speeds of driving simulation participants in a virtual replication of the work zones.

De Ceunynck et al. (2015) used Traffic Sign Simulator to study the influence of traffic signs on drivers' routing decisions, lane choices and eye movement behaviour, to investigate drivers' comprehension of the signs, and to collect suggestions from the drivers for improving traffic signs. Using a driving simulator mock-up, participants navigated through a full HD video from routes in which the planned traffic signs were digitally implemented for camera-tracking and 3D video-integration. Participants'

routes and lane choices and their eye movement behaviour are monitored while driving through different scenarios.

Grace et al. (2014) used a driving simulator to test the effects of the Roadside Animal Detection System (RADS) on collision rate and driver speed of 90 participants. They also examined if the warning signs associated with RADS would be more effective if the signs were redesigned. They found that their control group drivers, who were not warned an animal was near the road, were significantly more likely to experience a wildlife-vehicle collision, than their test group drivers. Grace et al. (2014) concluded redesigning conventional wildlife warning signs could result in fewer wildlife-vehicle collisions.

#### 6.4.2 Proposed WildHAZ® system driving simulation study

Use of a driving simulator would allow for the observation of driver behaviour related to conventional wildlife warning signs and WildHAZ® system augmented ones on a highway without exposing drivers to real wildlife hazards. Ideally, at least one hundred and twenty subjects would be tested. As was proposed in the focus group component of the WildHAZ® system evaluation, driving simulation participants would be selected according to the same twelve sex, age groupings, and previous wildlife-vehicle collision experience categories (Table 6.2). In an effort to ensure study subjects in the driving simulations did not have prior exposure to the WildHAZ® system, focus group participants would be excluded from the driving simulation stage.

To focus on the most vulnerable drivers in wildlife collisions, the selection of study subjects would be limited to those who primarily drive passenger vehicles only. Drivers who primarily operate vans, pickup trucks, SUVs or large

commercial/industrial vehicles would be excluded from the study. Observations of the drivers who had experienced wildlife collisions may provide information on whether being involved in a wildlife collision leads drivers to be more attentive and responsive to conventional wildlife warning signs. Observations of the drivers who had not experienced wildlife collisions may provide information on the influence of conventional wildlife warning signs on their driving behaviour.

The driving simulations would involve a rural highway scene for both night and day conditions. The first driving simulation for each day/night scenario would involve conventional deer warning signs. The second driving simulation for each day/night scenario would involve the conventional deer warning signs augmented with the WildHAZ® system. Ideally, the driving simulation scenarios would be based on two 20 kilometre to 30 kilometre long highway corridors where at least 25 conventional wildlife warning signs are located in a single direction along the highway right-of-way.

For the WildHAZ® system component of the scenarios, the sequencing of the WildHAZ® system colour-codes would be randomized along the highway corridors to avoid test subjects becoming complacent. To limit driving environment influences, the highway corridors would be free of traffic in both directions. This would allow for “free speed” measurements, uninfluenced by weather and other traffic (Lay, 2009). As per Reed et al. (2011), in the initial driving simulations, participants would be asked to drive a rural highway scene under both day and night conditions, as they normally would. After the first day and night driving simulations, each driver would be introduced to the WildHAZ® system (Figures 6.2 and 6.3).

#### 6.4.2.1 Monitoring driver behaviour

During the driving simulations, the driving speeds of test subjects would be monitored. Speed is one of the most commonly studied measures of driver behaviour

in driving simulations (Mullen et al., 2011). Studies into the effects of traffic signs on driver behaviour have typically focused on whether drivers respond to all types of hazard warning signs and how drivers perceive the information provided by the signs (Rämä, 2001).

Table 6.2 Proposed driving simulation groups for WildHAZ® system evaluation

<b>Focus Group</b>	<b>Gender</b>	<b>Age Range</b>	<b>History of wildlife-vehicle collisions</b>	<b>Operate passenger vehicle only</b>	<b>WildHAZ® Focus Group Participant</b>
1	Females	<25	Yes	Yes	No
2	Females	25 to 54	Yes	Yes	No
3	Females	55+	Yes	Yes	No
4	Females	<25	No	Yes	No
5	Females	25 to 54	No	Yes	No
6	Females	55+	No	Yes	No
7	Males	<25	Yes	Yes	No
8	Males	25 to 54	Yes	Yes	No
9	Males	55+	Yes	Yes	No
10	Males	<25	No	Yes	No
11	Males	25 to 54	No	Yes	No
12	Males	55+	No	Yes	No

Although drivers can respond to traffic signs in many ways, most responses, except for vehicle speed, are difficult to measure (Luoma (1991) cited in Rämä (2001). Tay and De Barros (2010) found the simplest design able to provide a valid inference on the effect of safety messages displayed on dynamic message signs involved measuring vehicle speeds when drivers were exposed to the messages and comparing them with vehicle speeds when drivers were not exposed to the messages.



Figure 6.2 Driving simulation with conventional wildlife warning sign



Figure 6.3 Driving simulation with WildHAZ® augmented conventional wildlife warning sign

#### 6.4.2 Primary questions for driving simulation

In observing the test subjects during the initial two driving simulations, the primary questions to be answered would be:

1. Do drivers reduce their vehicle speeds when they encounter conventional wildlife warning signs?
2. If drivers reduce their speeds when they encounter conventional wildlife warning signs:
  - a. how great is the speed reduction?
  - b. at what distance from a conventional wildlife warning sign do drivers initiate braking to reduce their vehicle speeds?
  - c. for what distance do drivers reduce their vehicle speeds after seeing a conventional wildlife warning sign?
  - d. is the speed reduction behaviour consistent at all times?

The answers to these questions may provide valuable insight into driver behaviour that may be useful for optimizing the field testing component of the testing and evaluation of the WildHAZ® system.

### **6.5 Field Testing**

Driver behaviour in driving simulation approximates, but does not exactly replicate on-road driving behaviour (Mullen et al., 2011). If the driving simulation sessions provide evidence the WildHAZ® system reduces driving speeds, the next stage of the system evaluation would be field testing. This stage of the evaluation process is anticipated to be the most costly, most time consuming, and most complex of the three stages. It would also be the stage most subject to external environmental factors and trends in driving safety.

Observational “before-after” studies are the most common approach used for traffic safety effectiveness evaluation (American Association of State Highway and Transportation Officials, 2010). These studies may incorporate control sites into the evaluation as a comparison group. Control sites allow for the consideration of general trends in collision frequency or severity whose causes may be unknown, but which are assumed to influence collision frequency and severity at the test and control sites equally (American Association of State Highway and Transportation Officials, 2010). If one could be certain nothing has changed from year to year, then one should take as long a “before” period as possible (Hauer, 1997). However, many causal factors (i.e. traffic volumes, weather, etc.) influence highway safety (Shankar et al., 1995).

It is often difficult to distinguish between changes due to a specific highway safety treatment and changes due to all other factors (Lyle et al. 2006). Fundamental to before and after evaluations is a recognition some or all of the observed changes in safety following a safety treatment can be due to factors other than the treatment (Persaud, 2001). Consequently, an assumption of “no change” due to all other factors over the course of a “before and after” study is never entirely correct (Hauer, 1997). For the results of a “before and after” study to be as credible as possible, there must not be a trend in the “before” accident counts, and there must not be reasons why the “before” period may differ from the “after” period (Hauer, 1997). The more trend-free the “before” period, the better.

According to Hauer (1997), there is no clearcut guidance on what length of time for the “before” period is best for a “before and after” study. The American Association of State Highway and Transportation Officials (2010) recommends three to five years of “before” data and three to five years of “after” data for “before-after” analysis. However, while a study may gain much from using two years of “before” observations instead of one, it may not be worthwhile to extend the “before” period

from three to four years (Hauer, 1997). “When the change in safety is large, the number of accidents needed is small enough to make a study practically feasible. However, changes in safety that amount to only a few percentage points may be practically undetectable; the number of accidents needed to detect such small changes is very large” (Hauer, 1997, p. 93).

For the test of the WildHAZ® system, I propose a three-year comparative parallel before-and-after study. The study would be divided into three components:

1. two control corridors,
2. two test corridors, and
3. twenty-four random locations.

The study would use speed change data as an indicator of wildlife-vehicle collision reduction potential. Any measure that reduces driver speed will provide the driver more time to respond to deer and will reduce the severity of a deer-vehicle collision, should one occur (Meyer, 2006). Typical traffic parameters include vehicle presence, speed, count, gap, headway and weight (Mimbela and Klein, 2007). If possible, all these traffic parameters would also be recorded. In the consideration of possible technologies, such as pneumatic loops (Figure 6.4), induction loops were found to be the most suitable (Figure 6.5) (McDavid and Hawthorn, 2006; Mimbela and Klein, 2007).



Figure 6.4 Pneumatic loop



Figure 6.5 Inductive loops  
Source: US Federal Highway Administration

Induction loops are commonly used to measure the vehicle speeds by road authorities (McDavid and Hawthorn, 2006) because of their relatively low cost, technology maturity, and installation aesthetics (Mimbela and Klein, 2007). Induction loops are widely used by transportation engineers to measure both traffic volumes and speeds. The devices are buried into shallow cuts in highway pavement with connections to roadside monitoring electronics. When a vehicle passes over an induction loop, the speed of the vehicle is measured and recorded. The technology is well understood by road authorities and considered mature by traffic safety engineers (Mimbela and Klein, 2007). These devices are considered reliable for measuring vehicle speed.

For the control corridors, vehicle speeds would be monitored at locations before and after twenty-four conventional wildlife warning signs. To manage the total length of the control and test corridors, and minimize travel times for researchers, the twenty-four signs would be divided into twelve sequentially paired locations along a single contiguous section of highway. The pairing would involve one wildlife warning sign oriented in one direction on the highway, and a corresponding second sign oriented in the opposite direction. Vehicle speed monitoring would be conducted at the control and test corridors, and the random locations for twelve months prior to the installation and activation of the WildHAZ® system at the test location, and twenty-four months following the installation and activation of the system.

The implementation strategy of the field tests would involve the following steps:

1. control and test sites selection,
2. system installation,
3. system maintenance,
4. data collection, and
5. data analysis.

### 6.5.1 Control and test sites selection

I believe the ideal location for testing the WildHAZ® would be a large national or state/provincial park with a number of two-lane highways running through it. The Insurance Corporation of British Columbia tested its Wildlife Protection System in Kootenay National Park (Newhouse, 2003). Conducting the study in a national or state/provincial park would provide an environment where the greatest control over the placement and management of traffic monitoring equipment and WildHAZ® augmented wildlife warning signs could be maintained. Two jurisdictions that stand out as the best potential test locations for the WildHAZ® system are the State of Utah in the US and the island of Hokkaido in Japan. Both jurisdictions have large deer populations and high numbers of deer-vehicle collisions (West, 2007; Kawata, 2011; Noro and Hagiwara, 2015; Olson et al., 2015).

Both the Utah Department of Transportation (UDOT) and the Hokkaido Development Engineering Centre (HDEC) have long histories of progressive efforts to reduce deer-vehicle collisions as well as very strong interests and willingness to test innovative wildlife warning systems (West, 2007; West, 2008; Sato, 2015; Seto, 2015) (Figures 6.6 and 6.7). The WildHAZ® system was introduced to HDEC researchers in July, 2015. Their positive interest in the system has been encouraging. Further dialogue with HDEC may result in a test of the WildHAZ® system on highways in Hokkaido. My next step is to approach UDOT to introduce the WildHAZ® system for its consideration.

Selecting suitable test sites will not be a simple task. Curves, hills, intersections, and driveways contribute to highway complexity. These highway features create driving environments where drivers may modify their vehicle speed are related to factors not specifically associated with the presence of potential wildlife hazards or wildlife warning signs. Consequently, drivers may be inclined, in these environments, to modify their vehicle speeds, with or without the presence of wildlife warning signs.



Figure 6.6 Internally illuminated deer warning sign in Hokkaido, Japan



Figure 6.7 Dynamic deer warning sign in Hokkaido, Japan

The ideal locations for monitoring vehicle speeds related to wildlife warning signs would be where a driver's choice of vehicle speed is not influenced by road complexity. Figures 6.8 and 6.9 illustrate the difference between a complex roadway and a non-complex one. It would be preferable for vehicle speed monitoring to be limited to only those periods when weather-related, visibility reducing and tire traction influencing factors (i.e. rain, snow, sleet, fog, etc.) that may modify driver behaviour are not present (Figures 6.10 and 6.11).

In order to minimize the potential influence of external factors, test areas should be, as much as possible, limited to sections of highway that have the following characteristics:

1. straight alignment,
2. two-lane roadway,
3. flat terrain,
4. constant posted speed limits,
5. no driveways,
6. no intersections,
7. non-illuminated roadway, and
8. undeveloped adjacent rural lands.

By selecting test sections that are as homogeneous as possible, the potential for determining if, and how, drivers will respond to the WildHAZ® system should be greater. The challenges of selecting suitable test locations are compounded by length of highway needed, depending on the posted speed limits. A basic driver response time is 1.8 seconds (Lay, 2009).



Figure 6.8 Non-ideal vehicle speed monitoring location



Figure 6.9 More ideal vehicle speed monitoring location



Figure 6.10 Non-ideal Fall speed monitoring conditions



Figure 6.11 Non-ideal Winter speed monitoring conditions

Table 6.3 illustrates the length of highway needed, if a 2 second travelling distance is used before and after a WildHAZ® augmented wildlife warning sign.

Table 6.3 Total length of speed monitoring zone required

Posted speed limit (km/hr)	Vehicle speed (m/second)	Distance vehicle travels in 2 seconds (m)	Total length of speed monitoring zone required (m)
80	22.2	44.4	88.9
90	25.0	50.0	100.0
100	27.8	55.6	111.1
110	30.6	61.1	122.2
120	33.3	66.7	133.3

To be effective, a warning sign must be located sufficiently in advance for a driver to properly detect, read, understand and act upon the sign's message (Lay, 2009).

Figure 6.12 illustrates the configuration of speed monitoring equipment at each location. While selecting identical sections of highway for the WildHAZ® system test would be ideal, achieving this in the field may be impractical, or even impossible.

Consequently, minimizing external factors, as much as possible, may offer the only realistic option for testing the WildHAZ® system in the field. A minimum of two highway corridors would be selected for each of the control and test components of the study. This redundancy would reduce the potential impacts on the study in case traffic-modifying events on a single corridor compromise the data from that corridor. Depending on the scale and duration of unexpected events (i.e. bridge failures, avalanches and rockfalls, etc.) traffic volumes and traffic characteristics could be significantly altered.

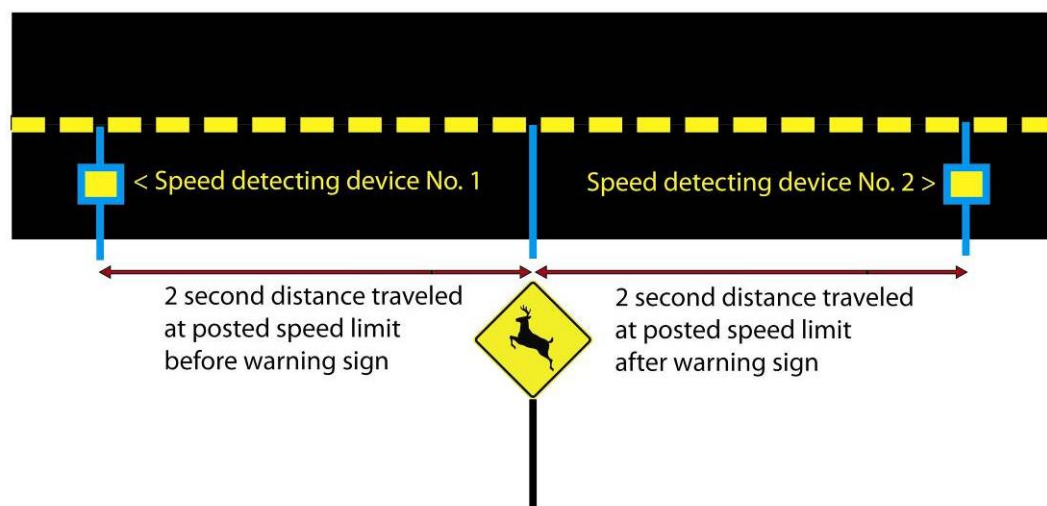


Figure 6.12 Locating speed detection devices

Each of the control and test corridors would have a minimum of twenty-four conventional wildlife warning signs located within the corridors. The American Association of State Highway and Transportation Officials (2010) recommends analyzing at least 10 to 20 locations where traffic safety improvement has been made. An additional twenty-four conventional wildlife warning signs, located randomly outside the control and test corridors, would also be selected. Random sampling provides for a portion of the observed vehicle speeds to be representative of the driving behaviour of drivers at all locations where wildlife warning signs are installed (Council et al., 1980). Data collected at the randomly located warning signs would be used to determine if there were corridor-effects present in the control and test corridors. It is conceivable drivers traveling through the control and test corridors may pass by all the wildlife warning signs located in the corridors. The ability to identify and track individual motor vehicles as they pass wildlife warning signs along the control and test corridors would make more detailed driver behaviour analysis possible. This may be accomplished with radar tracking systems that can not record licence plate numbers or other identifying motor vehicle characteristics. However, it

would be prohibitively expensive to install radar tracking systems on eight highway corridors, each possibly upwards of 20 to 30 kilometres in length. The use of multiple control corridors and randomly selected control sites should reduce the influence of concurrent widespread safety countermeasures on the recorded vehicle speeds.

Concurrent safety countermeasures, such as speed limit changes, speed enforcement, and drunk driving checkstop programs, can influence driver behaviour and vehicle collision rates (Persaud, 2001; Friedman et al., 2009). To maintain consistency in application of the WildHAZ® system along the control and test corridors, additional WildHAZ® enhanced warning signs may be required at locations where conventional wildlife warning signs are already located, but monitoring vehicle speeds is compromised by vehicle speed reductions caused by road alignment features (i.e. sharp curves, steep hills, tunnels, etc.), roadside complexity (i.e. intersections, land uses (agricultural, commercial, industrial, etc.), and/or roadside signage (i.e. speed limit signs, information signs, direction signs, etc.).

#### 6.5.1.1 Free-flowing traffic

Traffic congestion can affect driver behaviour and their choice of vehicle speed. When multiple vehicles travel in unison along a highway, the driver of the lead vehicle establishes a speed that drivers following adopt, unless they chose to pass the lead vehicle (Figures 6.13 and 6.14). The speed adopted by a following driver may lower than the speed they would drive if a vehicle was not immediately in front of them. In order to determine the effect of portable plastic rumble strips on driving behaviour of individual drivers, Wang et al. (2011) used only the speeds of free-flowing vehicles with a headway of at least 4 seconds in their analysis. By doing so, Wang et al. (2011) were able to minimize the influence of speed reductions caused by traffic congestion.



Figure 6.13 Vehicle with unimpeded headway



Figure 6.14 Vehicle with impeded headway

### 6.5.1.2 Differentiating vehicle sizes

It is important to determine the effect of WildHAZ® on the driving behaviour of the most vulnerable drivers. From a purely physics perspective, one might expect the vulnerability of drivers may be related to the size and weight of vehicles involved in wildlife-vehicle collisions. By weight only, it would appear a 50 kilogram deer represents a greater potential hazard to a 1057 kilogram 2016 Mazda Miata (Autoweek, 2015) than a 3583 kilogram 2016 Ford F250 Super Duty pickup truck (Ford Motor Company, 2015) or a fully-loaded semi and a trailer weighing 36,287 kilograms (Utah Department of Transportation, 2015). Figures 6.15, 6.16 and 6.17 illustrate the differences size and height between a small passenger sedan, a large pickup truck and a large semi with regards to potential impact with a deer.

Where a potential wildlife hazard exists, drivers of larger, higher, and heavier vehicles would appear to have less potential risk associated with a wildlife collision than drivers of smaller, lower and lighter vehicles (Figures 6.18 and 6.19). As a consequence, drivers of larger, higher, and heavier vehicles, in particular fully loaded semis with trailers, may be less inclined to reduce their vehicle speeds where elevated deer hazard risks exist than drivers of smaller, lower and lighter vehicles. Drivers of semis may have limited inclination to reduce their vehicle speeds in areas of elevated deer hazard risks if the results of an impact with a 50 kilogram deer pose little, or no, consequence to their vehicles. However, a concurrent situation may not exist in areas where the potential for collisions with 500 kilogram moose could render a semi inoperable. For this reason, recorded vehicle speeds should be differentiated by vehicle length and weight. The potential exists for WildHAZ® to have no significant influence on the behaviour of drivers operating large, higher and heavier vehicles. Consequently, the most appropriate target audience for WildHAZ® may be the drivers of smaller, lower and lighter vehicles. These drivers would appear to be the most vulnerable to the adverse consequences of wildlife collisions.



Figure 6.15 Full scale deer model and small sedan



Figure 6.16 Full scale deer model and pickup truck

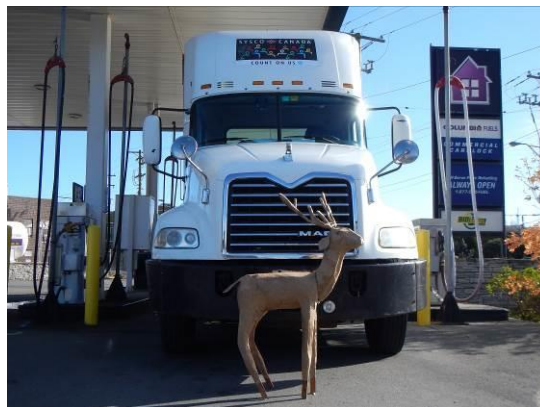


Figure 6.17 Full scale deer model and semi truck



Figure 6.18 Small sedan entering deer hazard area



Figure 6.19 Large pickup truck entering deer hazard area

### 6.5.1.3 System installation

The WildHAZ® system could be implemented using the manual device illustrated in Figure 6.5. Given its use of conventional materials and manufacturing processes, this technology could be implemented relatively quickly. These devices would require personnel to regularly visit each WildHAZ® augmented conventional wildlife warning sign and select the appropriate colour-code for the deer hazard risk, as per the estimated hazard risk. Another, less labour intensive approach, but more technologically sophisticated and expensive, would be to use solar-powered, programmable, LED enhanced WildHAZ® devices. I designed and constructed such an LED enhanced WildHAZ® device that could be programmed, powered by solar panels, and wirelessly operated (Figure 6.20).



Figure 6.20 LED enhanced modified WildHAZ® system

However, before a device like this could be used on a highway corridor, the technology would need to be thoroughly tested and shown to operate reliably under a variety of extreme environmental conditions. When considering the technologies to be used for traffic monitoring, the Illinois Department of Transportation (2004) advises the following issues be examined:

1. safety of workers,
2. quality and quantity of data collected,
3. cost of the equipment,
4. ease of operation,

5. ease of maintenance, and
6. durability.

Vehicle speeds can be easily observed from the roadside or recorded from loops in the pavement (Preusser Research Group, Inc. 2008). Devices such as the Nu-Metrics Hi-Star portable traffic classifiers measure speed, volume, and approximate vehicle length (Georgia Transportation Institute, 2005). These devices can be installed relatively easily in the centre of the highway lanes being studied. They can be programmed to collect data at specified dates and times. The devices can be temporarily attached to road surfaces by masonry anchors and left unattended for the study period. After data collection is complete, the devices are retrieved, and the data is analyzed.

#### 6.5.1.4 System maintenance

The installed components of the WildHAZ® system would need to be monitored on a regular basis. If a national park or state/provincial park was used as a study site, the system could be monitored on a daily basis by park wardens. Electronic equipment at each location would also need to be monitored, at least on a monthly basis, to avoid any potential of data loss due to malfunctions. Where communication services are available, remote monitoring and management of the WildHAZ® system may be possible using cell phone or cable networks.

#### 6.5.1.5 WildHAZ® system advisories for drivers prior to field testing

Prior to field testing the WildHAZ® system, efforts should be made to advise drivers likely to drive on the test corridors of the system. Public education should be used to explain the reasoning for implementing wildlife collision reduction measures (Gkritza et al., 2010). Drivers could be reached by automobile insurance company mailouts

and emails, vehicle registration agency mailouts and emails, and advisories via television news broadcasts and social media channels (i.e. Facebook, Twitter, etc.). Laughery, Sr. and Smith (2006) identified a number of principles useful for warning sign and warning message designers:

- 1) Do not assume the target audience knows about the hazard.
- 2) Do not assume the consequences of the hazard are obvious to the target audience.
- 3) If the hazard and its consequences are not obvious to the target audience, provide the target audience the information it needs to behave safely.
- 4) Match signs and messages to the target audience.
- 5) Keep signs and messages simple, if possible.

One should never assume a traffic safety program will be successful (Williams, 2007). The effectiveness of driver awareness initiatives depends on the drivers' perceived risk of a wildlife-vehicle collision and any subsequent change in their driving behavior as a result of the information they receive (Gkritza et al., 2010). However, providing drivers with information about a potential hazard does not guarantee the drivers will modify their driving behaviour (Rämä, 2001; Williams, 2007). What drivers actually do is governed by attitudes, motivations, lifestyle factors, and assumptions about risk (Williams, 2007).

Prior to testing of the WildHAZ® system, a public education campaign should be directed to drivers likely to encounter the system. “Most states now seem to be content with using only public service announcements to affect driver safety” (Vasan, 2014, p. 9). If the WildHAZ® system is field tested in a national or state/provincial park, drivers entering the park could be given information brochures about the potential consequences of a wildlife-vehicle collisions and the purpose of the

WildHAZ® system, and then see a billboard showing the WildHAZ® system as they pass through the park entrances.

### 6.5.2 Field testing

One of the challenges in designing a field test is determining how many comparison sites are necessary for a statistically robust analysis. “Typically, a guess is made as to how many sites are needed or as many comparison sites as possible are used” (Persuad, 2001, p.21). Sperry et al. (2009) found traffic data collection challenging when studying the effectiveness of dynamic messaging signs.

The placement of traffic monitoring equipment can be affected by construction, bridge closures, temporary road closures, temporary traffic generators, and other events that cause abnormal traffic during monitoring periods (Illinois Department of Transportation, 2004). Sperry et al. (2009) encountered problems ranging from personnel safety issues, relating to the placement and retrieval of on-road vehicle monitoring equipment, to unreliable vehicle monitoring equipment, that compromised their collection of uniform, consistent and relevant data. I anticipate the same challenges when field testing the WildHAZ® system.

#### 6.5.2.1 Year one

In the first year, all control and test corridor sites and the control random locations would be monitored for vehicle speed changes before and after wildlife warning signs. If the speed change data collected shows a statistically significant number of drivers reduce their vehicle speeds a statistically significant amount after observing conventional wildlife warning signs, then one could assume these signs contribute, in some part, to the incidence of wildlife-vehicle collision and/or the reduction of wildlife-vehicle collision severity. After the first year, one could determine if there

were vehicle speed change differences associated with wildlife warning signs at all locations, or if there were localized differences within the test and control corridors, or if the differences recorded at the test and control corridors were consistent with the differences recorded at the random locations. If one assumes conventional wildlife warning signs have no statistically significant effect on vehicle speed changes, then one could assume the vehicle speed change differences recorded at the test and control locations, and at the random locations, would show no statistical differences.

#### 6.5.2.2 Year two

In the second year, the wildlife warning signs in the two test corridors would receive WildHAZ® augmentation, while the wildlife warning signs in the two control corridors and the control random locations would remain unchanged. Vehicle speeds at all wildlife warning sign locations would be monitored before and after the signs. After the second year of monitoring, one could compare vehicle speeds recorded at all locations to determine if WildHAZ® augmented wildlife warning signs produce a statistically significant reduction in vehicle speeds when compared to non-augmented wildlife warning signs.

One could also compare the vehicle speeds recorded at the control corridors and the random locations to determine if there were changes in vehicle speeds before and after wildlife warning signs that were not associated with WildHAZ® augmentation. If vehicle speeds recorded at the control corridors and the random locations showed a reduction of vehicle speeds, then one might assume vehicle speed reductions at the test corridors may have been the result, at least in part, of factors other than WildHAZ® augmentation. In this case, one would need to determine if the reduction of vehicle speed changes at the test corridors was statistically greater than those recorded at the control corridors and the random locations.

### 6.5.2.3 Year three

In the third year, as in the second year, vehicle speeds at all test and control wildlife warning sign locations would be monitored. The third year of monitoring would help determine if vehicle speed changes recorded in the second year continued into the third year. After the third year of monitoring, one could compare vehicle speeds recorded at all locations to determine if WildHAZ® augmented wildlife warning signs produce a statistically significant reduction in vehicle speeds when compared to non-augmented wildlife warning signs. One would also examine the vehicle speeds recorded at the test corridors and the random locations.

## 6.6 Data analysis

Large volumes of driver behaviour data would be collected during the driving simulations and field tests of the WildHAZ® system. The Analysis of Variance (ANOVA) is a statistical analysis approach used by road authorities for evaluating the results of driving simulations (Chrysler et al., 2006; Mullen et al., 2011) and field tests (Persaud, 2001). ANOVA has been used to establish both absolute and relative validity in driving simulation for key driving variables such as mean speed and braking response time (Mullen et al., 2011).

The ANOVA statistical test provides a formalized procedure for analysis of variance between three or more sample populations (Davis, 1986). ANOVA is a suitable statistical test to compare the vehicle speeds observed along the control corridors, the test corridors, and the random test locations. The single factor ANOVA test can be used to determine if the mean vehicle speed change measurements recorded for the control corridor, corridor random, and test corridor are statistically different.

Before and after evaluations with yoked comparison are characterized by four measurements: before and after at the test sites, and before and after at the control sites (Persaud, 2001). This approach attempts to control extraneous factors, such as changes in traffic conditions and other factors, known and unknown. The comparability check is to ensure if vehicles speeds change in the test site, one should expect the same change at the control sites. The primary objective of the statistical analysis is to test for the following:

Hypothesis  $H_0$ : Mean vehicle speeds do not change at locations with WildHAZ® system augmented wildlife warning signs.

Hypothesis  $H_1$ : Mean vehicle speeds change at locations with WildHAZ® system augmented wildlife warning signs.

#### 6.6.1 Post hoc tests

A significant ANOVA indicates the group sample means being evaluated are not likely to be drawn from the same population, or from populations with the same mean (Thomas and Cohen, 1996; Devore, 2000). Traditionally, post hoc tests follow a significant ANOVA (Thomas and Cohen, 1996; Zar, 1999; Devore, 2000). The tests are used to determine which group sample means differ from one another. The Tukey Honestly Significant Difference (HSD) test is one of the most widely accepted and commonly used multiple comparison methods (Devore, 2000; Zar, 1999). In multiple comparison testing, equal sample sizes are desirable for maximum power and robustness. Larger sample sizes tend to result in a multiple comparison analysis more capable of identifying differences among the group sample means. The Tukey HSD test is considered a conservative post hoc test (Thomas and Cohen, 1996). The Tukey HSD test appears to be robust with respect to departures from the population normality and homogeneity of variance assumptions underlying ANOVA (Thomas and Cohen, 1996; Zar, 1999).

### 6.6.2 WildHAZ® field test simulation

To demonstrate the statistical analysis for the field tests I am proposing, I simulated the first two years of a field test of the WildHAZ® system. For the simulation, I established twenty-four observation locations along hypothetical control and test corridors, and twenty-four randomly located hypothetical observation locations. I used Microsoft® Excel to generate differences in mean vehicle speeds for the control and test corridors, and the random locations. For the first year of the simulated field test, I assumed conventional static wildlife warning signs installed along the control and test corridors, and at the random locations, did not modify driver behaviour as demonstrated by reductions in vehicle speeds. Using the Microsoft® Excel RANDBETWEEN function, I generated a simulated mean vehicle speed variance ranging from -1 to +1 km/hr at each observation location (Table 6.4). Using the one-way ANOVA with post-hoc Tukey HSD Test calculator developed by Navendu Vasavada, I analysed the simulation data I generated for mean vehicle speeds at the control and test corridors, and the random locations (Table 6.5). The ANOVA showed no statistically significant differences existed between the simulated mean vehicle speeds generated for the control and test corridors, and the random locations.

For the purposes of the simulation only, these results confirmed my simulation assumption that conventional static wildlife warning signs do not modify driver behaviour as demonstrated by changes in vehicle speeds. For the second year of the simulated field test when the WildHAZ® system was implemented along the test corridors, I assumed the following:

1. conventional static wildlife warning signs do not modify driver behaviour as demonstrated by reductions in vehicle speeds, and
2. WildHAZ® system conventional static wildlife warning signs do modify driver behaviour as demonstrated by changes in vehicle speeds.

Table 6.4 Year one WildHAZ® field test simulation data

<b>Year one WildHAZ® field test simulation</b>					
	<b>Change in mean vehicle speed (km/hr) recorded before/after wildlife warning signs at observation locations</b>				
<b>Observation Locations</b>	<b>Control Corridor One</b>	<b>Control Corridor Two</b>	<b>Random Locations</b>	<b>Test Corridor One</b>	<b>Test Corridor Two</b>
1	-1	1	-1	1	1
2	0	-1	-1	1	0
3	0	0	-1	1	1
4	-1	1	1	-1	-1
5	-1	1	1	-1	-1
6	0	-1	1	1	0
7	-1	0	-1	-1	1
8	1	1	1	0	0
9	-1	1	1	-1	0
10	0	1	0	1	0
11	-1	1	-1	1	-1
12	-1	0	0	-1	0
13	0	-1	-1	-1	-1
14	0	1	0	-1	0
15	1	1	-1	-1	-1
16	1	0	1	0	0
17	0	1	1	1	0
18	0	1	0	1	-1
19	-1	0	0	0	-1
20	1	0	1	-1	0
21	-1	1	1	1	-1
22	1	-1	1	-1	-1
23	0	0	1	0	0
24	1	0	1	1	1

Table 6.5 Year One Simulation ANOVA

<b>Year One Simulation ANOVA</b>						
<b>SUMMARY</b>						
Groups	Count	Sum	Average	Variance		
Control Corridor One	24	-3	-0.125	0.63587		
Control Corridor Two	24	8	0.333333	0.57971		
Random Locations	24	5	0.208333	0.780797		
Test Corridor One	24	0	0	0.869565		
Test Corridor Two	24	-5	-0.20833	0.519928		
<b>ANOVA</b>						
Source of Variation	SS	df	MS	F	P-value	F critical
Between Groups	4.916667	4	1.229167	1.815142	0.130634602	2.45057
Within Groups	77.875	115	0.677174			
Total	82.79167	119				

For the vehicle speed reductions resulting from the use of the WildHAZ® system, I assumed the vehicle speed reductions for each WildHAZ® system hazard level/colour code as shown in Table 6.6. My assumption for the reduced vehicle speeds for the higher level hazard ratings is based on my belief a majority of drivers would be inclined to reduce their vehicle speeds when they are presented a warning advising that a high hazard risk exists. There is the potential the lower hazard ratings and colour codes, in particular the low hazard and its green colour code, may result in higher vehicle speeds. My assumptions about modifications in driver behaviour resulting from the implementation of the WildHAZ® system, as demonstrated by changes in vehicle speeds, can only be verified if field tests are conducted.

Using Navendu Vasavada's one-way ANOVA with post-hoc Tukey HSD Test calculator, I analysed the second year of the simulated field test simulation data I generated (Tables 6.7 and 6.8). The ANOVA showed statistically significant differences existed between the simulated mean vehicle speeds generated for the control and test corridors, and the random locations. The Tukey HSD Test results showed which treatment pairs were found to be significantly different from each other. The significantly different treatment pairs are shown in Table 6.9.

Table 6.6 Assumed mean vehicle speed reductions resulting from the WildHAZ® system

WildHAZ® System Hazard Rating and Colour Codes	Assumed Mean Vehicle Speed Change (km/hr)
Low - Green	0.0
Moderate - Blue	-0.1
High - Yellow	-0.25
Very High - Orange	-0.5
Extreme - Red	-1.0

Table 6.7 Year Two WildHAZ® Simulation Data (Set One)

Year Two WildHAZ® field test simulation (Set One)													
Change in mean vehicle speed (km/hr) recorded before/after wildlife warning signs at observation locations													
Observation Locations	Control Corridor One	Control Corridor Two	Random Locations	Test Corridor One					Test Corridor Two				
				Hazard Rating and Colour Codes					Hazard Rating and Colour Codes				
				Low - Green	Moderate - Blue	High - Yellow	Very High - Orange	Extreme - Red	Low - Green	Moderate - Blue	High - Yellow	Very High - Orange	Extreme - Red
1	0	0	1	0	-1.1	0.75	-0.5	0	1	-1.1	-0.25	0.5	0
2	0	0	0	-1	0.9	-1.25	-1.5	0	0	0.9	-0.25	0.5	-2
3	1	0	0	-1	-0.1	-0.25	-1.5	0	-1	0.9	-1.25	0.5	-2
4	-1	0	1	0	-0.1	-1.25	0.5	-1	-1	0.9	-0.25	0.5	-2
5	1	0	1	-1	-0.1	-1.25	0.5	-1	0	0.9	-0.25	-1.5	-1
6	0	0	1	-1	-0.1	-0.25	0.5	-1	1	-1.1	0.75	-0.5	0
7	-1	-1	0	0	-0.1	-1.25	-1.5	-2	0	0.9	0.75	-1.5	-1
8	0	1	-1	0	-1.1	0.75	-1.5	0	1	0.9	-1.25	0.5	-2
9	-1	1	0	1	0.9	0.75	-1.5	0	1	-1.1	-0.25	-1.5	-2
10	1	0	0	1	-1.1	-0.25	-0.5	-2	-1	0.9	0.75	0.5	-2
11	0	-1	-1	-1	0.9	-1.25	-0.5	0	0	-1.1	-1.25	-1.5	-1
12	-1	0	-1	1	-0.1	-0.25	-0.5	-1	1	-1.1	-0.25	0.5	-1
13	0	1	1	0	-1.1	-1.25	0.5	-2	1	0.9	-0.25	-1.5	-2
14	0	-1	1	-1	-1.1	-0.25	-0.5	-1	-1	0.9	-0.25	-0.5	-1
15	-1	0	-1	0	-1.1	0.75	-1.5	-1	-1	-1.1	-1.25	0.5	0
16	0	-1	1	0	-0.1	-0.25	-1.5	-2	1	0.9	-1.25	0.5	-1
17	0	0	1	-1	-0.1	0.75	-1.5	-1	1	0.9	-1.25	-0.5	0
18	-1	0	-1	0	-0.1	0.75	-0.5	0	0	-1.1	-1.25	-1.5	-1
19	1	0	-1	-1	-0.1	0.75	-0.5	0	1	-1.1	-1.25	0.5	-1
20	1	0	-1	0	0.9	-1.25	-0.5	0	-1	-0.1	-0.25	-0.5	0
21	1	-1	-1	1	-1.1	-1.25	-1.5	-1	-1	0.9	-0.25	0.5	0
22	0	0	0	1	0.9	0.75	0.5	0	1	0.9	-1.25	-0.5	-1
23	1	1	0	1	0.9	-1.25	-1.5	-2	1	-0.1	-1.25	-0.5	-1
24	-1	0	-1	-1	-1.1	-1.25	0.5	-1	1	-1.1	-0.25	0.5	-2

Table 6.8 Year Two Simulation ANOVA for WildHAZ® Simulation Data (Set One)

<b>YEAR TWO SIMULATION ANOVA (Set One)</b>						
<b>SUMMARY</b>						
Groups	Count	Sum	Average	Variance		
Control Corridor One	24	0	0	0.608696		
Control Corridor Two	24	-1	-0.04167	0.389493		
Random Locations	24	-1	-0.04167	0.737319		
Test Corridor One - Low Hazard - Green Code	24	-3	-0.125	0.63587		
Test Corridor One - Moderate Hazard - Blue Code	24	-4.4	-0.18333	0.601449		
Test Corridor One - High Hazard - Yellow Code	24	-8	-0.33333	0.775362		
Test Corridor One - Very High Hazard - Orange Code	24	-16	-0.66667	0.666667		
Test Corridor One - Extreme Hazard - Red Code	24	-19	-0.79167	0.606884		
Test Corridor Two - Low Hazard - Green Code	24	5	0.208333	0.780797		
Test Corridor Two - Moderate Hazard - Blue Code	24	1.6	0.066667	0.927536		
Test Corridor Two - High Hazard - Yellow Code	24	-13	-0.54167	0.476449		
Test Corridor Two - Very High Hazard - Orange Code	24	-6	-0.25	0.717391		
Test Corridor Two - Extreme Hazard - Red Code	24	-26	-1.08333	0.601449		
<b>ANOVA</b>						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	41.07154	12	3.422628	5.219035	5.68E-08	1.784642
Within Groups	196.0833	299	0.655797			
Total	237.1549	311				

Table 6.9 Tukey HSD Test of Simulation One Data (Set One)

<b>Tukey HSD Test of Simulation One Data (Set One)</b>			
<b>Treatment Pairs</b>	<b>Tukey HSD Q statistic</b>	<b>Tukey HSD p-value</b>	<b>Tukey HSD inference</b>
Control Corridor One vs. Test Corridor One Extreme Hazard - Red Code	4.8951	0.0151	p<0.05
Control Corridor One vs. Test Corridor Two Extreme Hazard Red Code	6.5582	0.00101	p<0.01
Control Corridor Two vs. Test Corridor One Extreme Hazard - Red Code	4.6375	0.02678	p<0.05
Control Corridor Two vs. Test Corridor Two Extreme Hazard - Red Code	6.3059	0.00101	p<0.01
Random Locations vs. Test Corridor One Extreme Hazard - Red Code	4.6375	0.02678	p<0.05
Random Locations vs. Test Corridor Two Extreme Hazard - Red Code	6.3059	0.00101	p<0.01

To confirm the results of the Tukey HSD Test, I simulated an additional year of mean vehicle speeds (Table 6.10) and ran an ANOVA. Like the first ANOVA, this ANOVA also showed statistically significant differences existed between the simulated mean vehicle speeds generated for the control and test corridors, and the random locations (Table 6.11). To determine which treatment pairs were significantly different, I ran a Tukey HSD Test. The results of the Tukey HSD Test indicated both the very high hazard (orange code) and the extreme hazard (red code) warnings resulted in significantly different simulated mean vehicle speeds when compared to the simulated mean vehicle speeds of the control corridors and the random locations.

The analysis of two year's simulated mean vehicle speed data suggests that in order for the WildHAZ® system to demonstrate its effectiveness for modifying driver behaviour, as observed by a change in mean vehicle speeds, a reduction in mean vehicle speeds of at least 1 km/hr would need to occur. While lesser reductions in mean vehicle speed could result in less severe wildlife-vehicle collisions, the change in driver behaviour, as demonstrated by a change in mean vehicle speeds, ANOVA may not indicate statistically significant differences exist between treated and untreated locations. If the WildHAZ® system was found to increase mean vehicle speeds at the lower hazard ratings, while reducing mean vehicle speeds at higher hazard ratings, further investigation would be required. One would need to determine if increased wildlife-vehicle collision severity at the lower hazard rating levels significantly contradicts any benefits resulting from reductions in wildlife-vehicle collision severity at the higher hazard rating levels. Using the one-way ANOVA with post-hoc Tukey HSD Test calculator developed by Navendu Vasavada, I analysed the simulation data I generated. The treatment pairs that were found to be significantly different from each other are shown in Table 6.12.

Table 6.10 Year Two WildHAZ® Simulation Data (Set Two)

Year Two WildHAZ® field test simulation (Set Two)													
Change in mean vehicle speed (km/hr) recorded before/after wildlife warning signs at observation locations													
Observation Locations	Control Corridor One	Control Corridor Two	Random Locations	Test Corridor One					Test Corridor Two				
				Hazard Rating and Colour Codes					Hazard Rating and Colour Codes				
				Low - Green	Moderate - Blue	High - Yellow	Very High - Orange	Extreme - Red	Low - Green	Moderate - Blue	High - Yellow	Very High - Orange	Extreme - Red
1	-1	1	1	-1	-0.1	-0.25	0.5	0	0	0.9	-1.25	-1.5	-2
2	1	-1	0	-1	-0.1	0.75	-1.5	-1	1	-1.1	0.75	0.5	-2
3	0	0	1	0	-1.1	0.75	-0.5	0	1	-0.1	0.75	-0.5	-2
4	1	1	0	1	-0.1	0.75	-0.5	-2	-1	0.9	-1.25	-0.5	-2
5	0	-1	0	0	0.9	-1.25	-0.5	-2	-1	0.9	-1.25	0.5	0
6	0	-1	1	0	0.9	0.75	0.5	-2	0	-0.1	0.75	-0.5	0
7	0	0	0	1	-0.1	-1.25	0.5	-1	0	0.9	0.75	-0.5	0
8	0	-1	1	1	-1.1	-0.25	-0.5	-2	1	-1.1	0.75	0.5	0
9	-1	-1	0	0	0.9	-0.25	-1.5	-1	1	-1.1	-0.25	-1.5	-1
10	1	1	1	0	-1.1	0.75	0.5	-2	1	0.9	-1.25	-1.5	-2
11	0	1	1	-1	0.9	0.75	-1.5	-1	-1	-0.1	0.75	0.5	0
12	-1	0	0	0	-0.1	-0.25	-0.5	0	0	0.9	-1.25	0.5	-2
13	1	1	-1	0	-0.1	-0.25	-1.5	-1	-1	-0.1	0.75	-1.5	-2
14	1	1	0	0	0.9	0.75	-0.5	0	1	-0.1	0.75	-0.5	-1
15	1	0	1	1	0.9	-1.25	-0.5	-1	-1	-0.1	0.75	0.5	-2
16	-1	-1	0	-1	0.9	-1.25	0.5	0	0	-1.1	-1.25	0.5	-1
17	0	0	0	1	-0.1	0.75	-1.5	0	1	-0.1	-0.25	-0.5	0
18	1	1	1	0	-0.1	0.75	-1.5	-2	-1	-0.1	-0.25	-0.5	-2
19	1	0	1	1	-1.1	0.75	0.5	-1	-1	0.9	-0.25	-0.5	-2
20	1	0	-1	0	0.9	-1.25	-1.5	0	-1	-0.1	-0.25	-0.5	-2
21	1	0	1	0	-1.1	0.75	-0.5	-1	1	-0.1	-1.25	-0.5	-1
22	1	1	-1	0	-0.1	0.75	-0.5	-1	0	-1.1	-1.25	-1.5	-1
23	-1	1	1	0	-0.1	-1.25	-1.5	0	1	-0.1	0.75	-0.5	-1
24	0	0	0	-1	-1.1	-0.25	-0.5	-1	0	0.9	0.75	0.5	-2

Table 6.11 Year Two Simulation ANOVA for WildHAZ® Simulation Data (Set Two)

<b>YEAR TWO SIMULATION ANOVA (Set Two)</b>						
<b>SUMMARY</b>						
Groups	Count	Sum	Average	Variance		
Control Corridor One	24	6	0.25	0.630435		
Control Corridor Two	24	3	0.125	0.63587		
Random Locations	24	8	0.333333	0.492754		
Test Corridor One - Low Hazard - Green Code	24	1	0.041667	0.476449		
Test Corridor One - Moderate Hazard - Blue Code	24	-0.4	-0.01667	0.601449		
Test Corridor One - High Hazard - Yellow Code	24	0	0	0.717391		
Test Corridor One - Very High Hazard - Orange Code	24	-14	-0.58333	0.601449		
Test Corridor One - Extreme Hazard - Red Code	24	-22	-0.91667	0.601449		
Test Corridor Two - Low Hazard - Green Code	24	1	0.041667	0.737319		
Test Corridor Two - Moderate Hazard - Blue Code	24	0.6	0.025	0.548913		
Test Corridor Two - High Hazard - Yellow Code	24	-3	-0.125	0.809783		
Test Corridor Two - Very High Hazard - Orange Code	24	-9	-0.375	0.548913		
Test Corridor Two - Extreme Hazard - Red Code	24	-30	-1.25	0.717391		
<b>ANOVA</b>						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	63.14846	12	5.262372	8.425431	9.59E-14	1.784642
Within Groups	186.75	299	0.624582			
Total	249.8985	311				

Table 6.12 Tukey HSD Test of Simulation Two Data (Set Two)

<b>Tukey HSD Test of Simulation One Data (Set Two)</b>			
<b>Treatment Pairs</b>	<b>Tukey HSD Q statistic</b>	<b>Tukey HSD p-value</b>	<b>Tukey HSD inference</b>
Control Corridor One vs. Test Corridor One Very High Hazard - Orange Code	5.2941	0.00582	p<0.01
Control Corridor One vs. Test Corridor One Extreme Hazard - Red Code	7.4117	0.00101	p<0.01
Control Corridor One vs. Test Corridor Two Extreme Hazard - Red Code	9.1844	0.00101	p<0.01
Control Corridor Two vs. Test Corridor One Very High Hazard - Orange Code	4.5000	0.03586	p<0.05
Control Corridor Two vs. Test Corridor One Extreme Hazard - Red Code	6.6176	0.00101	p<0.01
Control Corridor Two vs. Test Corridor Two Extreme Hazard - Red Code	8.419	0.00101	p<0.01
Random Locations vs. Test Corridor One Very High Hazard - Orange Code	5.8235	0.00147	p<0.01
Random Locations vs. Test Corridor One Extreme Hazard - Red Code	7.9411	0.00101	p<0.01
Random Locations vs. Test Corridor Two Extreme Hazard - Red Code	9.6946	0.00101	p<0.01

## **6.7 Cost Estimates for Three-Stage Testing and Evaluation Approach of WildHAZ® System**

To determine the effectiveness of the WildHAZ® system and avoid the unfortunate situation that developed for wildlife reflectors, significant investments in testing the WildHAZ® system would be needed. My estimate of the costs for the necessary focus groups, driving simulation and field testing approaches \$1.5 million.

### **6.7.1 Estimated focus groups costs**

The cost of hiring a professional market research company to conduct and evaluate focus group sessions for twelve, 10-person groups would range between \$35,000 and \$40,000 (Johansen, P. November 2, 2015, Personal communication). Each session would run between 90 minutes and 120 minutes. This estimate would cover all session material development and session hosting. This would not include the cost of locating and recruiting focus group participants or any honourariums paid to the participants to offset their personal costs or compensate for their time. Depending on the difficulty of recruiting focus group participants, it is estimated it may cost as much as \$10,000 to have a professional human resources consultant perform this function. A honourarium of \$100 per participant would increase the cost of the focus groups by an additional \$12,000. In total, the focus group sessions may cost upwards of \$60,000 (Johansen, P. November 2, 2015, Personal communication). .

### **6.7.2 Estimated driving simulation costs**

Driving simulators are available for research purposes at a number of universities in Europe and North America. Currently, state-of-the-art driving simulators are being designed and built by VRX in Sidney, British Columbia, Canada. VRX simulators are available for research studies at a cost between \$50 and \$60 per hour (Dinnage, D.

November 2, 2015. Personal communication). For 120, 1-hour driving simulation sessions, the cost for driving simulator rental would range between \$6000 and \$7200. Depending on the difficulty of recruiting driving simulation participants, it is estimated it may cost as much as \$10,000 to have a professional human resources consultant perform this function.

A honourarium of \$100 per participant would increase the cost of the focus groups by an additional \$12,000. Each session would require at least one attending researcher to manage, instruct and observe the participants. At a wage of \$100 per hour, the cost of this researcher would be approximately \$12,000. It is estimated the data collected during the driving simulation sessions would take a researcher 80 hours to analyze, at a cost of \$8,000. To incorporate WildHAZ® augmented conventional wildlife warning signs into existing driving simulation software would require the creation of 3-D digital images. Each image would need to be incorporated into the driving simulation software.

Depending on the complexity of the images, it could cost between \$500 and \$1500 to add each image to the driving simulation software ( Dinnage, D. November 2, 2015, Personal communication). Adding 100 images to the driving simulation software could cost between \$50,000 and \$150,000. In total, the driving simulation sessions could cost upwards of \$200,000 to conduct (Dinnage, D. November 2, 2015. Personal communication).

### **6.7.3 Estimated field testing costs**

The most complex and costly stage of the evaluating the WildHAZ® system would be the field testing. This stage would require the installation of WildHAZ® augmented wildlife warning signs and traffic monitoring equipment on public roads and highways. Field inspections to determine suitable test locations would cost

upwards of \$25,000 to perform. Fabricating and installing 100 WildHAZ® augmented wildlife warning signs would cost in the order of \$350,000. The cost of providing traffic monitoring equipment at 125 locations would range between \$250,000 and \$350,000 (Cook, W. October 30, 2015. Personal communication). Depending on field test locations, relative to the geographic availability of qualified technicians, installing the equipment would cost an additional \$250,000 to \$300,000 (Peterse, K. October 30, 2015. Personal communication).

Monitoring and maintenance of the installed equipment for three years by technicians would cost upwards of \$200,000. Data analysis is estimated to cost between \$8,000 and \$10,000. In total, a comprehensive, three year-long, field test of WildHAZ® augmented wildlife warning signs sessions could cost upwards of \$1.25 million to conduct.

#### **6.7.4 Pre-study Assessment**

Depending on the resources needed and the technology involved, implementing an extensive, statistically robust, multi-year experiment designed to assess a new wildlife hazard warning system on roads and highways could be very costly to a road authority. Consequently, road authorities should assess the potential for the experiment succeeding prior to committing resources. The results of an experiment with a low potential for success due to inadequate sampling may result in a road authority dismissing a new system that is actually effective. Conversely, limited road authority resources may be used unnecessarily when the sampling regime of an experiment is larger than needed to achieve success.

Power analyses are routinely requested as part of research funding grant applications in the biological and social sciences to address concerns regarding adequate sample size determination (Lachenbruch, 1989; Hallahan and Rosenthal, 1996; McDonald,

2014). Failing to complete a power analysis when planning and interpreting empirical studies can lead to erroneous conclusions from the data (Hallahan and Rosenthal, 1996). Consequently, a power analysis should be conducted on any experiment developed to field test the Wildlife Hazard Warning System® to determine if the experiment has a sampling regime with a potential for success.

#### 6.7.4.1 Power Analysis

Power is a very important issue for researchers in the biological and social sciences (Pagano, 1986; McDonald, 2014). It is a measure of the sensitivity of a study to detect a difference between test and control samples if a difference truly exists (Pagano, 1986; Harkavy-Friedman, 2016). Power analyses then are very useful for designing experiments as well as interpreting their results (Pagano, 1986; Mayr, 2007), especially so as they enable researchers to plan studies that are adequately sensitive to the predicted effects. In power analyses experiments, there are two possible outcomes that can occur during data analysis. The null hypothesis can be either retained or rejected. The decision to retain or reject a null hypothesis is subject to two potential errors (Table 6.13). Rejecting a null hypothesis when it is actually true is considered a Type I error. Retaining a null hypothesis when it is actually false is considered a Type II error. By minimizing Type I and Type II errors, researchers maximize the likelihood their conclusions will be correct (Pagano, 1986).

Table 6.13 Null Hypothesis Decision Matrix

<b>Decision</b>	<b>Null hypothesis is true</b>	<b>Null Hypothesis is false</b>
Retain null hypothesis	Correct decision prob = $1-\alpha$	Type II error prob = $\beta$
Reject null hypothesis	Type I error prob = $\alpha$	Correct Decision prob = $1-\beta$

Power can be defined in three ways (Pagano, 1986):

1. It is the probability that the results of an experiment will allow the rejection of the null hypothesis if the null hypothesis is false.
2. It is the probability of accepting the alternative hypothesis if the alternative hypothesis is true.
3. It is the probability of making a correct decision when the null hypothesis is false.

The American Foundation for Suicide Prevention (Harkavy-Friedman, 2006) requires its research grant applicants to provide the following power analysis information:

1. Type I error ( $\alpha$  or alpha),
2. Type II error ( $\beta$  or beta),
3. What difference is expected (effect size), and
4. Sample size.

For power analysis, the commonly used value for  $\alpha$  (Type I error) is 0.05 while the value of  $\beta$  (Type II error) is 0.80 (McDonald, 2014). The convention to use  $\alpha=0.05$  is strong (Hallahan and Rosenthal, 1996) and Cohen (1988) suggests power = 0.80 as a sensible goal for research. For applied research, the goal of an experiment may be to detect a very definite effect, with the effect size recognized as the difference between a null hypothesis and the alternative hypothesis that a researcher hopes to detect (McDonald, 2014). With regards to field testing the Wildlife Hazard Warning System® the effect size should be a measurable decrease in vehicle speeds that would indicate drivers are responding to the system in a positive manner that may ultimately lead to fewer wildlife-vehicle collisions and/or collisions with lower severity.

The Governors Highway Safety Association (2005) found drivers apparently believe posted speed limits can be exceeded by 8 kmh to 16 kmh with impunity. If the Wildlife Hazard Warning System® could be shown to reduce vehicle speeds to at least conform with posted speed limits, then the system would have traffic safety benefits with respect to wildlife-vehicle collisions. On highways where the posted speed limit is 100 kmh, and where the average vehicle travels at 110 kmh during times when wildlife hazards are greatest, a 10 kmh reduction in vehicle speed would be a suitable effect size.

Sample size estimation is an important issue for researchers (McCrum-Gardner, 2010). Power increases with sample size as it is easier to detect a large effect than it is to detect a small effect (Hallahan and Rosenthal, 1996). It is also easier to detect an effect with more observations than it is to detect an effect with fewer observations. An adequate sample size can be calculated using one of a number of power analysis calculators available free for use on the Internet (McDonald, 2014). By maximizing power, a researcher minimizes the probability they will make a Type II error (Hallahan and Rosenthal, 1996).

There are a number of power analysis calculators available free for use on the Internet (McDonald, 2014). Using the power analysis calculator provided by AI-Therapy ([www.ai-therapy.com](http://www.ai-therapy.com)), I calculated the sample sizes required to compare vehicle speed means from two samples using a one-tailed significance level.

My power analysis assumptions were:

1. A base vehicle speed of 110 kmh,
2. An effect size ranging from 1 kmh to 10 kmh reductions in vehicle speed,
3. A standard deviation of 10 kmh for all vehicle speed reductions,
4. A Type I error ( $\alpha$ ) of 0.05, and
5. A Type II error ( $\beta$ ) of 0.80

The standard deviation of 10 kmh used is a conceptually simple value for analyses that falls within the 8 kmh and 16 kmh range of standard deviations for vehicle speeds observed by earlier researchers (Kyte et al., 2000; Mannering, 2006; and Young, 2013). An initial base speed of 110 kmh was selected to represent vehicle speeds on a hypothetical highway with a posted 100 kmh speed limit where the average vehicle speed is 110 kmh. This scenario is consistent with the general public perception that speeds 8 kmh to 16 kmh above posted speed limits are not subject to citation by law enforcement agencies (Governors Highway Safety Association, 2005).

The Type I and Type II error values chosen are values typically used in biological and social science research (Pagano, 1986; Hallahan and Rosenthal, 1996; McDonald, 2014). A one-tailed significance level was chosen because I am trying to detect vehicle speed reductions. The results of the power analysis (Table 6.14) I conducted indicate in order to successfully detect an effect size of 5 kmh reduction in average vehicle speed, a field test would require a sample size of 50 control sites and 50 test sites. By increasing the effect size to a 10 km reduction in average vehicle speed, a sample size of 13 control sites and 13 test sites would be required.

Table 6.14 .Power Analysis Calculated Sample Sizes

Average Vehicle Speed Reduction (kmh)	1	2	3	4	5	6	7	8	9	10
Sample Size Required	1236	309	138	78	50	35	26	20	16	13

If the standard deviation in average vehicle speed observed during the field test is less than the 10 kmh predicted then a smaller sample size would suffice (McDonald, 2014). Any reduction in average vehicle speed during times of elevated wildlife hazard levels should contribute to a reduction in the number of wildlife-vehicle

collisions and/or their severity. However, from a road authority cost-effectiveness perspective, given the implications of vehicle speed on collision severity, I believe vehicle speed reductions in excess of 5 kmh should provide a driver safety benefit, in terms of vehicle damage and human injuries and fatalities, in excess of the investment required for implementing a wildlife hazard warning system.

#### **6.7.4.2 Implications for Traffic Safety Analysis**

From the literature, it appears power analyses are not commonly applied in transportation safety studies. By not considering power when planning a study, a researcher may design the study that has little chance of recognizing an effect that exists where the detection is defined by the  $\alpha$  set by the researcher. A researcher may risk committing both time and resources to research unlikely to reject the null hypothesis at the specified level of significance. In addition, by not considering power when interpreting study results, a researcher terminate the experiment prematurely, thus forfeiting promising research opportunities. This decision is oftentimes a result of mistakenly interpreting a non-significant result to mean that the null hypothesis is true, regardless the sample's ability to detect an existing non-null effect (Hallahan and Rosenthal, 1996). My recommendation then is that a power analysis should be conducted prior to moving forward with a field test of the Wildlife Hazard Warning System.

### **6.8 Discussion**

Using the proposed three-stage testing and evaluation approach on the WildHAZ® system would be costly and time-consuming. To recruit drivers with suitable profiles to participate in the focus groups and driving simulations, researchers would require the support of automobile insurance companies and/or driver licensing agencies. In order to select suitable test subjects, researchers would need access to personal

driving histories or automobile insurance information. For the field testing, the support, cooperation and coordination of road authorities would be required to have WildHAZ® augmented wildlife warning signs and traffic monitoring equipment installed on public roads and highways.

The proposed three-stage approach to the evaluation of the WildHAZ® system would provide researchers, automobile insurance companies and road authorities with the opportunity to control investments in time and money by establishing discrete points where decisions to continue evaluating the WildHAZ® system can be made. The focus groups and driving simulation sessions would be conducted in safe and controlled environments. In complete contrast, the field tests would be vulnerable to the extremes of the natural environment, concurrent trends in other aspects of driver safety, the irrationality of vandals and thieves, and the potential of liability for any wildlife-related collisions occurring in the test corridors. Statistical analysis of the driving simulation and field test data would provide insight into how a range of drivers respond to conventional wildlife warning signs and WildHAZ® enhanced warning signs. It is important to note if the results of analysis indicate implementing the WildHAZ® system produce “statistically significant” changes in driver behaviour, that does not mean the WildHAZ® system would be considered “programmatically significant” or “meaningful” by a road authority (Pullen-Seufert and Hall, 2008).

Driving simulation is not a panacea since drivers who are aware of being observed are liable to drive in an overly cautious and unnatural manner (Fisher et al., 2011b). In addition, it is important to appreciate driving simulation studies often do not satisfy road authorities’ criterion for the effectiveness of a traffic control device (Chrysler and Nelson, 2011). Road authorities may not be satisfied the WildHAZ® system made a real difference with regards to changes in driver behaviour. The WildHAZ®

system may be found not to positively influence driver behaviour with regards to vehicle speed at highway locations where wildlife hazards exist.

There are many issues and challenges to be considered with respect to changing driver behaviour (Preusser et al., 2008). People underestimate risks that are supposed to be under their control, thus insulating themselves with “illusory zones of immunity” (Jasanoff, 1998). Since fatal and injury producing vehicle collisions are extremely rare events per kilometre driven, speeding generally has no downside consequences to drivers (Preusser et al., 2008).

## **6.9 Conclusions**

Given the annual cost of wildlife-vehicle collisions in the US exceeds \$1US Billion, the potential to reduce wildlife-vehicle collisions by only ten percent could produce a \$100US million a year savings. To date, no studies have evaluated and quantified the effectiveness of conventional wildlife warning signs in increasing driver awareness of wildlife, in reducing driving speeds, or in reducing wildlife-vehicle collisions (Knapp et al., 2003; Hedlund et al., 2004). Investing as little as \$1.5 million, for a thorough evaluation of conventional static wildlife warning signs and the WildHAZ® system, could provide the first critical insight into the effectiveness of traffic safety systems designed to modify driver behaviour to reduce the potential for wildlife-related collisions. This could also result in substantially greater long-term savings for automobile insurance companies and road authorities while reducing human injuries and fatalities.

My simulations of the WildHAZ® system demonstrate if a mean vehicle speed reduction as low as 1 kmh is achieved, the results could be statistically significant. Even a small reduction in the number and/or severity in vehicle collisions could produce considerable social benefits (Council et al., 1980).

Woodham (1991) recommended the effectiveness of wildlife reflectors be investigated in a regional pooled-fund study. To fully test and evaluate the WildHAZ® system, researchers would require the support and cooperation of automobile insurance companies and road authorities. A large-scale effort is necessary to obtain results in a short period of time and to ensure study validity (Woodham, 1991). Researchers would need access to personal automobile insurance information to recruit study subjects, and to have WildHAZ® augmented wildlife warning signs and traffic monitoring equipment installed on public roads and highways.

To distribute the cost of testing and evaluating the WildHAZ® system, funding could be provided by a co-operative partnership of national and state transportation authorities, such as the US Federal Highway Administration (FHWA) and the Association of State Highway and Transportation Officials (ASHTO), and large national automobile insurers, such as State Farm Insurance. These parties have a collective interest in reducing wildlife-vehicle collisions.

## **7.0 DISCUSSION**

### **7.1 The Anticipated Future of the Deer-Vehicle Collision Phenomena**

I believe no state government in the United States (US) would knowingly and/or intentionally create a situation where its citizens would be put at unnecessary risk. However, from my research, it appears the deer-vehicle collision phenomena in the US can be attributed, in large part, to the state programs developed to reintroduce deer into predator-free areas where deer were found in low numbers or extirpated, and/or established regulated environments to promote the increase in deer populations. The dramatic increase in deer-vehicle in the US in the last three decades was an unforeseen adverse consequence of extremely successful state deer population promotion and protection programs. Although state transportation agencies face the challenge of protecting drivers from the hazard deer pose, these agencies have no mandate to control deer populations as that responsibility falls under the jurisdiction of federal and state natural resource agencies.

If all other environmental conditions remain stable, without an increase in the number of natural predators, an increase in the harvest by hunters, or an outbreak of a fatal disease fatal to deer, deer populations in the US will likely continue to grow until the collective carrying capacity of natural and human-altered environments is reached. Given this scenario, it appears unlikely the deer-vehicle collision phenomena in the US will subside in the immediate future. In the absence of state transportation agency initiatives, such as deer exclusion fencing systems and/or selective speed reductions, and unless steps are taken to manage deer populations by state natural resource agencies, it seems conceivable the number of deer-vehicle collisions in the US will continue to increase.

## **7.2 State Driver Manuals in the United States**

Driver manuals, produced by state motor vehicle licensing administrations and departments of transportation in the US, are the primary reference resource for new drivers. While deer have become an increasingly significant natural hazard for drivers in the US, judging from driver manuals published by state motor vehicle licensing administrations and departments of transportation, new drivers may not be receiving enough information on the fundamentals of the deer problem, and the relationships of the contributing factors and processes. For decades, the majority of driver manuals have lacked significant factual information about the physical characteristics deer and their geographic distribution and seasonal activities. The consequences of deer-vehicle collisions are not portrayed in any detail as even the potential for serious injuries and death is rarely mentioned. In many states, new drivers are not receiving even rudimentary information on how to deal with the potential hazard deer pose to them. It is apparent, new drivers are not being uniformly informed of the risk of deer hazards, of effective strategies for avoiding deer, and of ways in which the consequences of deer-vehicle collisions can be minimized.

## **7.3 Obstacles to the Implementation of the WildHAZ® System**

I developed the WildHAZ® system and proposed it be used by state transportation agencies in the US. The WildHAZ® system was designed to reduce the occurrence of deer-vehicle collisions and their severity by modifying driver behaviour. By providing drivers with a measure of the risk hazard potential posed by deer at any given time, drivers would be able to make decisions on which collision avoidance measure to take (i.e. reduce speed, scan rights-of-way, use high beams, etc.). The system's use of a risk matrix to manage a colour-coded risk hazard warning sign system represents a dramatic improvement over conventional static deer crossing signs used by state transportation agencies. While the results of my survey suggest the WildHAZ system may have the potential to reduce the incidence and/or severity

of wildlife-related motor vehicle collisions, implementing a paradigm shifting innovation like the WildHAZ® system would not be a simple task. Given the financial and operational obstacles to its testing, use and wholesale adoption, I can not move the WildHAZ® system forward at this time, without both the acceptance of the WildHAZ® system concept by state transportation agencies, and, in some cases, support for the system through the actions of other state agencies.

The two primary obstacles to the successful testing, use and wholesale adoption of the WildHAZ® system by US states are:

1. The acceptance of a new concept of a dynamic, risk matrix-based, hazard rating system for wildlife by federal and state transportation agencies.
2. The timely collection and analysis of accurate and complete, geographically referenced, wildlife-vehicle collision data by state transportation agencies, law enforcement agencies and/or natural resource agencies.

#### **7.4.1 Acceptance of a new driving hazard communication concept**

The design and operation of roads and highways of the US is closely regulated by federal and state governments, and government actions are traditionally supported by transportation industry associations and professional transportation engineering associations. Great collective effort is made to develop and maintain safe road environments for all road users. Modifications to this environment are not made without great consideration, deliberation and thorough evaluation. As evidenced by the evolution of the deer warning sign from a word sign to a symbol sign starting in the early 1960's and culminating in early 1970's, adoption of new communication concepts and equipment by the state transportation agencies can be a slow and methodical process.

The WildHAZ® system represents a paradigm shift with regards to moving beyond the use of static deer crossing signs by transportation agencies in the US. Although dynamic traffic control devices are becoming more commonly used by these agencies, WildHAZ® represents an advancement which will require both bureaucratic acceptance and operational support. Consideration of the WildHAZ® system for use by any state transportation agency would be subject to considerable scrutiny. In order for the WildHAZ® system to be tested, a strong case would have to be made and substantiated to senior engineering staff and agency executives. Before the WildHAZ® system would be considered for statewide use, a controlled study would most likely be conducted and subject to a thorough review. The WildHAZ® system would be required to pass rigorous field testing to ensure the system could withstand the extremes of the hostile roadside environment and perform consistently.

One of the major challenges of testing the WildHAZ® system would be establishing a statistically-sound measure of success. One might argue a simple one or two year before/after study of the number of deer-vehicle collisions would provide an easy and straightforward approach to measuring the success of the WildHAZ® system. I would argue fluctuations in traffic volumes and composition compounded by temporal and spatial variations in deer populations and weather which occur could compromise the utility of such a study. Even if the WildHAZ® system was effective in reducing the potential for deer-vehicle collisions, ongoing increases in deer populations could complicate testing of the system. An increase in deer-vehicle collisions caused by an expanding deer population could mask the system's actual performance. A study that compared changes in driver behaviour, such as reductions in driving speed, or measured changes in average deer-vehicle collision severity, might provide a better evaluation of the WildHAZ® system.

Before the WildHAZ® system could receive consideration for inclusion in the Manual of Uniform Traffic Control Devices (MUTCD), proof would have to be provided to show the system was effective (ie. contribute to the safety of road users) and compatible with existing federal and state systems of traffic control devices. Careful and methodical scrutiny of the WildHAZ® system by the US Department of Transportation (USDOT), the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO) would precede any consideration of implementing the system.

#### **7.4.2 Comprehensive deer-vehicle collision data collection**

To enable the WildHAZ® system to achieve its anticipated potential, state databases containing temporal and spatial information about deer-vehicle collisions would be required. One of the major operational obstacles to the full and consistent implementation of the WildHAZ® system in all states will be the lack of uniformity in collision reporting. Animal-vehicle collision data is typically collected by transportation agencies, law enforcement agencies and/or natural resource agencies (Huijser et al., 2007). From state to state, the motivation and reporting efforts vary tremendously due to difference in their mandates. Consequently, there are considerable discrepancies between the types and quality of the information collected by these agencies.

Huijser et al., (2007) found the perceived lack of a demonstrated need; underreporting and poor data quality; and, delays in data entry represented the main obstacles to these agencies for implementing or improving animal-vehicle collision data collection and analysis. Standardizing reporting procedures, global positioning system (GPS) technology, faster data entry, centralized databases, and geographic information systems (GIS) were identified as ways to improve the data collection and data analyses process. Delucia and Scopatz (2005) found the use of GPS to locate vehicle

collision locations is increasing in most US states. The lack of a consistent nationwide methodology for deer-vehicle collision reporting, however, would preclude a nationally uniform implementation of the WildHAZ® system. Adoption of the WildHAZ® system would definitely demonstrate a real need for consistent, systematic deer-vehicle collision data collection. However, until the reporting situation was remedied, use of the WildHAZ® system by US states could be initiated using the best deer-vehicle collision data currently available. The information value of the WildHAZ® system for drivers could be increased as deer-vehicle collision reporting is improved.

## **8.0 CONCLUSIONS AND FUTURE RESEARCH**

*“A program that makes only a one percent difference overall may very well be quite a good safety bargain.”* (Council et al., 1980, p.28)

### **8.1 Conclusions**

I anticipate deer will continue to represent a significant hazard to drivers in many states throughout the United States (US). Efforts of state natural resource agencies to protect deer and foster deer population growth lead to the continued increase in deer populations. Consequently, the potential for deer-vehicle collisions should will to increase throughout the US. In the absence of effective deer population control, by natural or human-influenced factors, the long-term deer-vehicle collision situation in the US does not appear promising.

While deer have become an increasingly significant natural hazard for drivers in the US, judging from the content of driver manuals published by state motor vehicle licensing administrations and departments of transportation, new drivers may not be receiving enough information on the fundamentals of the deer problem, and the relationships of the contributing factors and processes. It is apparent new drivers are not being uniformly informed of the risk of deer hazards or of effective strategies for avoiding deer-vehicle collisions or minimizing their consequences. The majority of driver manuals produced by state driver licensing agencies and departments of transportation in the US have lack significant factual information about the physical characteristics deer, their geographic distribution and their seasonal activities.

Although thousands of people are killed or injured in deer-vehicle collisions each year, the consequences of deer-vehicle collisions are not portrayed in any detail as even the potential for serious injuries and death is rarely mentioned. Most driver

manuals do not provide strategies for anticipating deer hazards and avoiding them, or reducing the consequences of collisions with deer. This situation is compounded by the ongoing use of static deer crossing warning signs by state and local road authorities. Although the deer hazard varies both spatially and temporally, conventional static deer crossing warning signs do not provide drivers with the dynamic spatial and temporal context of the deer hazard severity.

The findings of this dissertation suggest the deer-vehicle collision situation in the US can be remedied by: (1) better driver education; (2) improved state driver manuals; and (3) the implementation of a wildlife hazard rating system. Many state driver manuals could be improved by the inclusion of more factual information about deer and the hazard they represent to drivers. State driver manuals could also provide drivers with strategies for anticipating deer hazards and avoiding them, or reducing the consequences of collisions with deer. The results of my survey of US and Canadian drivers suggest the Wildlife Hazard Rating System® (WildHAZ®) I developed may have the potential to reduce the potential of wildlife-related motor vehicle collisions and/or the severity of such collisions. The survey results also suggest the majority of drivers would like a system like WildHAZ® to provide them with information about the changing risk level of wildlife hazards for drivers.

The WildHAZ® system offers state and local road authorities in the US a relatively simple approach for providing drivers with timely information on the seasonal potential severity of the deer hazard. WildHAZ® uses a simple, colour-coded hazard rating system that parallels the existing forest fire danger rating system used for decades in the US to warn the public of changing forest fire potential. Although WildHAZ® represents a paradigm shift in the way road authorities communicate the potential of the deer hazard to drivers, WildHAZ® offers a conceptually simple approach to augmenting the existing conventional, static deer crossing hazard signs installed across the US.

Given the growing magnitude of deer-vehicle collisions in the US, and the cost of these collisions in terms of property damage, human injuries and human deaths, it may be prudent for those responsible for producing state driver manuals to include more factual information about the risk deer pose on roads and highways, and present the information in a manner that communicates the deer hazard to drivers more completely. The implementation of the WildHAZ® system by state and local road authorities could provide drivers in the US with greater awareness of the spatially and temporally changing deer hazard potential and possibly encourage drivers to modify their driving behavior to reduce their potential for deer-vehicle collisions.

## **8.2 Future Research**

I do not expect the deer hazard for drivers in the US will subside in the near future. However, I believe there are many opportunities to help drivers avoid the consequences of the deer hazard. While state driver manuals are static documents, the potential of smart phone apps utilizing citizen science presents the opportunity for providing drivers with an interactive platform for learning about the deer hazard. YouTube videos showing deer and the hazard these animals pose for drivers could be integrated into the apps.

Using state agency collected deer-vehicle collision data or deer population data to populate risk matrices, the WildHAZ® system could be integrated into Google Maps to display the deer hazards potential along roads and highways in the US. The WildHAZ® system symbols could be incorporated into motor vehicle dashboards so drivers could be advised of the changing deer hazard potential as they drive from one area to another. Where wildlife detection systems are installed, the WildHAZ® system could be integrated into corridor deer warning signage so drivers could be advised of changing deer hazard potential as they drive along a corridor. Self-driving motor vehicles could be programmed to modify driving speeds based on the

WildHAZ® system parameters, so where the deer hazard potential is greatest vehicle speeds could be reduced accordingly.

Use of the WildHAZ® concept for reducing wildlife-vehicle collisions is only the first possible application of the WildHAZ® colour code and risk matrix-based concept for warning drivers of spatially and temporally changing driving hazards. If applied in a conscientious manner, I believe the WildHAZ® concept has the potential to reduce the number and severity of vehicle collisions resulting from spatially and temporally dynamic driving hazards that occur each year.

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## **10.0 APPENDICES**

**Appendix A**

**Canadian Version of Wildlife Hazard Warning System® Survey**

## Wildlife Hazard Warning System Survey 2016

### Introduction

You are invited to participate in a study entitled the "Wildlife Hazard Warning System Survey" that is being conducted by Leonard Sielecki using FluidSurveys web-based services. Leonard Sielecki is a graduate student in the Department of Geography at the University of Victoria and you may contact him by email at [lsieleck@uvic.ca](mailto:lsieleck@uvic.ca) if you have further questions regarding this survey. As a graduate student, I am required to conduct research as part of the requirements for a Ph.D. degree in Geography. This survey is being conducted under the supervision of Dr. Dan Smith. You may contact my supervisor by email at [smith@uvic.ca](mailto:smith@uvic.ca).

### Purpose and Objectives

The purpose of this research project is collect opinions from drivers in Canada and the United States regarding the new wildlife hazard warning system. The system is intended to increase the amount of information drivers are provided regarding wildlife hazard levels from location to location along roads and highways throughout the year. The objectives of the survey are to determine if drivers understand the new wildlife hazard warning system; to determine how drivers will respond to the system; and to determine if drivers think the system has potential for advising drivers of wildlife hazard levels.

### Importance of this Research

Research of this type is important because over one million wildlife-vehicle collisions occur each year in Canada and the United States. Hundred of motor vehicle occupants are killed and thousands of motor vehicle occupants are seriously injured in these accidents. The total cost of

wildlife-vehicle accidents is estimated to exceed one billion dollars annually. If the new wildlife hazard warning system is found to have potential for reducing wildlife-vehicle collisions, the system may eventually be considered as a potential tool for road authorities, such as provincial and state departments of transportation, in their efforts to reduce the number of wildlife-vehicle collisions that occur on roads and highways throughout Canada and the United States each year.

### Participants Selection

To ensure the survey collects the opinions of as wide a range of drivers as possible, participants will be recruited from a wide range of backgrounds. You are being asked to participate in this study because you are a friend, colleague or acquaintance of Leonard Sielecki.

### What is involved

If you consent to voluntarily participate in this research, your participation will include answering multiple choice questions and providing written answers to 20 survey questions.

### Inconvenience

Participation in this study may cause some inconvenience to you, including taking up 5 to 7 minutes of your time.

### Risks

There are no known or anticipated risks to you by participating in this research.

### Benefits

The potential benefits of your participation in this research include the potential for future reduction of human injuries and fatalities caused by wildlife-vehicle collisions occurring on roads and highways throughout the Canada and the United States.

### Voluntary Participation

Your participation in this research must be completely voluntary. If you do decide to participate, you may withdraw at any time during the survey without any consequences or any explanation.

### Researcher's Relationship with Participants

Potential participants as the participants are persons known to the researcher as colleagues, friends or acquaintances. To help prevent this relationship from influencing your decision to participate, the following steps to prevent coercion have been taken so all surveys will be anonymous and participants are requested not to include any identifying details in their responses to survey questions.

### Anonymity

In terms of protecting your anonymity, no personal information that can be used to identify you will be requested or collected, and you are advised not to include any details in your responses to the survey questions that could be used to identify you.

### Confidentiality

This web-based survey uses a University of Victoria version of FluidSurveys, which stores data in Canada. Only Leonard Sielecki will have access to the raw survey data. All survey

data handled by Leonard Sielecki will be stored in password protected files.

### Dissemination of Results

It is anticipated the results of this study will be shared with others in the following ways: on websites; on television programs; in newspaper and magazines; in published academic and trade articles; my dissertation; my dissertation defense presentation; my class presentations; and my presentations at scholarly meetings, workshops and conferences.

### Commercial Use of Results

This research may lead to a commercial product or service. The nature of this commercial use is production of hardware and software systems that can facilitate the implementation of the new wildlife hazard warning system on roads and highways in Canada and the United States.

### Disposal of Data

Data from this study will be disposed of by December 31, 2018. By December 31, 2018, Leonard Sielecki will have completed all analysis of the data collected during this study. At that time, all electronic data will be erased and all paper records will be shredded.

### Contacts

Individuals that may be contacted regarding this study include the principal researcher, Leonard Sielecki at the Department of Geography at the University of Victoria at lsieleck@uvic.ca, or his supervisor, Dr. Dan Smith at the Department of Geography at the University of Victoria at smith@uvic.ca. In addition, you may verify the ethical approval of this study, or raise any concerns you might

have, by contacting the Human Research Ethics Board at the University of Victoria (250-472-4545 or [ethics@uvic.ca](mailto:ethics@uvic.ca)).

## Participant Consent

By completing and submitting the questionnaire, YOUR FREE AND INFORMED CONSENT IS IMPLIED and indicates that you understand the above conditions of participation in this study and that you have had the opportunity to have your questions answered by the researchers. Please retain a copy of this letter for your reference.

## SURVEY QUESTIONS

Question 1: Do you have a drivers licence?

- Yes
- No

Question 2: How long have you had a drivers license?

- Less than 1 year
- 1 to 5 years
- 5 to 10 years
- 10 to 20 years
- 20 to 40 years
- More than 40 years

Question 3: What kind of driving do you do? (Please check all options that apply to you)

- For pleasure
- To and from work
- To and from school
- For work

Question 4: What province or territory do you live in?  
(please select one)

- British Columbia
- Alberta
- Saskatchewan
- Manitoba
- Ontario
- Quebec
- Nova Scotia
- New Brunswick
- Prince Edward Island
- Newfoundland and Labrador
- Yukon
- Northwest Territories
- Nunavut
- Other

Question 5: Where do you live?

- Rural area (acreage, farm, etc.)
- Small population centre (population between 1,000 and 29,999)
- Medium population centre (population between 30,000 and 99,999)
- Large urban population centre (population of 100,000 or more)

Question 6: What is your gender?

- Male
- Female
- Other

Question 7: What is your age?

- 19 years and under
- 20 - 24 years
- 25 - 29 years
- 30 - 34 years
- 35 - 39 years
- 40 - 44 years
- 45 - 49 years
- 50 - 54 years
- 55 - 59 years
- 60 - 64 years
- 65 - 69 years
- 70 - 74 years
- 75+ years

Question 8: How far do you usually drive each day?

- Less than 8 km
- Between 8 km and 16 km
- Between 16 km and 40 km
- Between 40 km and 80 km
- Between 80 and 160 km
- Between 160 and 400 km
- Over 400 km
- Don't know

Question 9: What kind of wildlife warning sign is this?



- Bear crossing
- Deer crossing
- Moose crossing
- Don't know

Question 10: Have you ever seen a deer on or near a road or highway?



- Yes
- No

Question 11: Have you ever had an accident with a deer on a road or highway?



- Yes
- No

Question 12: Using the deer crossing sign as your ONLY reference, which driving situation shown in the pictures below has the greatest potential deer hazard for drivers?



Picture 1



Picture 2

- Picture 1
- Picture 2
- Can not tell from the deer crossing signs

The Wildlife Hazard Warning System (shown below) was developed to help drivers know how deer hazard levels change from location to location along roads and highways throughout the year. The system uses colour codes to differentiate wildlife hazard levels. The colour codes range from "Green" for "Low" hazard levels to "Red" for "Extreme" hazard levels.

# Wildlife Hazard Warning System™



The colour codes range from "Green" for "Low" hazard levels to "Red" for "Extreme" hazard levels. The green and red coloured borders have white dashes to make the system suitable for persons who are red/green colour blind.

The colour codes are selected using wildlife-vehicle accidents data collected by police departments, natural resource agencies, and road maintenance staff. The colour code system is similar to the one used by forest fire agencies to advise the public of forest fire danger. Examples of fire danger rating signs are shown below.

Examples of fire danger rating signs

Question 13: Using the Wildlife Hazard Warning System as your only guide, which driving situation shown in the pictures below do you think has the LOWER deer hazard level?



Picture 1



Picture 2

- Picture 1
- Picture 2
- Don't know

Question 14: Using the Wildlife Hazard Warning System as your only guide, which driving situation shown in the pictures below do you think has the HIGHER deer hazard level?



Picture 1



Picture 2

- Picture 1
- Picture 2
- Don't know

Question 15: If you are driving down an unfamiliar road or highway, in another province or territory, would the Wildlife Hazard Warning System help you know how severe the deer hazard is?





- Yes
- No
- Don't know

Question 16: Knowing the Wildlife Hazard Warning System is being used to warn drivers of deer hazard levels, if you are driving down an unfamiliar road or highway and saw this LOW deer hazard warning sign, what would you do?



- Slow down

- Watch for deer
- Slow down and watch for deer
- Speed up
- Speed up and watch for deer
- Keep driving the same speed
- Keep driving the same speed and watch for deer

Question 17: Knowing the Wildlife Hazard Warning System is being used to warn drivers of deer hazard levels, if you are driving down an unfamiliar road or highway and saw this EXTREME deer hazard warning sign, what would you do?



- Slow down
- Watch for deer
- Slow down and watch for deer
- Speed up
- Speed up and watch for deer
- Keep driving the same speed
- Keep driving the same speed and watch for deer

Question 18: Knowing the Wildlife Hazard Warning System is being used to warn drivers of deer hazard levels, if you

are driving down an unfamiliar road or highway and saw this HIGH deer hazard warning sign, what would you do?



- Slow down
- Watch for deer
- Slow down and watch for deer
- Speed up
- Speed up and watch for deer
- Keep driving the same speed
- Keep driving the same speed and watch for deer

Question 19: Would you like to see a system like the Wildlife Hazard Warning System used on roads in your province or territory to warn drivers of deer hazard levels?

## Wildlife Hazard Warning System™



Low

Medium

High

Very High

Extreme

- Yes
- No
- Don't know

Question 20: Do you have any comments or suggestions you'd like to give about the Wildlife Hazard Warning System?

## Wildlife Hazard Warning System™



Low



Medium



High



Very High



Extreme

Thank you for participating in the survey. Your time and contributions are greatly appreciated.

**Appendix B**

**United States Version of Wildlife Hazard Warning System® Survey**

## Wildlife Hazard Warning System Survey (USA)

### Introduction

You are invited to participate in a study entitled the "Wildlife Hazard Warning System Survey" that is being conducted by Leonard Sielecki using FluidSurveys web-based services. Leonard Sielecki is a graduate student in the Department of Geography at the University of Victoria and you may contact him by email at [lsieleck@uvic.ca](mailto:lsieleck@uvic.ca) if you have further questions regarding this survey. As a graduate student, I am required to conduct research as part of the requirements for a Ph.D. degree in Geography. This survey is being conducted under the supervision of Dr. Dan Smith. You may contact my supervisor by email at [smith@uvic.ca](mailto:smith@uvic.ca).

### Purpose and Objectives

The purpose of this research project is collect opinions from drivers in Canada and the United States regarding the new wildlife hazard warning system. The system is intended to increase the amount of information drivers are provided regarding wildlife hazard levels from location to location along roads and highways throughout the year. The objectives of the survey are to determine if drivers understand the new wildlife hazard warning system; to determine how drivers will respond to the system; and to determine if drivers think the system has potential for advising drivers of wildlife hazard levels.

### Importance of this Research

Research of this type is important because over one million wildlife-vehicle collisions occur each year in Canada and the United States. Hundred of motor vehicle occupants are killed and thousands of motor vehicle occupants are seriously injured in these accidents. The total cost of

wildlife-vehicle accidents is estimated to exceed one billion dollars annually. If the new wildlife hazard warning system is found to have potential for reducing wildlife-vehicle collisions, the system may eventually be considered as a potential tool for road authorities, such as provincial and state departments of transportation, in their efforts to reduce the number of wildlife-vehicle collisions that occur on roads and highways throughout Canada and the United States each year.

### Participants Selection

To ensure the survey collects the opinions of as wide a range of drivers as possible, participants will be recruited from a wide range of backgrounds. You are being asked to participate in this study because you are a friend, colleague or acquaintance of Leonard Sielecki.

### What is involved

If you consent to voluntarily participate in this research, your participation will include answering multiple choice questions and providing written answers to 20 survey questions.

### Inconvenience

Participation in this study may cause some inconvenience to you, including taking up 5 to 7 minutes of your time.

### Risks

There are no known or anticipated risks to you by participating in this research.

### Benefits

The potential benefits of your participation in this research include the potential for future reduction of human injuries and fatalities caused by wildlife-vehicle collisions occurring on roads and highways throughout the Canada and the United States.

### Voluntary Participation

Your participation in this research must be completely voluntary. If you do decide to participate, you may withdraw at any time during the survey without any consequences or any explanation.

### Researcher's Relationship with Participants

Potential participants as the participants are persons known to the researcher as colleagues, friends or acquaintances. To help prevent this relationship from influencing your decision to participate, the following steps to prevent coercion have been taken so all surveys will be anonymous and participants are requested not to include any identifying details in their responses to survey questions.

### Anonymity

In terms of protecting your anonymity, no personal information that can be used to identify you will be requested or collected, and you are advised not to include any details in your responses to the survey questions that could be used to identify you.

### Confidentiality

This web-based survey uses a University of Victoria version of FluidSurveys, which stores data in Canada. Only Leonard Sielecki will have access to the raw survey data. All survey data handled by Leonard Sielecki will be stored in password

protected files contained in password protected desktop and laptop computers.

### Dissemination of Results

It is anticipated the results of this study will be shared with others in the following ways: on websites; on television programs; in newspaper and magazines; in published academic and trade articles; my dissertation; my dissertation defense presentation; my class presentations; and my presentations at scholarly meetings, workshops and conferences.

### Commercial Use of Results

This research may lead to a commercial product or service. The nature of this commercial use is production of hardware and software systems that can facilitate the implementation of the new wildlife hazard warning system on roads and highways in Canada and the United States.

### Disposal of Data

Data from this study will be disposed of by December 31, 2018. By December 31, 2018, Leonard Sielecki will have completed all analysis of the data collected during this study. At that time, all electronic data will be erased and all paper records will be shredded.

### Contacts

Individuals that may be contacted regarding this study include the principal researcher, Leonard Sielecki at the Department of Geography at the University of Victoria at lsieleck@uvic.ca, or his supervisor, Dr. Dan Smith at the Department of Geography at the University of Victoria at smith@uvic.ca. In addition, you may verify the ethical

approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Board at the University of Victoria (250-472-4545 or [ethics@uvic.ca](mailto:ethics@uvic.ca)).

### Participant Consent

By completing and submitting the questionnaire, YOUR FREE AND INFORMED CONSENT IS IMPLIED and indicates that you understand the above conditions of participation in this study and that you have had the opportunity to have your questions answered by the researchers. Please retain a copy of this letter for your reference.

### SURVEY QUESTIONS

Question 1: Do you have a drivers licence?

- Yes
- No

Question 2: How long have you had a drivers license?

- Less than 1 year
- 1 to 5 years
- 5 to 10 years
- 10 to 20 years
- 20 to 40 years
- More than 40 years

Question 3: What kind of driving do you do? (Please check all options that apply to you)

- For pleasure
- To and from work
- To and from school
- For work

Question 4: What state or territory do you live in? (please select one)

- Alabama
- Alaska
- Arizona
- Arkansas
- California
- Colorado
- Connecticut
- Delaware
- District of Columbia
- Florida
- Georgia
- Hawaii
- Idaho
- Illinois
- Indiana
- Iowa
- Kansas
- Kentucky
- Louisiana
- Maine
- Maryland
- Massachusetts
- Michigan
- Minnesota
- Mississippi
- Missouri
- Montana
- Nebraska

- Nevada
- New Hampshire
- New Jersey
- New Mexico
- New York
- North Carolina
- North Dakota
- Ohio
- Oklahoma
- Oregon
- Pennsylvania
- Rhode Island
- South Carolina
- South Dakota
- Tennessee
- Texas
- Utah
- Vermont
- Virginia
- Washington
- West Virginia
- Wisconsin
- Wyoming
- Other, please specify...

Question 5: Where do you live?

- Rural area (acreage, farm, etc.)
- Small population centre (population between 1,000 and 29,999)

- Medium population centre (population between 30,000 and 99,999)
- Large urban population centre (population of 100,000 or more)

Question 6: What is your gender?

- Male
- Female
- Other

Question 7: What is your age?

- 19 years and under
- 20 - 24 years
- 25 - 29 years
- 30 - 34 years
- 35 - 39 years
- 40 - 44 years
- 45 - 49 years
- 50 - 54 years
- 55 - 59 years
- 60 - 64 years
- 65 - 69 years
- 70 - 74 years
- 75+ years

Question 8: How far do you usually drive each day?

- Less than 5 miles
- Between 5 and 10 miles
- Between 10 and 25 miles
- Between 25 and 50 miles
- Between 50 and 100 miles

- Between 100 and 250 miles
- Over 250 miles
- Don't know

Question 9: What kind of wildlife warning sign is this?



- Bear crossing
- Deer crossing
- Moose crossing
- Don't know

Question 10: Have you ever seen a deer on or near a road or highway?



- Yes
- No

Question 11: Have you ever had an accident with a deer on a road or highway?



- Yes
- No

Question 12: Using the deer crossing sign as your ONLY reference, which driving situation shown in the pictures below has the greatest potential deer hazard for drivers?



Picture 1

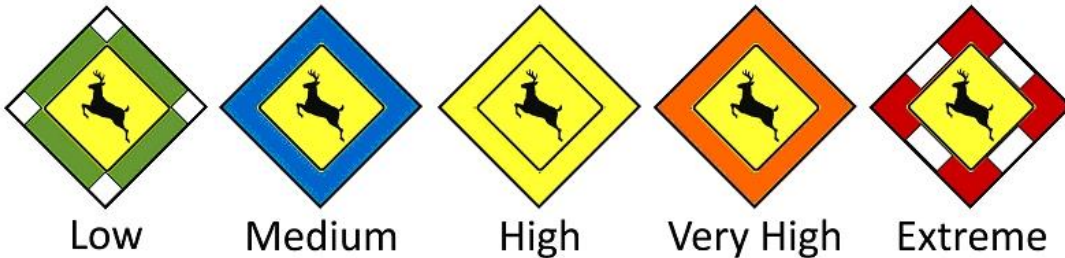


Picture 2

- Picture 1
- Picture 2
- Can not tell from the deer crossing signs

The Wildlife Hazard Warning System (shown below) was developed to help drivers know how deer hazard levels change from location to location along roads and highways throughout the year. The system uses colour codes to differentiate wildlife hazard levels. The colour codes range from "Green" for "Low" hazard levels to "Red" for "Extreme" hazard levels.

## Wildlife Hazard Warning System™





The colour codes range from "Green" for "Low" hazard levels to "Red" for "Extreme" hazard levels. The green and red coloured borders have white dashes to make the system suitable for persons who are red/green colour blind.

The colour codes are selected using wildlife-vehicle accidents data collected by police departments, natural resource agencies, and road maintenance staff. The colour code system is similar to the one used by forest fire agencies to advise the public of forest fire danger. Examples of fire danger rating signs are shown below.

Examples of fire danger rating signs



USA Example



Canadian Example

Question 13: Using the Wildlife Hazard Warning System as your only guide, which driving situation shown in the pictures below do you think has the LOWER deer hazard level?



Picture 1



Picture 2

- Picture 1
- Picture 2
- Don't know

Question 14: Using the Wildlife Hazard Warning System as your only guide, which driving situation shown in the pictures below do you think has the HIGHER hazard level?



Picture 1



Picture 2

- Picture 1
- Picture 2
- Don't know

Question 15: If you are driving down an unfamiliar road or highway, in another state or territory, would the Wildlife Hazard Warning System help you know how severe the deer hazard is?



- Yes
- No
- Don't know

Question 16: Knowing the Wildlife Hazard Warning System is being used to warn drivers of deer hazard levels, if you are driving down an unfamiliar road or highway and saw this LOW deer hazard warning sign, what would you do?



- Slow down
- Watch for deer
- Slow down and watch for deer
- Speed up
- Speed up and watch for deer
- Keep driving the same speed
- Keep driving the same speed and watch for deer

Question 17: Knowing the Wildlife Hazard Warning System is being used to warn drivers of deer hazard levels, if you are driving down an unfamiliar road or highway and saw this EXTREME deer hazard warning sign, what would you do?



- Slow down
- Watch for deer
- Slow down and watch for deer
- Speed up
- Speed up and watch for deer
- Keep driving the same speed
- Keep driving the same speed and watch for deer

Question 18: Knowing the Wildlife Hazard Warning System is being used to warn drivers of deer hazard levels, if you are driving down an unfamiliar road or highway and saw this HIGH deer hazard warning sign, what would you do?



- Slow down
- Watch for deer
- Slow down and watch for deer
- Speed up
- Speed up and watch for deer
- Keep driving the same speed
- Keep driving the same speed and watch for deer

Question 19: Would you like to see a system like the Wildlife Hazard Warning System used on roads in your state or territory to warn drivers of deer hazard levels?

## Wildlife Hazard Warning System™



Low



Medium



High



Very High



Extreme

- Yes
- No
- Don't know

Question 20: Do you have any comments or suggestions you'd like to give about the Wildlife Hazard Warning System?

## Wildlife Hazard Warning System™



Low



Medium



High



Very High



Extreme

END OF SURVEY

Thank you for participating in the survey. Your time and contributions are greatly appreciated.

**Appendix C**

**Wildlife Hazard Warning System® Survey Participant Recruitment Email Texts**

**Wildlife Hazard Warning System® Survey**  
**Email Script for Friends, Colleagues and Acquaintances**

Hello:

As part of my Ph.D. program at the University of Victoria, I am conducting a web-based survey on the opinions of driver on a wildlife hazard warning system that was developed at the university.

The system was developed to give drivers more information about wildlife hazards on roads and highways. The system is designed to let drivers know how wildlife hazards change from place to place, during different times of the year on roads and highways.

The survey is an anonymous survey so no personal information, like your name, your address, or any other identifying information is requested or will be recorded. The survey takes about 5 to 7 minutes to complete. **All participants will need to read an online consent form before they start the survey.**

The survey is completely voluntary so please do not feel any obligation to do the survey.

If during the survey you don't want to complete the survey, you are under no obligation to do so. If you don't want to complete the survey, just close your email browser.

If you, have a drivers licence and are 19 years of age or older, and are interested in participating in the survey, the link for the survey is below:

(FLUIDSURVEY LINK)

Your participation in this survey is greatly appreciated. If you think your friends, colleagues and acquaintances might be interested in participating in this survey, please feel free to forward this email to them. The more participants that I have in this survey, the more valid the results of the survey will be. I would like to get as many participants for my survey as possible.

Thank you.

Leonard

Leonard Sielecki  
Department of Geography  
University of Victoria

**Wildlife Hazard Warning System® Survey**  
**Email Script for Snowballing Component of Survey (Canadian Version)**

Hello:

My name is Leonard Sielecki. I am a graduate student at the University of Victoria.

As part of my program at the University of Victoria, I am conducting a web-based survey on the opinions of driver on a wildlife hazard warning system that was developed at the university.

I am contacting people across Canada who have publicly available contact information.

The system was developed to give drivers in Canada more information about wildlife hazards on roads and highways. The system is designed to let drivers know how wildlife hazards change from place to place, during different times of the year on roads and highways.

The survey is an anonymous survey so no personal information, like your name, your address, or any other identifying information is requested or will be recorded. The survey takes about 5 to 7 minutes to complete. **All participants will need to read an online consent form before they start the survey.**

You are not under any obligation to complete the survey. So, if during the survey, you want to stop doing the survey, just close the window of your Internet browser.

If you, have a drivers licence and are 19 years of age or older, and are interested in participating in the survey, the link for the survey is below:

(FLUIDSURVEY LINK)

Your participation in this survey is greatly appreciated. If you think your friends, colleagues and acquaintances might be interested in participating in this survey, please feel free to forward this email to them. The more participants that I have in this survey, the more valid the results of the survey will be. I would like to get as many participants for my survey as possible.

Thank you.

Leonard  
Leonard Sielecki  
Department of Geography  
University of Victoria

**Wildlife Hazard Warning System® Survey**  
**Email Script for Snowballing Component of Survey (United States Version)**

Hello:

My name is Leonard Sielecki. I am a graduate student at the University of Victoria.

As part of my program at the University of Victoria, I am conducting a web-based survey on the opinions of driver on a wildlife hazard warning system that was developed at the university.

I am contacting people across the United States who have publicly available contact information.

The system was developed to give drivers in the United States more information about wildlife hazards on roads and highways. The system is designed to let drivers know how wildlife hazards change from place to place, during different times of the year on roads and highways.

The survey is an anonymous survey so no personal information, like your name, your address, or any other identifying information is requested or will be recorded. The survey takes about 5 to 7 minutes to complete. **All participants will need to read an online consent form before they start the survey.**

You are not under any obligation to complete the survey. So, if during the survey, you want to stop doing the survey, just close the window of your Internet browser.

If you, have a drivers licence and are 19 years of age or older, and are interested in participating in the survey, the link for the survey is below:

(FLUIDSURVEY LINK)

Your participation in this survey is greatly appreciated. If you think your friends, colleagues and acquaintances might be interested in participating in this survey, please feel free to forward this email to them. The more participants that I have in this survey, the more valid the results of the survey will be. I would like to get as many participants for my survey as possible.

Thank you.

Leonard  
Leonard Sielecki  
Department of Geography  
University of Victoria

**Appendix D**

**Wildlife Hazard Warning System® Survey Participant Consent Forms**

**Canadian Survey Participant Consent Form**



**University  
of Victoria**

## *Participant Consent Form*

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### **Wildlife Hazard Warning System Survey**

You are invited to participate in a study entitled the “**Wildlife Hazard Warning System Survey**” that is being conducted by Leonard Sielecki using FluidSurveys web-based services.

Leonard Sielecki is a graduate student in the Department of Geography at the University of Victoria and you may contact him by email at [lsieleck@uvic.ca](mailto:lsieleck@uvic.ca) if you have further questions regarding this survey.

As a graduate student, I am required to conduct research as part of the requirements for a Ph.D. degree in Geography. This survey is being conducted under the supervision of Dr. Dan Smith. You may contact my supervisor by email at [smith@uvic.ca](mailto:smith@uvic.ca).

#### **Purpose and Objectives**

The purpose of this research project is collect opinions from drivers in Canada and the United States regarding the new wildlife hazard warning system. The system is intended to increase the amount of information drivers are provided regarding wildlife hazard levels from location to location along roads and highways throughout the year. The objectives of the survey are to determine if drivers understand the new wildlife hazard warning system; to determine how drivers will respond to the system; and to determine if drivers think the system has potential for advising drivers of wildlife hazard levels.

#### **Importance of this Research**

Research of this type is important because over one million wildlife-vehicle collisions occur each year in Canada and the United States. Hundred of motor vehicle occupants are killed and thousands of motor vehicle occupants are seriously injured in these accidents. The total cost of wildlife-vehicle accidents is estimated to exceed one billion dollars annually. If the new wildlife hazard warning system is found to have potential for reducing wildlife-vehicle collisions, the system may eventually be considered as a potential tool for road authorities, such as provincial and state departments of transportation, in their efforts to reduce the number of wildlife-vehicle collisions that occur on roads and highways throughout Canada and the United States each year.

#### **Participants Selection**

To ensure the survey collects the opinions of as wide a range of drivers as possible, participants will be recruited from a wide range of backgrounds. You are being asked to participate in this study because you are a friend, colleague or acquaintance of Leonard Sielecki, or you have been identified, by means of an Internet search of publicly

accessible websites, as someone affiliated with one of the following agencies, associations, companies, institutions, organizations and schools:

Automobile associations,  
Computer software companies,  
Conservation associations,  
Driving schools,  
Education institutes,  
Fish and wildlife associations,  
Government agencies,  
Manufacturing companies,  
Medical and dental offices,  
Veterans organizations,  
Outdoor recreational associations,  
Private insurance companies,  
Public insurance corporations,  
Religious organizations,  
Seniors care facilities,  
Seniors organizations,  
Trucking associations, and  
Trucking companies.

**What is involved**

If you consent to voluntarily participate in this research, your participation will include answering multiple choice questions and providing written answers to 20 survey questions.

**Inconvenience**

Participation in this study may cause some inconvenience to you, including taking up 5 to 7 minutes of your time.

**Risks**

There are no known or anticipated risks to you by participating in this research.

**Benefits**

The potential benefits of your participation in this research include the potential for future reduction of human injuries and fatalities caused by wildlife-vehicle collisions occurring on roads and highways throughout the Canada and the United States.

**Voluntary Participation**

Your participation in this research must be completely voluntary. If you do decide to participate, you may withdraw at any time during the survey without any consequences or any explanation.

**Researcher's Relationship with Participants**

The researcher may have a relationship to potential participants as the participants are persons known to the researcher as colleagues, friends or acquaintances. To help prevent this relationship from influencing your decision to participate, the following steps to prevent coercion have been taken so all surveys will be anonymous and participants are requested not to include any identifying details in their responses to survey questions.

**Anonymity**

In terms of protecting your anonymity, no personal information that can be used to identify you will be requested or collected, and you are advised not to include any details in your responses to the survey questions that could be used to identify you.

**Confidentiality**

Your confidentiality and the confidentiality of the data will be protected by the storage of anonymous survey responses on University of Victoria computer servers located in Victoria, British Columbia, Canada. The University of Victoria computer servers are controlled by the University of Victoria and are subject to University of Victoria regulations pertaining to the storage of confidential data. Only Leonard Sielecki will have access to the raw survey data. The data collected using FluidSurvey services is stored on FluidSurveys servers located in Canada. All data will be hosted in Canada. All information and data collected, used and disclosed in the course of using the FluidSurveys surveys will be treated in the manner set out at <http://fluidsurveys.com/about/privacy> and in SurveyMonkey's main Privacy Policy located at <http://www.surveymonkey.com/mp/policy/privacy-policy>. The FluidSurveys privacy statement describes privacy practices that are specific to FluidSurveys, but it should be read in conjunction with the SurveyMonkey's main Privacy Policy located at <http://www.surveymonkey.com/mp/policy/privacy-policy>.

**Dissemination of Results**

It is anticipated the results of this study will be shared with others in the following ways: on websites; on television programs; in newspaper and magazines; in published academic and trade articles; my dissertation; my dissertation defense presentation; my class presentations; and my presentations at scholarly meetings, workshops and conferences.

**Commercial Use of Results**

This research may lead to a commercial product or service. The nature of this commercial use is production of hardware and software systems that can facilitate the implementation of the new wildlife hazard warning system on roads and highways in Canada and the United States.

**Disposal of Data**

Data from this study will be disposed of upon the completion of my Ph.D. program. At that time, all electronic data will be erased and all paper copies will be shredded.

**Contacts**

Individuals that may be contacted regarding this study include the principal researcher, Leonard Sielecki at the Department of Geography at the University of Victoria at

lsieleck@uvic.ca, or his supervisor, Dr. Dan Smith at the Department of Geography at the University of Victoria at smith@uvic.ca.

In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Board at the University of Victoria (250-472-4545 or ethics@uvic.ca).

By completing and submitting the questionnaire, **YOUR FREE AND INFORMED CONSENT IS IMPLIED** and indicates that you understand the above conditions of participation in this study and that you have had the opportunity to have your questions answered by the researchers.

*Please retain a copy of this letter for your reference.*

**United States Survey Participant Consent Form**



**University  
of Victoria**

## *Participant Consent Form*

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### **Wildlife Hazard Warning System Survey**

You are invited to participate in a study entitled the “**Wildlife Hazard Warning System Survey**” that is being conducted by Leonard Sielecki using FluidSurveys web-based services.

Leonard Sielecki is a graduate student in the Department of Geography at the University of Victoria and you may contact him by email at [lsieleck@uvic.ca](mailto:lsieleck@uvic.ca) if you have further questions regarding this survey.

As a graduate student, I am required to conduct research as part of the requirements for a Ph.D. degree in Geography. This survey is being conducted under the supervision of Dr. Dan Smith. You may contact my supervisor by email at [smith@uvic.ca](mailto:smith@uvic.ca).

#### **Purpose and Objectives**

The purpose of this research project is collect opinions from drivers in the United States regarding the new wildlife hazard warning system. The system is intended to increase the amount of information drivers are provided regarding wildlife hazard levels from location to location along roads and highways throughout the year. The objectives of the survey are to determine if drivers understand the new wildlife hazard warning system; to determine how drivers will respond to the system; and to determine if drivers think the system has potential for advising drivers of wildlife hazard levels.

#### **Importance of this Research**

Research of this type is important because over one million wildlife-vehicle collisions occur each year in the United States. Hundred of motor vehicle occupants are killed and thousands of motor vehicle occupants are seriously injured in these accidents. The total cost of wildlife-vehicle accidents is estimated to exceed one billion dollars annually. If the new wildlife hazard warning system is found to have potential for reducing wildlife-vehicle collisions, the system may eventually be considered as a potential tool for road authorities, such as provincial and state departments of transportation, in their efforts to reduce the number of wildlife-vehicle collisions that occur on roads and highways throughout the United States each year.

#### **Participants Selection**

To ensure the survey collects the opinions of as wide a range of drivers as possible, participants will be recruited from a wide range of backgrounds. You are being asked to participate in this study because you are a friend, colleague or acquaintance of Leonard Sielecki, or you have been identified, by means of an Internet search of publicly

accessible websites, as someone affiliated with one of the following agencies, associations, companies, institutions, organizations and schools:

Automobile associations,  
Computer software companies,  
Conservation associations,  
Driving schools,  
Education institutes,  
Fish and wildlife associations,  
Government agencies,  
Manufacturing companies,  
Medical and dental offices,  
Veterans organizations,  
Outdoor recreational associations,  
Private insurance companies,  
Public insurance corporations,  
Religious organizations,  
Seniors care facilities,  
Seniors organizations,  
Trucking associations, and  
Trucking companies.

**What is involved**

If you consent to voluntarily participate in this research, your participation will include answering multiple choice questions and providing written answers to 20 survey questions.

**Inconvenience**

Participation in this study may cause some inconvenience to you, including taking up 5 to 7 minutes of your time.

**Risks**

There are no known or anticipated risks to you by participating in this research.

**Benefits**

The potential benefits of your participation in this research include the potential for future reduction of human injuries and fatalities caused by wildlife-vehicle collisions occurring on roads and highways throughout the United States.

**Voluntary Participation**

Your participation in this research must be completely voluntary. If you do decide to participate, you may withdraw at any time during the survey without any consequences or any explanation.

**Researcher's Relationship with Participants**

The researcher may have a relationship to potential participants as the participants are persons known to the researcher as colleagues, friends or acquaintances. To help prevent this relationship from influencing your decision to participate, the following steps to prevent coercion have been taken so all surveys will be anonymous and participants are requested not to include any identifying details in their responses to survey questions.

**Anonymity**

In terms of protecting your anonymity, no personal information that can be used to identify you will be requested or collected, and you are advised not to include any details in your responses to the survey questions that could be used to identify you.

**Confidentiality**

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It is anticipated the results of this study will be shared with others in the following ways: on websites; on television programs; in newspaper and magazines; in published academic and trade articles; my dissertation; my dissertation defense presentation; my class presentations; and my presentations at scholarly meetings, workshops and conferences.

**Commercial Use of Results**

This research may lead to a commercial product or service. The nature of this commercial use is production of hardware and software systems that can facilitate the implementation of the new wildlife hazard warning system on roads and highways in the United States.

**Disposal of Data**

Data from this study will be disposed of upon the completion of my Ph.D. program. At that time, all electronic data will be erased and all paper copies will be shredded.

**Contacts**

Individuals that may be contacted regarding this study include the principal researcher, Leonard Sielecki at the Department of Geography at the University of Victoria at

lsieleck@uvic.ca, or his supervisor, Dr. Dan Smith at the Department of Geography at the University of Victoria at smith@uvic.ca.

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*Please retain a copy of this letter for your reference.*


**Appendix E**

**University of Victoria Human Research Ethics Board (HREB) approval document**



Office of Research Services | Human Research Ethics Board  
 Administrative Services Building, Rm B202, PO Box 1700 STN CSC, Victoria BC V8W 2Y2 Canada  
 T 250-472-4545 | F 250-721-8960 | uvic.ca/research | ethics@uvic.ca

## Certificate of Approval

PRINCIPAL INVESTIGATOR: Leonard Sielecki	ETHICS PROTOCOL NUMBER: 16-192
UVic STATUS: Ph.D. Student	ORIGINAL APPROVAL DATE: 03-Jun-16
UVic DEPARTMENT: GEOG	APPROVED ON: 03-Jun-16
SUPERVISOR: Dr. Dan Smith	APPROVAL EXPIRY DATE: 02-Jun-17
PROJECT TITLE: Wildlife Hazard Warning System	
RESEARCH TEAM MEMBER: None	
DECLARED PROJECT FUNDING: None	
<b>CONDITIONS OF APPROVAL</b>	
<p>This Certificate of Approval is valid for the above term provided there is no change in the protocol.</p> <p><b>Modifications</b>          To make any changes to the approved research procedures in your study, please submit a "Request for Modification" form. You must receive ethics approval before proceeding with your modified protocol.</p> <p><b>Renewals</b>          Your ethics approval must be current for the period during which you are recruiting participants or collecting data. To renew your protocol, please submit a "Request for Renewal" form before the expiry date on your certificate. You will be sent an emailed reminder prompting you to renew your protocol about six weeks before your expiry date.</p> <p><b>Project Closures</b>          When you have completed all data collection activities and will have no further contact with participants, please notify the Human Research Ethics Board by submitting a "Notice of Project Completion" form.</p>	
<b>Certification</b>	
<p>This certifies that the UVic Human Research Ethics Board has examined this research protocol and concluded that, in all respects, the proposed research meets the appropriate standards of ethics as outlined by the University of Victoria Research Regulations Involving Human Participants.</p>	
	
<p>Dr. Rachael Scarth          Associate Vice-President Research Operations</p>	

Certificate Issued On: 03-Jun-16

16-192 Sielecki, Leonard