EVALUATION OF RADAR SENSING IN REDUCING VEHICLE-DEER COLLISIONS ON INDIANA TOLL ROAD I-80

Sedat Gulen
Statistical Research Engineer

Samuel E. Wolfe
Road Operations Engineer
INDOT - Toll Road

Professor George McCabe
Department of Statistics
Purdue University

Joint Transportation Research Program
Project No. SPR-2495
<table>
<thead>
<tr>
<th>State</th>
<th>Fatal</th>
<th>Injury A</th>
<th>Injury B</th>
<th>Injury C</th>
<th>PDO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona</td>
<td>$3,000,000</td>
<td>$210,000</td>
<td>$42,000</td>
<td>$22,000</td>
<td>$3,000</td>
</tr>
<tr>
<td>Iowa</td>
<td>$1,000,000</td>
<td>$150,000</td>
<td>$10,000</td>
<td>$2,500</td>
<td>$2,500</td>
</tr>
<tr>
<td>Louisiana</td>
<td>$3,000,000</td>
<td>$63,000</td>
<td>$63,000</td>
<td>$63,000</td>
<td>$2,300</td>
</tr>
<tr>
<td>Maine</td>
<td>$2,600,000</td>
<td>$180,000</td>
<td>$36,000</td>
<td>$19,000</td>
<td>$2,000</td>
</tr>
<tr>
<td>Nebraska</td>
<td>$3,770,000</td>
<td>$316,000</td>
<td>$66,900</td>
<td>$34,900</td>
<td>$6,200</td>
</tr>
<tr>
<td>Oregon</td>
<td>$1,350,000</td>
<td>$1,350,000</td>
<td>$55,000</td>
<td>$55,000</td>
<td>$13,000</td>
</tr>
<tr>
<td>Texas</td>
<td>$854,000</td>
<td>$854,000</td>
<td>$41,000</td>
<td>$41,000</td>
<td>$1,400</td>
</tr>
<tr>
<td>Vermont</td>
<td>$3,400,000</td>
<td>$260,000</td>
<td>$56,000</td>
<td>$27,000</td>
<td>$4,000</td>
</tr>
</tbody>
</table>

**INDIANA:** Yearly: 16,000 deer-vehicle collisions;

$22 million Property damage; 3 Fatalities.

**State Farm Reports nationwide from July 1, 2004 to June 30, 2005:**

1 million deer_vehicel collisions; 150 deaths;

$1.1 Billion in vehicle damages: (Average PDO Claim=$11,100)
The overall objective of this project is to evaluate The Radar Sensing Approach developed by “Sensor Technologies & Systems, Inc.” in reducing vehicle-deer collisions on Indiana Toll Road.
Expected Implementation and Study Benefits

If the results of the study statistically show a significant reduction in deer kills, the Indiana Toll Road will install radar-sensing devices on the Toll Road at sensitive locations. INDOT will likely install the same equipment on other state routes with a history of vehicle-deer collisions.
## Accumulative Deer Kill Reports on Toll Road

<table>
<thead>
<tr>
<th>Year</th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>22</td>
<td>6</td>
<td>16</td>
<td>24</td>
<td>95</td>
<td>50</td>
<td>21</td>
<td>9</td>
<td>6</td>
<td>73</td>
<td>128</td>
<td>49</td>
<td>499</td>
</tr>
<tr>
<td>1993</td>
<td>16</td>
<td>9</td>
<td>22</td>
<td>20</td>
<td>77</td>
<td>60</td>
<td>14</td>
<td>10</td>
<td>24</td>
<td>84</td>
<td>115</td>
<td>62</td>
<td>513</td>
</tr>
<tr>
<td>1994</td>
<td>16</td>
<td>9</td>
<td>12</td>
<td>47</td>
<td>84</td>
<td>54</td>
<td>16</td>
<td>11</td>
<td>13</td>
<td>116</td>
<td>148</td>
<td>51</td>
<td>577</td>
</tr>
<tr>
<td>1995</td>
<td>22</td>
<td>7</td>
<td>18</td>
<td>22</td>
<td>98</td>
<td>61</td>
<td>14</td>
<td>10</td>
<td>14</td>
<td>89</td>
<td>143</td>
<td>61</td>
<td>559</td>
</tr>
<tr>
<td>1996</td>
<td>38</td>
<td>13</td>
<td>17</td>
<td>20</td>
<td>124</td>
<td>152</td>
<td>23</td>
<td>9</td>
<td>15</td>
<td>92</td>
<td>143</td>
<td>44</td>
<td>690</td>
</tr>
<tr>
<td>1997</td>
<td>22</td>
<td>17</td>
<td>20</td>
<td>28</td>
<td>108</td>
<td>97</td>
<td>23</td>
<td>8</td>
<td>12</td>
<td>90</td>
<td>128</td>
<td>61</td>
<td>614</td>
</tr>
<tr>
<td>1998</td>
<td>40</td>
<td>22</td>
<td>17</td>
<td>32</td>
<td>92</td>
<td>55</td>
<td>18</td>
<td>10</td>
<td>16</td>
<td>88</td>
<td>184</td>
<td>82</td>
<td>656</td>
</tr>
<tr>
<td>1999</td>
<td>28</td>
<td>20</td>
<td>25</td>
<td>33</td>
<td>125</td>
<td>67</td>
<td>22</td>
<td>13</td>
<td>13</td>
<td>111</td>
<td>144</td>
<td>28</td>
<td>629</td>
</tr>
<tr>
<td>2000</td>
<td>24</td>
<td>20</td>
<td>11</td>
<td>48</td>
<td>135</td>
<td>65</td>
<td>30</td>
<td>15</td>
<td>26</td>
<td>102</td>
<td>131</td>
<td>27</td>
<td>634</td>
</tr>
<tr>
<td>2001</td>
<td>11</td>
<td>28</td>
<td>19</td>
<td>39</td>
<td>103</td>
<td>74</td>
<td>24</td>
<td>9</td>
<td>22</td>
<td>151</td>
<td>201</td>
<td>63</td>
<td>744</td>
</tr>
<tr>
<td>2002</td>
<td>43</td>
<td>14</td>
<td>9</td>
<td>39</td>
<td>134</td>
<td>78</td>
<td>10</td>
<td>13</td>
<td>17</td>
<td>72</td>
<td>169</td>
<td>57</td>
<td>655</td>
</tr>
<tr>
<td>2003</td>
<td>28</td>
<td>8</td>
<td>27</td>
<td>26</td>
<td>128</td>
<td>121</td>
<td>23</td>
<td>10</td>
<td>21</td>
<td>140</td>
<td>134</td>
<td>57</td>
<td>723</td>
</tr>
<tr>
<td>2004</td>
<td>25</td>
<td>12</td>
<td>34</td>
<td>47</td>
<td>126</td>
<td>93</td>
<td>19</td>
<td>15</td>
<td>26</td>
<td>122</td>
<td>161</td>
<td>35</td>
<td>715</td>
</tr>
<tr>
<td>2005</td>
<td>33</td>
<td>24</td>
<td>13</td>
<td>40</td>
<td>175</td>
<td>92</td>
<td>24</td>
<td>9</td>
<td>16</td>
<td>200</td>
<td>160</td>
<td>35</td>
<td>821</td>
</tr>
</tbody>
</table>
Deer Killed on Toll Road I-80/90

Years

Deer Killed

NATURAL OCCURANCES of DEER _VEHICLE ACCIDENTS by YEARS and MONTHS on I-80/90
There are two Peaks as seen in the graph:

1) **Smaller peak (May to June):**
   more probably due to:
   - Fawning and
   - Increased nutritional requirements of razing young cause females to travel more.
   - Availability of high quality of food cause travel

2) **Larger Peak (October to November):**
   more probably due to:
   - Breeding season; animals are more active and careless
   - Hunting season cause extensive movement
   - Lack of food can cause greater travel.
TOP 10 STATES FOR DEER-CAR ACCIDENTS

1. Pennsylvania
2. Michigan
3. Illinois
4. Ohio
5. Georgia
6. Minnesota
7. Virginia
8. Indiana
9. Texas
10. Wisconsin
Location of the experiment on I-80/90 between Mile Markers 130 and 143.
RADS
Roadway Animal Detection System

RADS in Operation
DESIGN OF EXPERIMENT

The Following is the Design of Experiment actually used to place radar sensors and the control sections in between on I-80/90 Toll Road in Indiana.

There is two replicates and this design is statistically sound and valid.

The radar system has been functional since October 2004 and deer-vehicle accident data has been collected daily and reported monthly. The unit of data for the Poisson Regression is the total amount of Deer-Vehicle collisions per mile.
**DESIGN OF EXPERIMENT**

**Typical Layout**

<table>
<thead>
<tr>
<th></th>
<th>Replicate 1</th>
<th></th>
<th>Replicate 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>T2</td>
<td>T3</td>
<td>T4</td>
<td>T5</td>
</tr>
<tr>
<td></td>
<td>T6</td>
<td>T7</td>
<td>T8</td>
<td>T9</td>
</tr>
<tr>
<td>Mile Posts</td>
<td>130</td>
<td>131</td>
<td>132</td>
<td>133</td>
</tr>
<tr>
<td></td>
<td>134</td>
<td>135</td>
<td>136</td>
<td>137</td>
</tr>
<tr>
<td></td>
<td>138</td>
<td>139</td>
<td>140</td>
<td>141</td>
</tr>
<tr>
<td></td>
<td>142</td>
<td>143</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

T1, T2, ..., T14 ARE TREATMENTS

- **1-Mile Radar Sensor**
- **1-Mile Control**

**POISSON REGRESSION ANALYSIS** will be used to analyze the data

**Dependent Variable:** Number of Deer-Vehicle Collisions

**Explanatory Variables:** Month, Replicate, Treatments, AADT, etc.
Typical Layout of the radar sensing systems

- Roadway
- Sensor
- Distance in Miles

Scale is for sensor placement reference only. Otherwise, drawing is not to scale.
Deer Sensors
Milepost 130 – Milepost 142
I-80/90 Indiana Toll Road

The Indiana Toll Road in cooperation with the Indiana Department of Transportation Research Division, Purdue University and the University of Montana installed 72 sensors (6 per mile rather than 4 due to over-pass bridges and curving) and are testing an animal detection/warning system.

The system uses radio frequency transmitters and receivers to send a beam parallel to the road. If an animal (most likely a deer) breaks the beam, the flashing yellow beacons turn on and flash for two minutes to warn the drivers.
STATISTICAL APPROACH

Poisson Regression

\[ P(y = r) = \frac{\left( \mu^r e^{-\mu} \right)}{r!} \quad \cdots \quad r = 0,1,2,\ldots \]

where: \( \mu = E(y) = \) Expected Value

\( \mu > 0 \) then \( \mu \) can be log linear function of \( X's \)

\[ \log(\mu_i) = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_p X_{ip} \]

or \( \mu_i = e^{\beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_p X_{ip}} \)

This can make \( \mu \) positive for any values of \( X's \) or \( \beta's \).

\( X's \) are Explanatory Variables such as:

Months, Years, Geographic al rating of the test sections, replicate, the previous year (1998) as a covariate.
The Following Warning Sign was used

ANIMAL
PRESENT
WHEN
FLASHING
This sign was used in Europe
Radar Systems in Place
The system is 100% solar powered and each mile of the test area operates independently from the other locations.

Each system is connected to a cell phone for remote monitoring, checking and data collection.

The system was activated in 10/2004.
<table>
<thead>
<tr>
<th>YEAR</th>
<th>MONTH</th>
<th>GROUP</th>
<th>DEER-VEHICLE COLLISION</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>October</td>
<td>Control</td>
<td>10</td>
</tr>
<tr>
<td>2004</td>
<td>October</td>
<td>Radar</td>
<td>6</td>
</tr>
<tr>
<td>2004</td>
<td>November</td>
<td>Control</td>
<td>10</td>
</tr>
<tr>
<td>2004</td>
<td>November</td>
<td>Control</td>
<td>5</td>
</tr>
<tr>
<td>2005</td>
<td>May</td>
<td>Control</td>
<td>13</td>
</tr>
<tr>
<td>2005</td>
<td>May</td>
<td>Radar</td>
<td>13</td>
</tr>
<tr>
<td>2005</td>
<td>June</td>
<td>Control</td>
<td>4</td>
</tr>
<tr>
<td>2005</td>
<td>June</td>
<td>Radar</td>
<td>10</td>
</tr>
<tr>
<td>2005</td>
<td>October</td>
<td>Control</td>
<td>14</td>
</tr>
<tr>
<td>2005</td>
<td>October</td>
<td>Radar</td>
<td>11</td>
</tr>
<tr>
<td>2005</td>
<td>November</td>
<td>Control</td>
<td>14</td>
</tr>
<tr>
<td>2005</td>
<td>November</td>
<td>Radar</td>
<td>18</td>
</tr>
<tr>
<td>Year</td>
<td>Month</td>
<td>Type</td>
<td>Value</td>
</tr>
<tr>
<td>------</td>
<td>--------</td>
<td>--------</td>
<td>-------</td>
</tr>
<tr>
<td>2006</td>
<td>May</td>
<td>Control</td>
<td>7</td>
</tr>
<tr>
<td>2006</td>
<td>May</td>
<td>Radar</td>
<td>16</td>
</tr>
<tr>
<td>2006</td>
<td>June</td>
<td>Control</td>
<td>8</td>
</tr>
<tr>
<td>2006</td>
<td>June</td>
<td>Radar</td>
<td>6</td>
</tr>
<tr>
<td>2006</td>
<td>October</td>
<td>Control</td>
<td>1</td>
</tr>
<tr>
<td>2006</td>
<td>October</td>
<td>Radar</td>
<td>7</td>
</tr>
</tbody>
</table>
PRELIMINARY CONCLUSIONS

1. High Accident Months Data (May to June & October to November) will be used in the statistical analyses.

2. Current data from 2004 to 2006 was not enough to make any statistical conclusion.

3. Data collection will continue for another 2 or 3 years.

4. Following variables were selected for Poisson Regression Models:
   
a. Dependent variable:
      
      Number of Deer_vehicle collisions per mile per month.
b. Independent Variables

Months, Years and

Treatments, 14 of them:

( 1-mile long radar sections, total of 6
and

1-mile long control sections, total of 8).

5- The Vehicle–Deer collisions data will be used to compare these 14-treatments to evaluate the effectiveness of radar sensing systems combined with reactions of drivers.
RADAR SPECIFICATIONS & CONTACT INFORMATION

Terry_Wilson@sensor-tech.com
8900 East Chaparral Road,
Scottsdale, Arizona 85250
Phone: (480) 483-1997
Fax: (480) 483-2011
www.sensor-tech.com
**RADS SPECIFICATIONS**

### SYSTEM
- Animal Sizes
- Maximum Range per Sensor: 402 meters
- Network Range – Typical: 1.6 km increments, extendable
- Minimum Sensor Range: 0 meters
- Approximate Weight: 3 kg
- Outputs – Hardware: Relay Contact Closure
- Outputs – Data: Time/Date of Crossing, Segment, Duration
- Communications: Dedicated Short Range Wireless in Network
- Power: 12 VDC
- Power System: Solar with Batteries or AC Power as Available

### ENVIRONMENTAL
- Temperature: -40°C to +85°C
- Humidity: 0 to 95% RH, non-condensing (60°C max)
- Altitude (above sea level):
  - Operating: -150 to 4270 m (-500 to +14,000 ft.)
  - Storage: -150 to 12,190 m (-500 to +40,000 ft.)
- Wind: 45 meters/second maximum
- Weather: All weather conditions
QUESTIONS