Deer Detection and Warning System

Project Summary Report

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OVERVIEW

Collisions between vehicles and animals have been an issue around the world for decades. In the United States, it is estimated that approximately 195 fatalities and 17,000 injuries resulted from a total of 300,000 crashes with animals in 2004.(1) The Insurance Institute for Highway Safety estimates the total economic impact at 1.1 billion dollars per year.(2)

In Minnesota, a large deer population and an extensive rural highway system create conditions that are conducive to Deer Vehicle Collisions (DVC). Standard techniques such as static signing and fencing have been employed to mitigate the problem, however the number of DVCs remains constant at approximately 5,500 per year or 10 per hundred million miles of vehicle travel in the State.(3)

To reduce the number of DVCs in the highest frequency locations, the Minnesota Department of Transportation (Mn/DOT) deployed an active deer warning system in 2001, which consisted of an infrared detection system and sign-mounted flashing beacons in a 1-mile section of road that encountered very high rates of DVCs.

While effective, it had technical limitations that reduced its viability. Specifically, the use of incandescent light sources and mechanical rotators resulted in excessive power consumption. Power consumption was so great that replacement of the rechargeable batteries was necessary after 3-4 days, creating an unreasonable maintenance requirement. An additional limitation was the need to hard-wire connections between the detectors and the beacons, which limited the flexibility of the system (a detection on one side of the roadway could not activate a sign on the other side without expensive under-roadway conduit) and drove up installation costs by requiring underground-buried cabling.

In 2006 Mn/DOT contracted with SRF Consulting Group, Inc. to revise the system with the following goals:

- Reduce power consumption and allow for continuous system operation.
- Improve system flexibility
- Reduce installation costs and complexity
- Create data collection mechanisms
- Develop a design that could be re-used in a variety of locations
- Leverage recent advances in wireless data technology

PREVIOUS ACTIVE DEER WARNING APPROACHES

Previous deployments in the USA and other countries (4), have largely been technology evaluations and have shown promising results. However, these have generally been site-specific solutions and costs have been high. In all cases, the systems have consisted of a RADAR or infrared detection system, a power source (usually solar/battery) and a sign/beacon device. Power requirements have necessitated large (~0.6 square meters) solar arrays that present aesthetic and safety issues when placed close to roadways. High costs have also made widespread deployment of these systems impractical.

DESIGN APPROACH

The first goal in the Minnesota redesign was to reduce power consumption. The largest power draw was for an incandescent beacon, which could draw up to 100 watts. This was replaced with an LED beacon 200 mm in diameter. The peak power draw of this device is only 15 watts (an 85% reduction). To ensure continuous operation, the sign/beacon was fitted with a small (0.1 square meter) solar panel.

The detection system built on the previous experience by re-using the beam-type infrared detection system (which consumed only 75 milliamps) and fitting it with a solar panel and battery system identical to that used in the sign.

The goals of improving system flexibility, reducing installation costs and data collection were achieved through the novel implementation of mesh networking devices.

Using Coronis Wavelog™ devices, the ability to communicate detector status to the sign beacons and maintain a record of system activity was combined into a single, low power, environmentally robust device.

Because the devices were software-driven, the relationships between detectors and signs are highly flexible and user-definable. These and other system parameters can be adjusted through software run on a Compaq iPAQ or similar device with a Coronis Waveport™device connected.

Communications and Processing

The system intelligence consists of a single-board solution comprised of a transceiver, network controller, battery, processor and memory. The entire board measures roughly 3 X 2 cm and is encased in epoxy and placed in a small, weatherproof enclosure. This consolidated design allowed all of the system software (including the sign activation logic) to be incorporated directly into the device, greatly reducing system costs and simplifying field installation. The devices also included the input/output interfaces needed to sense detector activations and operate the power relays to for the roadside beacons.

Using an unlicensed 900-MHz frequency also simplifies installation as no permits are needed to utilize the spectrum. Built in-diagnostics in the set-up software allow for measurements of signal strength and quality (signal to noise ratio). However, given that most deployments will be rural locations; this is not envisioned to be a problem. The very low power radiated by the devices is not anticipated to create interference issues with other users of the same frequency band.

The specific devices used for the system allow for either mesh operation or a simpler "broadcast" mode. The current installation has been put into broadcast mode for two reasons: 1) broadcast mode will maximize the life of the internal battery due to its lower power consumption, and: 2) testing on site revealed that signal propagation was such that relays through mesh nodes were not needed.

Lastly, wireless networks eliminate the need for communications cabling. In an outdoor environment, this is particularly critical since any cables must be buried below frost action lines and are subject to disturbances from construction equipment.

Power System

DVCs frequently occur in rural areas that lack the easily accessible power infrastructure found in cities. While electric power is relatively ubiquitous in the United States, accessing it in remote locations can entail costly new connections. By aggressively managing the power needed by the system, a simple photovoltaic solar panel and battery charging device can supply both the detection devices and the warning beacons.

The panels used for this deployment are simple, commercially available devices, with costs in the $100-$200 USD range. A number of manufactures are available to choose from, with differing packaging and mounting options. The panels used in this application were chosen for their small size per watt output (10-20 watts) and ease of installation.

In addition to reducing the labor, complexity and costs of installation, solar power is a renewable resource that has no emissions once installed. The batteries use a lead-acid chemistry and can be recycled once they reach the end of their service life (estimated at 3 years). These characteristics of the power system minimize environmental impacts and ensure long-term viability.

SYSTEM DEPLOYMENT

The initial evaluation deployment for the system used 18 detection zones and 10 roadside sign/beacon units along one mile of rural highway in Minnesota. A portion of the deployment is shown schematically in Figure 1.

Although design and installation costs will be highly variable depending on the location of a deployment, SRF estimates the hardware cost for the system will be approximately USD $40,000 to $50,000 per mile. This is substantially less than previous systems, and allows it to be used much more widely in areas that would have been cost-prohibitive otherwise.

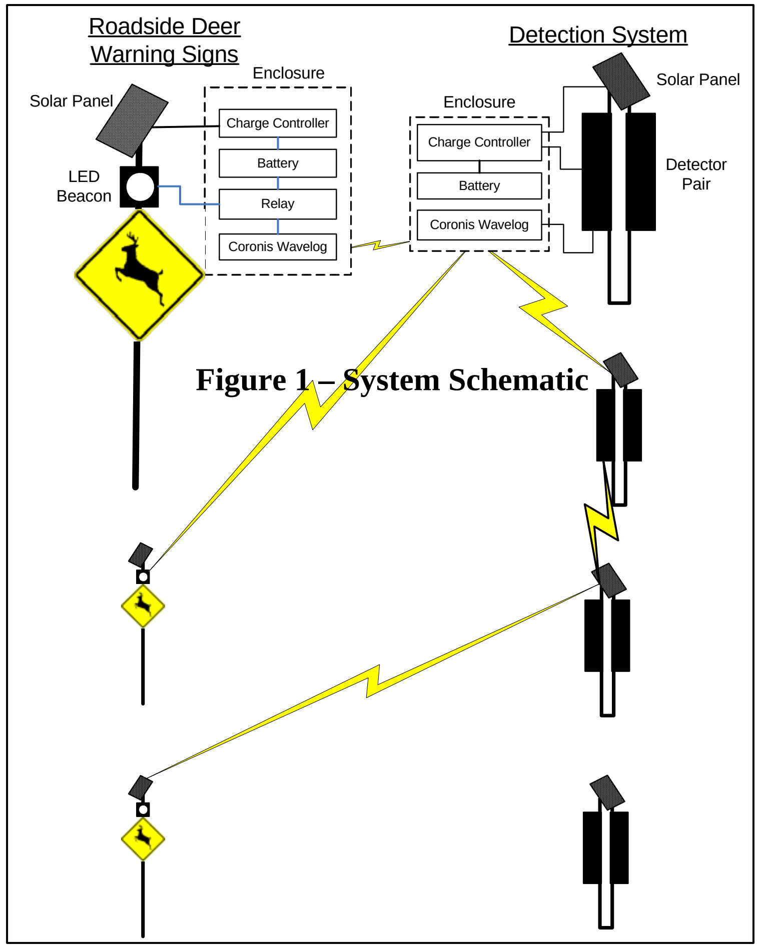

Figure 1 – System Schematic

SYSTEM PERFORMANCE

Safety Impacts

The system was installed in April of 2007, and was activated on April 27th. Daily inspections were made by a Minnesota Department of Natural Resources Park Ranger of the project area to locate deer carcasses, as these are the best indication of DVCs. During the evaluation period from May through November of 2007, seven deer carcasses were observed in the project area, compared to 20 during the same period in 2006, a 65% reduction in DVCs. Technical factors may have increased the number of collisions in November 2007, as noted below.

Equipment Performance

Several issues have emerged with the overall reliability of the prototype system, which have been addressed through design revisions. These are detailed in the following sections.

Power System

Environmental conditions in Minnesota during the late fall to early winter are particularly poor for solar power systems. The combination of low temperatures and extremely low sunlight input created conditions where the detection system power draw was greater than could be supplied. This resulted in erratic system performance during much of the month of November, which coincided with the largest movement of the deer population. Consequently, there may have been more DVCs in November than would have occurred had the system been fully functional.

SRF re-designed the detection power system and retrofit the prototype with new components in 2008. This is not expected to have a substantial impact on system costs.

Proper sizing of the solar panels and batteries has been an iterative process. Unforeseen factors such as local shading conditions (due to trees, etc.) affected performance in addition to weather. Power system capacity was ultimately determined based on an acceptable likelihood of down-time rather than an absolute up-time requirement. Ultimately, the system design was revised to offer four days of operation at the highest possible power drain (detectors dynamically increase power consumption when the beams between them are partially blocked) with the lowest "average worst day" solar input. While this doesn't guarantee a zero-down-time system, it does provide an acceptable balance between uptime, cost, and physical system size.

Interestingly, power issues relate almost exclusively to system reliability, rather than performance. Given the small power consumption of the detection and communications systems, additional peak power would not provide performance benefits. More sophisticated detection devices (machine vision processing, etc.) could be supported with greater peak power, however doing so would entail an order of magnitude (or more) larger solar collectors and given the results so far, may not provide significantly improved safety impacts.

Communications System

The initial design called for a communications system that was entirely self-contained, including power. The expected life of the units was two to three years, and the initial cost (approximately $70) was low enough that periodic replacement was seen as a viable option. However, three conditions emerged that required a re-evaluation of this approach.

During 2008 there were substantial changes in the exchange rate between the US dollar and the Euro. Since the devices were manufactured in Europe, the delivered cost roughly doubled between the purchase of the first devices and the conclusion of the project. At current prices (approximately $150) replacement is no longer a practical maintenance option.

Because of the low number of parts purchased, the project was unable to have the customized units mass-produced, resulting in long delays due to the hand-assembly of boards and international shipping. These conditions caused long delays in replacing failed components and associated partial system down time.

The largest issue uncovered in the prototype deployment was the much shorted service life of the internal battery than had been planned. Instead of the expected two to three years, typical battery life was six to eight months. The shorter battery life was a particular issue as the batteries were not replaceable and the devices were a critical failure point for the system. Ultimately, all Wavelogs were replaced during the course of the project, but these also failed during the six to eight month window. SRF has since re-designed the power supply for the devices, as described in the "Future Directions" section.

Detection System

The detectors used in the initial deployment were re-used for the re-designed system. However issues emerged with the mounting methods and reliability of the detectors that had sat un-powered for up to six years.

The previous installation did not completely secure the detector mounts and thus allowed the alignment between transmitters and receivers to "drift" over time. The mounting also allowed vibration to affect detector alignment in high-wind conditions. All of the original detection devices were replaced and properly secured during the course of the project. A re-design of the detector mount will drastically reduce vibration of future systems

FUTURE DIRECTIONS

The initial deployment of the system has provided a great deal of information that will be incorporated into a revised design. A summary of design revisions by subsystem is given below.

Sign/Beacon Design

The mechanical design of the beacon assembly has been re-designed to eliminate the separate equipment enclosure and solar panel mount for the power system and the associated flexible conduits. The revised version connects the equipment enclosure directly to the supporting steel conduit and eliminates the need to assemble components on site. The resulting assembly can be bench tested prior to field installation and will be a more reliable and serviceable product.

Power System

As noted above, the power system proved to be inadequate for the needs of the system. The Sign power system will be provisioned with a 50% larger battery than in the initial design, which should enable very high availability. The system in Marshall has been retrofitted with these batteries.

The detector power system is more problematic, due to the dynamic and continuous power consumption of the detectors. A re-designed system will incorporate solar panels with 300% greater output and batteries offering 350% more reserve capacity. These changes require substantial changes in the mounting arrangement of components and cannot be retrofitted in Marshall without a wholesale replacement of the existing system. A more conservative upgrade has been fitted, however, and it appears to have resolved the power issues.

Communications System

The communications system has been the most problematic of the prototype subsystems. As noted in the Equipment Performance section, several specific issues have been identified and strategies have been created to address each of these in future deployments.

Device Lifetime

The built-in power source of the Coronis device is not adequate for the deer warning application. To address this shortcoming, future versions of the device will include connections to the beacon or detector power source. The very low power drain of the Wavelog device (<50 microamps average) will not have a significant impact on the overall power consumption or reserve capacity of the system batteries.

The first examples of the revised design have been produced and are being evaluated now.

Availability

Since moving to a mass-production scenario is not feasible in the near future, Wavelogs will continue to be assembled in low-volume batches. To mitigate the long lead times for part availability, a manufacturing partner in the United States will be located. Raw components will then be supplied from Europe and assembled in the U.S., eliminating the hand-assembly problems associated with the current arrangement.

Arrangements for “local” assembly are expected to be completed by late summer 2009.

References:

(1) "Traffic Safety Facts 2004", National Highway Traffic Safety Administration, U.S. Department of Transportation, Washington, DC, 2004, p.54

(2) "Worst 10 states for auto-deer collisions", CNN Money, available at: http://money.cnn.com/2005/11/04/news/newsmakers/deer/

(3) Knapp, et al, "Statewide and Upper Midwest Summary of Deer-Vehicle Crash and Related Data from 1993 To 2003", Midwest Regional University Transportation Center Deer-Vehicle Crash Information Clearinghouse, December 2005

(4) Knapp, et al, "Deer-Vehicle Crash Countermeasure Toolbox: A Decision And Choice Resource", Midwest Regional University Transportation Center Deer-Vehicle Crash Information Clearinghouse, June 2004