Wildlife Warning Signs and Animal Detection Systems

Marcel Huijser, PhD
Ecological Impacts Roads and Traffic

1. Loss of wildlife habitat
2. Road mortality
3. Barrier effect
4. Decrease in habitat quality (disturbance, pollution)
5. Ecological function of verges
Strategies

Habitat

Road effect zone

Mitigate
# Effective measures collision reduction

<table>
<thead>
<tr>
<th>Mitigation measure</th>
<th>Effectiveness</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonal wildlife warning sign</td>
<td>26%</td>
<td>Sullivan et al. (2004): 51%; Rogers (2004): 0%</td>
</tr>
<tr>
<td>Fence, gap, crosswalk</td>
<td>40%</td>
<td>Lehnert and Bissonette (1997): 42%, 37%</td>
</tr>
<tr>
<td>Population culling</td>
<td>50%</td>
<td>Review in Huijser et al. 2007a</td>
</tr>
<tr>
<td>Relocation</td>
<td>50%</td>
<td>Review in Huijser et al. 2007a</td>
</tr>
<tr>
<td>Anti-fertility treatment</td>
<td>50%</td>
<td>Review in Huijser et al. 2007a</td>
</tr>
<tr>
<td>Animal detection system (ADS)</td>
<td>87%</td>
<td>Mosler-Berger and Romer (2003): 82%; Dodd and Gagnon (2008): 91%</td>
</tr>
<tr>
<td>Fence, gap, ADS</td>
<td>87%</td>
<td>Mosler-Berger and Romer (2003): 82%; Dodd and Gagnon (2008): 91%</td>
</tr>
<tr>
<td>Elevated roadway</td>
<td>100%</td>
<td>Review in Huijser et al. 2007a</td>
</tr>
<tr>
<td>Road tunnel</td>
<td>100%</td>
<td>Review in Huijser et al. 2007a</td>
</tr>
</tbody>
</table>
Warning Signs

Purpose: Reducing wildlife-vehicle collisions by warning drivers about the potential or actual presence of wild animals on the road.
Warning Signs

- Wildlife warning signs do not reduce the traffic volume and animals still have to avoid vehicles while crossing the road.

- Do not make it more attractive for wildlife to approach and cross road.

- Warning signs do not change that roads are linear open areas

- Wildlife warning signs are typically located at collision hotspots. Not necessarily the same locations where:
  - Wildlife crosses the road successfully
  - Locations that need improved connectivity to enhance population viability of the species of concern or T&E species
1. Loss of wildlife habitat
2. Road mortality
3. Barrier effect
4. Decrease in habitat quality (disturbance, pollution)
5. Ecological function of verges
Standard Wildlife Warning Signs

• Typically large mammal, stylized symbol
• Species:
  – Common
  – Wide-spread
  – Large enough to be a human safety concern

Huijser et al. in press
Enhanced Wildlife Warning Signs

- Do not necessarily follow the standard style of traffic warning signs
  - Larger
  - Permanently flashing lights
  - Bright flags
  - Eye-catching
  - Disturbing illustrations
  - Images of certain species
  - Collision statistics or other customized text

Better capturing the attention of the drivers and educating them about the safety and nature conservation impact of WVC
Temporal Wildlife Warning Signs

- Specific times of the year or day
- Tend to be species specific
- Typically only visible to drivers during the most risky time of year or day
  - Removed in the off-season
  - Signs that fold in half
  - Programmable message signs

Seasonal feature

Migration corridors
Animal Detection Systems

• Electronic sensors to detect large animals that approach the road
• Signs are activated to warn drivers.
• Very specific in time and place
• Current animal detection systems not suitable for small to medium sized animals
How do Warning Signs Work?

Reliable warning signals

Increased driver awareness; large animals may be on or near the road

Lower vehicle speed

Increased driver alertness

Reduced reaction time when confronted with an animal ahead

Shorter stopping distance

Vehicle may hit animal at lower speed

Vehicle may not hit animal

Huijser et al. 2006
Increased Driver Alertness???

- Often for long distances

- Only 5-10% of the drivers that were stopped 200 m after passing a warning sign were able to recall it (Drory & Shinar 1982)

- Once a sign has been installed it is rarely removed, even if the problem no longer exists (Krisp & Durot 2007)
Increased Driver Alertness???

- Enhanced warning signs are indeed more frequently observed and recalled by drivers than standard warning signs (Summala & Hietamaki 1984)
- But… non-standard… conflict with “standard procedures”, divert attention from other driving tasks
Reduce collisions: driver warning signs

Driving Simulator

Speed vs Sign Treatment

N = 77

Speed (mph)

60  65  70  75  80  85

Sign Treatment

1  2  3  4

76.59
73.26
71.98
74.60

ANIMAL CROSSING NEXT 20 MILES BE ALERT

NEXT 20 MILES

NEXT 20 MILES

Western Transportation Institute
Reduce collisions: driver warning signs

Driving Simulator

Braking Distance from Deer vs Sign Treatment

N = 77

Sign Treatment

Braking Distance from Deer (ft)

ANIMAL CROSSING
NEXT 20 MILES
BE ALERT

Western Transportation Institute
**Vehicle Speed Reduction: Seasonal Warning Signs**

Table 3. Vehicles exceeding speed limit by 8 km/h or more at treatment and control sites in Idaho and Utah, 2000–2001.

<table>
<thead>
<tr>
<th>Site</th>
<th>Corridor</th>
<th>Vehicles</th>
<th>Speeders</th>
<th>Speeders (%)</th>
<th>Vehicles</th>
<th>Speeders</th>
<th>Speeders (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boise River, Idaho</td>
<td>Control</td>
<td>270</td>
<td>93 (34)</td>
<td></td>
<td>211</td>
<td>54 (26)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Treatment</td>
<td>340</td>
<td>64 (19)</td>
<td></td>
<td>243</td>
<td>10 (4)</td>
<td></td>
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<tr>
<td>Mantua, Utah</td>
<td>Control</td>
<td>233</td>
<td>50 (21)</td>
<td></td>
<td>212</td>
<td>33 (16)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Treatment</td>
<td>208</td>
<td>42 (20)</td>
<td></td>
<td>219</td>
<td>22 (10)</td>
<td></td>
</tr>
<tr>
<td>Red Rocks, Idaho</td>
<td>Control</td>
<td>81</td>
<td>23 (28)</td>
<td></td>
<td>54</td>
<td>9 (17)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Treatment</td>
<td>67</td>
<td>19 (22)</td>
<td></td>
<td>73</td>
<td>14 (19)</td>
<td></td>
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<tr>
<td>Montpelier, Idaho</td>
<td>Control</td>
<td>75</td>
<td>13 (17)</td>
<td></td>
<td>71</td>
<td>14 (20)</td>
<td></td>
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<tr>
<td></td>
<td>Treatment</td>
<td>80</td>
<td>19 (24)</td>
<td></td>
<td>79</td>
<td>3 (4)</td>
<td></td>
</tr>
<tr>
<td>Mackay, Idaho</td>
<td>Control</td>
<td>76</td>
<td>8 (11)</td>
<td></td>
<td>100</td>
<td>12 (13)</td>
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<tr>
<td></td>
<td>Treatment</td>
<td>90</td>
<td>6 (7)</td>
<td></td>
<td>118</td>
<td>6 (5)</td>
<td></td>
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<tr>
<td>Total</td>
<td>Control</td>
<td>735</td>
<td>167 (25)</td>
<td></td>
<td>648</td>
<td>123 (19)</td>
<td></td>
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<tr>
<td></td>
<td>Treatment</td>
<td>805</td>
<td>150 (19)</td>
<td></td>
<td>732</td>
<td>55 (8)</td>
<td></td>
</tr>
</tbody>
</table>

Reduction in speed 2nd yr not great

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Sullivan et al 2004
Vehicle Speed Reduction

Animal detection systems:

- **Somewhat (<5 km/h)** (Kistler 1998 (from 51 km/h to 47 km/h without mandatory speed limit reduction), Muurinen & Ristola 1999 (from 103.9 km/h to 102.3 km/h in the dark), Hammond & Wade 2004 (from 61.9 km/h to 59.6 km/h), Huijser et al. 2006 (from 97.8/91.2 to 96.1/88.2 km/h for passenger cars for the two travel directions)

- **More substantially (≥5 km/h)** in response to the activated warning signs of animal detection systems (Kistler 1998 (from 68 to 46 km/h with mandatory speed limit reduction to 40 km/h), Kinley et al. 2003 (from 92.9/91.0 km/h to 80.8/87.0 km/h for the two travel directions), Gordon et al. 2004 (from about 103 km/h to about 97 km/h), Gagnon et al. 2010 (from 86.1 km/h to 71.6 km/h), Sharafsaleh et al. 2012 (from 90.4 km/h to 85.4 km/h).

Greatest reductions in vehicle speed seem to occur when the warning signs are associated with advisory or mandatory speed limit reductions or if road conditions and visibility for drivers are poor (Kistler 1998, Muurinen & Ristola 1999).
Effectiveness

- **Standard**: Majority of studies concluded that these signs are not effective in reducing collisions (Pojar et al. 1975, Coulson 1982, Rogers 2004, Meyer 2006, Bullock et al. 2011).

- **Standard**: 34% reduction in collisions immediately after installation (Found & Boyce 2011) or at a gap in a fence with a crosswalk painted on the road surface (37-43%) (Lehnert & Bissonette 1997).


Standard and Enhanced Wildlife Warning Signs

• Not effective in reducing collisions

• Widespread use
  – Engrained practices
  – Relatively low cost
  – Desire to inform the public about the impact of WVC on human safety and nature conservation
  – Possible litigation concerns, rather than a proven substantial reduction in these types of collisions

Huijser et al. in press
Temporal Warning Signs and Animal Detection Systems

Place and time specific:
Can be effective in reducing collisions.
How do Warning Signs Work?

Reliable warning signals

Increased driver awareness; large animals may be on or near the road

Lower vehicle speed

Increased driver alertness

Reduced reaction time when confronted with an animal ahead

Shorter stopping distance

Vehicle may hit animal at lower speed

Vehicle may not hit animal

Huijser et al. 2006
Reliability: Blind spots

Trigger system at 20 m intervals
Reliability: Blind spots

East side road

West side road

Road

Curves

Slopes
Reliability: Interpretation animal crossings

28/11/04 20:11:58M7 90 50 A0 D0 30 80 C0 B0 E0 41 70 10 0 60 20
28/11/04 20:12:03M7 R0 R0 A0 D0 30 80 C0 B0 E0 40 70 10 0 60 20
28/11/04 20:13:05M7 90 50 A0 D0 30 80 C0 B0 E1 40 70 10 0 60 20
28/11/04 20:13:12M7 90 50 A0 D0 30 80 C0 B0 E0 40 70 10 0 60 20
28/11/04 20:24:00M7 90 50 A0 D0 30 80 C0 B0 E0 41 70 10 0 60 20
28/11/04 20:24:07M7 R0 R0 R0 R0 R0 R0 R0 B0 E0 40 70 10 0 60 20
28/11/04 21:25:16M7 R0 R0 A0 D0 30 80 C0 B0 E0 41 70 10 0 60 20
28/11/04 21:25:28M7 90 50 A0 D0 30 80 C0 B0 E0 40 70 10 0 60 20

Crossing events (n)
east-west (n=144)
west-east (n=126)

Hour of day
Reliability: Snow tracking

Detection data

87% of elk tracks detected

Snow tracking data
11 systems in test-bed

Magal Senstar (Perimitrax)

Icx Radar Systems (STS III)
Reliability tests
Horses, Llamas, and Sheep

- Model for deer, pronghorn, elk, moose
- Caretaker
<table>
<thead>
<tr>
<th>System #</th>
<th>Manufacturer and system name</th>
<th>ID #</th>
<th>System type</th>
<th>Signal type</th>
<th>Maximum range</th>
<th>Installation date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Xtralis (ADPRO)</td>
<td>7</td>
<td>Area cover</td>
<td>Passive IR</td>
<td>500 ft (152 m)</td>
<td>21 Sep 2006</td>
</tr>
<tr>
<td>2</td>
<td>Xtralis (ADPRO)</td>
<td>5-6</td>
<td>Area cover</td>
<td>Passive IR</td>
<td>200 ft (61 m) (one detector on each side)</td>
<td>21 Sep 2006</td>
</tr>
<tr>
<td>3</td>
<td>STS (ICx radar systems) (RADS I)</td>
<td>1</td>
<td>Break-the-Beam</td>
<td>Microwave radio (± 35.5 GHz)</td>
<td>¼ mi (402 m)</td>
<td>19 Oct 2006</td>
</tr>
<tr>
<td>4</td>
<td>STS (RADS II)</td>
<td>2</td>
<td>Break-the-beam</td>
<td>Microwave radio (± 35.5 GHz)</td>
<td>Well over ¼ mi (402 m)</td>
<td>19 Jul 2007</td>
</tr>
<tr>
<td>5</td>
<td>Calstrom GmbH CAR92,LS-WS-WE 45</td>
<td>1</td>
<td>Break-the-beam</td>
<td>Laser</td>
<td>984 (built-up areas) -1148 ft (open areas) (300-350 m)</td>
<td>21-22 Sep 2006</td>
</tr>
<tr>
<td>6</td>
<td>Calstrom GmbH CAR92,IR-204-319/M3</td>
<td>2</td>
<td>Area cover</td>
<td>Passive IR</td>
<td>328 ft (100 m)</td>
<td>21-22 Sep 2006</td>
</tr>
<tr>
<td>7</td>
<td>Camrix (A.L.E.R.T.)</td>
<td></td>
<td>Area cover</td>
<td>Passive IR</td>
<td>300 ft (91 m)</td>
<td>19-31 Oct 2006</td>
</tr>
<tr>
<td>8</td>
<td>Xtralis (ADPRO)</td>
<td>1-2</td>
<td>Area cover</td>
<td>Passive IR</td>
<td>200 ft (61 m) (2 detectors, one facing each way)</td>
<td>8 Aug 2006</td>
</tr>
<tr>
<td>9</td>
<td>Goodson</td>
<td></td>
<td>Break-the-beam</td>
<td>Active IR</td>
<td>90 ft (27 m)</td>
<td>Dec 2006</td>
</tr>
<tr>
<td>10</td>
<td>Magal Senstar Perimitrax</td>
<td></td>
<td>Buried cable</td>
<td>Electromagnetic field</td>
<td>About 0.1 mi (161 m)</td>
<td>11/12 Aug 2009</td>
</tr>
<tr>
<td>11</td>
<td>STS (RADS III)</td>
<td>3</td>
<td>Break-the-beam</td>
<td>Microwave radio (± 35.5 GHz)</td>
<td>About 1/2 mi (804 m)</td>
<td>16 Dec 2009</td>
</tr>
</tbody>
</table>
**Dependent Variables**

- **Correct detection**: Detection and animal present in detection area
- **False positives**: Detection but no animal present in detection area
- **False negatives**: Animal passes line of detection but no detection
- **False negatives 1**: Animal lingered in the detection zone before passing through the line of detection but no detection
- **False negatives 2**: Animal(s) lingered in the detection zone and other animal(s) passed through the line of detection but no detection
Dependent Variables

Break-the-beam

Line of detection

Area-cover

Detection zone

\[ F^- = \frac{F_N^-}{N_{1(\text{centerline})}} \times 100 = \frac{F_N^-}{N_{d(\text{centerline})} + F_N^-} \times 100 \]

\[ F^+ = \frac{F_N^+}{N_{1(\text{detections recorded by system})}} \times 100 = \frac{F_N^+}{N_{1(\text{valid detections})} + F_N^+} \times 100 \]

\[ I = \frac{I_d}{I_t} \times 100 = \frac{E_1}{E_1 + E_2} \times 100 \]

\[ I_{\text{system, f'}} = \frac{I_{d(\text{system, f'})}}{I_t(\text{system, f'})} \times 100 = \frac{E_1}{E_1 + E_2 + E_3} \times 100 \]

where

- \( F^- \) = percent of animal movements across the centerline that were not detected
- \( F_N^- \) = total number of false negatives, false negative 1 and false negative 2
- \( N_{1(\text{centerline})} \) = total number of times an animal crossed the centerline and should have been detected
- \( N_{d(\text{centerline})} \) = total number of times an animal crossed the centerline and was detected
- \( F^+ \) = percent of all detections recorded by the data logger that were false positives
- \( F_N^+ \) = total number of false positives
- \( N_{1(\text{detections recorded by system})} \) = total number of detections recorded by a system
- \( N_{1(\text{valid detections})} \) = total number of valid detections
- \( I \) = percent of all intrusions detected
- \( I_d \) = total number of intrusions detected
- \( I_t \) = total number of intrusions
- \( E_1 \) = total number of event 1
- \( E_2 \) = total number of event 2
- \( I_{\text{system, f'}} \) = percent of all intrusions detected for system “f”
- \( I_{d(\text{system, f'})} \) = total number of intrusions detected by system “f”
- \( I_{t(\text{system, f'})} \) = total number of intrusions detected by system “f”
Intrusions detected (%)
Suggested norms reliability

- Transportation agencies
- Natural resource management agencies
- Public
- Majority (≥50%)
Meet the minimum norms?

Table 8.2: The reliability of each system in relation to the recommended minimum norms. The percentage of intrusions detected is similar, though not exactly the same as the inverse of the percentage of false negatives (see chapter 4) (*alternative calculation: 81.2%*, **alternative calculation: 81.8%**, ***alternative calculation: 75.5%).

<table>
<thead>
<tr>
<th>System number (Figure 3.2)</th>
<th>Manufacturer and system name</th>
<th>ID number</th>
<th>False positives (%)</th>
<th>False negatives (all types combined) (%)</th>
<th>Intrusions detected (%)</th>
<th>Meets recommended norms (yes/no)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Xtralis (ADPRO)</td>
<td>7</td>
<td>0.00</td>
<td>10.29</td>
<td>91.75</td>
<td>Yes</td>
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<td>2</td>
<td>Xtralis (ADPRO)</td>
<td>5.6</td>
<td>0.00</td>
<td>20.88</td>
<td>$5.48</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>STS (RADS I)</td>
<td>1</td>
<td>0.00</td>
<td>30.91</td>
<td>72.47</td>
<td>No</td>
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<tr>
<td>4</td>
<td>STS (RADS II)</td>
<td>2</td>
<td>0.00</td>
<td>15.94</td>
<td>88.35</td>
<td>No</td>
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<td>5</td>
<td>Calidus Energy (CAL 92, LS-WE, WE 45)</td>
<td>1</td>
<td>0.60</td>
<td>0.48</td>
<td>99.54</td>
<td>Yes</td>
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<tr>
<td>6</td>
<td>Calidus Energy (CAL 92, IR-204-319-M3)</td>
<td>2</td>
<td>0.00</td>
<td>1.16</td>
<td>98.85</td>
<td>Yes</td>
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<tr>
<td>7</td>
<td>Canmix (ALERT)</td>
<td>Overall Before mod. After mod.</td>
<td>0.07</td>
<td>30.21</td>
<td>89.41*</td>
<td>No</td>
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<td>8</td>
<td>Xtralis (ADPRO)</td>
<td>1-2</td>
<td>0.97</td>
<td>6.53</td>
<td>95.19</td>
<td>Yes</td>
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<td>9</td>
<td>Goodson</td>
<td>0.82</td>
<td>0.00</td>
<td>100.00</td>
<td>Yes</td>
<td></td>
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<td>10</td>
<td>Magal Sonnet</td>
<td>0.33</td>
<td>1.88</td>
<td>99.32</td>
<td>Yes</td>
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<td>11</td>
<td>ICx</td>
<td>0.41</td>
<td>16.76</td>
<td>$8.62</td>
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<td></td>
</tr>
</tbody>
</table>
Explanatory Variables

• Wind Speed
• High Wind (winds over 15 mph)
• Wind Gust (present/ absent)
• Wind direction (split into 4 categories for N, E, S or W)
• Temperature
• Day or night
• Visibility (10 or not)
• Relative Humidity
• Precipitation (presence/ absent)
• Animal (none, horse or llama)
• System modifications (e.g. threshold settings)
Data analyses

- Multinomial logistic regression model
- Akaike’s An Information Criterion (AIC)
- Stepwise model selection procedure for each system

- **Effect and direction of effect** was investigated for each type of FN or FP relative to correct detections

- System modifications and animal species were **forced** into the models
### Significant effects (P≤0.05):

- FN = False Negative
- FP = False Positive
- + = Increase in error rate
- - = Decrease in error rate

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<table>
<thead>
<tr>
<th>Variable included in model</th>
<th>Excluded</th>
<th>System modifications (at Ref)</th>
<th>Wind speed (mph)</th>
<th>High wind (&gt; 15 ≤ 15 mph)</th>
<th>Wind gust (present/absent)</th>
<th>Wind direction (N, W, S, E)</th>
<th>Temperature (°C)</th>
<th>Day or night (N/D)</th>
<th>Visibility (excellent/mod. good)</th>
<th>Relative humidity (%)</th>
<th>Precipitation (present/absent)</th>
<th>Animal (trampled)</th>
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<tr>
<td>Xtras 1</td>
<td></td>
<td>+FN</td>
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<td>+FN</td>
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<td>Xtras 3</td>
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<td>+FN2</td>
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Huijser et al., 2009

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**Montana State University**
Conclusions

• Some systems are very reliable
• 6 out of the 11 systems tested met reliability norms
• Reliability is dependent on environmental conditions
• Not “one system fits all”; variety technologies needed
Potential applications

Combinations with other Mitigation measures:

- Wildlife fencing
- Crossing structures
Animal detection systems or wildlife crossing structures?

Positive
- Wider crossing areas (without fences)
- Less expensive?
- No major work to road or roadbed

Negative
- Large animals only
- Avoidance open areas / pavement
- Human safety (animals, posts)
Work to be Done!

Researchers
Suggest norms for system reliability (ongoing)
Investigate effective warning signs; message, spacing (driving simulator study)
Investigate system effectiveness further (dependent on study sites)
Communicate, share data for meta-analyses

Vendors
More robust systems (less maintenance)
Increase reliability (detecting 91-95% animals)
Smaller systems
Further integration with other ITS systems

DOTs/FHWA
Discuss and adopt norms system reliability
Require tests before installation
Standardize warning signs (type, spacing)
Develop further standards for ITS integration (car – roadside communication)
Implement systems and monitor effectiveness
Communicate, share data for meta-analyses