Innovative "Intelligent" Awareness System for Roadway Workers Using Dedicated Short-Range Communications

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Introduction

Every day, there are thousands of roadway workers that must perform their duties near passing motorists in both defined and undefined work areas. These roadway workers include construction crews, public safety workers, survey crews, and roadway clean-up/mowing personnel.

In defined work zone areas, the movement of vehicles (e.g., traffic, dump trucks and powered mobile construction equipment) around a work zone poses a significant safety risk to nearby workers-on-foot (WOFs). Each year more than 20,000 injuries and more than 100 fatalities occur at road construction zones. Nearly two-thirds (62 percent) of these incidents involved a worker being struck by a construction vehicle.

In undefined roadside work areas, such as traffic stops, vehicle accidents, surveying for future construction, or clean-up, there are several groups of vulnerable roadway workers that are particularly exposed to vehicle strikes due to the fluidity of the traffic site and the lack of infrastructure protections (e.g., barriers) afforded more established work zones.

Defined Work Area

Undefined Work Area

While all roadway personnel (i.e., workers in both defined and undefined work areas) could benefit from an intelligent traffic awareness system; this project will primarily focus on developing the system for workers in and around undefined work areas. These individuals would gain the greatest benefit from such a wearable intelligent traffic awareness system. Given the prevalence and severity of these struck-by injuries, a novel approach is needed to mitigate the conflicts between vehicle and WOFs. Connected vehicle technology offers this opportunity to develop an effective and reliable alerting system for all roadway workers whether working within a structured work zone or standing along the roadway in an undefined work area.

This project will use the expertise of the research team in the fields of vehicle-to-vehicle (V2V) communication and pervasive computing to develop an innovative "intelligent" awareness system. The system will comprise dedicated short-range communications (DSRC) technology mounted on vehicles and worn by roadway personnel. Since roadway personnel are required to wear Class 2 or 3 apparel (image below) while working in right-of-ways on federal-aid highways, 5 this project will embed the DSRC technology within these types of garments for the purposes of demonstration.

Class 2 Reflective Vest

Research Objectives

The objectives of this study are twofold. The first is to develop and test a wearable "intelligent" traffic awareness system, *InZoneAlert*, to be deployed on both vehicles and WOFs. The system will alert WOFs and vehicle operators of impending struck-by incidents. This system will alert workers only in the case of accidental close interactions and will not provide false alarms for intentional close interactions between traffic and the equipped worker. The alert system should provide warnings in sufficient time to allow the accident to be avoided and should require minimal, cost-effective redesign of both vehicles and workers' clothing. The second objective is to evaluate the functional effectiveness of the developed *InZoneAlert* system under operational conditions. This evaluation will occur on the Connected Vehicle/Infrastructure University Transportation Center (CVI-UTC) test bed at the Virginia Smart Road in Blacksburg, Va. This project will provide a solid research-to-practice (R2P) approach to mitigating work zone struck-by incidents via the development of a novel countermeasure specific to the problem and verification of its effectiveness under realistic operational conditions.

Methodology

The first task will develop the *InZoneAlert* system. First, the research team will be to incorporate DSRC technology (e.g., Denso's MiniWSU) into the previously developed *ZoneAlert* construction work vest (image below left). The Denso MiniWSU provides a small (106 mm x 72 mm X 25 mm) unit size that will allow it to be worn by the user without overly restricting movement. The foremost challenge will be developing a sufficient power supply for the worn system; however, the research team feels confident a solution can be quickly developed.

The previous *ZoneAlert* vest was a product of an interdisciplinary design project course taken by Virginia Tech students. This vest has woven circuitry, light-emitting diodes (LEDs), and vibration motor systems for warnings; a microcontroller board; Bluetooth capability; and software. A DSRC radio will be incorporated into the design of the vest to provide the wearer's relative position to adjacent vehicles. These modifications will be completed by students of the Virginia Tech Interdisciplinary Product Development Studio, which focuses on the design of pervasive computing products. The iterative design process will include creating concepts, constructing prototypes, evaluating the prototypes with users, and feeding evaluation results into the creation of the next concept or prototype.

Second, the research team will develop an in-vehicle driver interface to the alerting system using a device (e.g., electronic tablet) to emulate a "factory-installed" stacked display (image below right). This display will use both visual and auditory signals to alert the driver of an impending collision with a WOF. Once the individual *InZoneAlert* system components have been finalized, the entire system will be integrated and tested on the CVI-UTC test bed at the Virginia Smart Road.

Prototype ZoneAlert Vest

Simulated Integrated Factory-Installed Display

Evaluation

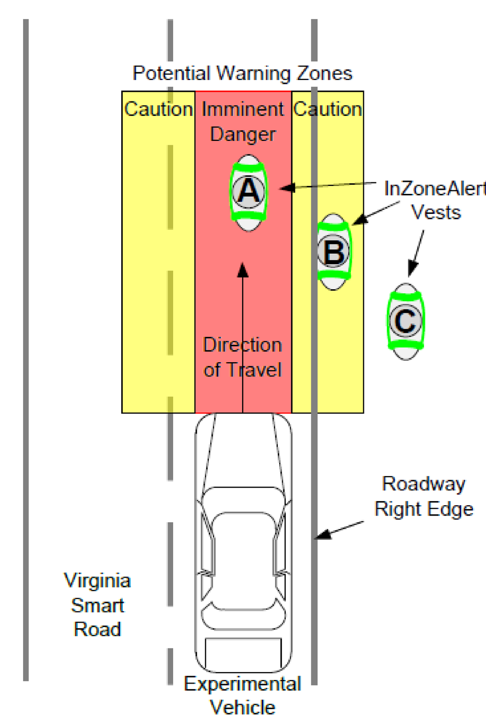
To evaluate the effectiveness of the *InZoneAlert* system, researchers will focus on system activation testing (i.e., does it work?) in Task 2. The research team will exercise the system using a signal detection paradigm. Determining when to activate and de-activate the *InZoneAlert* system is a critical component of an effective system. If such a system is activated correctly, it should provide the warning only when a struck-by incident is likely to occur and not at any other time. Additionally, it must not miss situations where a struck-by incident is likely to occur.

There are actually four aspects to such a system, as with any other detection system, as follows when applied to struck-by incidents:
1. Activation when a struck-by incident would otherwise occur (correct detection),
2. Non-activation when a struck-by incident would otherwise occur (missed detection),
3. Activation when a struck-by incident would not otherwise occur (false alarm), and
4. Non-activation when a struck-by incident would not otherwise occur (correct non-detection).

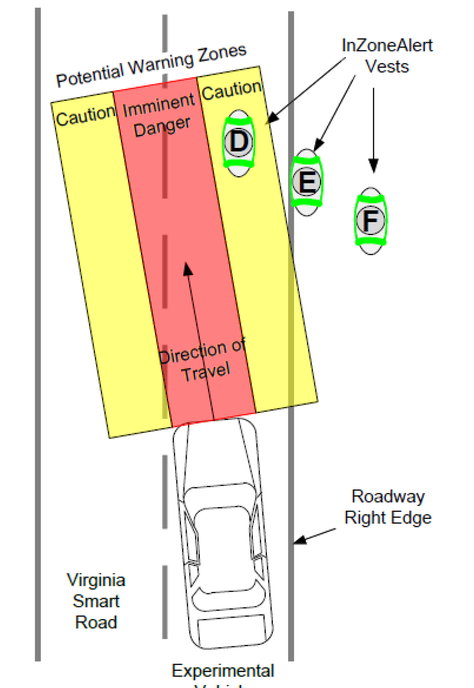
The objective is to maximize the probabilities of occurrence of #1 and #4, and minimize the probabilities of occurrence of #2 and #3. While this may seem to be a straightforward situation, closely related to signal detection theory, in practice it can be very difficult to achieve with developmental systems.

	Threat (Worker in Path of Vehicle)	**No Threat** (Worker *NOT* in Path of Vehicle)
Yes (Alert)	Hit (Correct Detection)	False Alarm
No (No Alert)	Miss (Missed Detection)	Correct Rejection (Correct Non-detection)

To exercise this signal detection matrix, researchers will perform six struck-by vehicle scenarios when there is a threat present or when there is no threat present on the Virginia Smart Road. Using a CVI-UTC DSRC-equipped test vehicle, the research team will drive by the InZoneAlert vests positioned in the middle of the lane, along the lane edge, and in the road's shoulder to determine the system's efficacy. Key measures to be collected include the relative position between the vehicle and the vest to determine if the vest is present/absent in the system's warning zones and the system's response (i.e., a warning of imminent danger, a caution, or no response) based on the programmed algorithmic thresholds. Each scenario will be repeated 15 times.



Simulated Work Area (Straight)



Simulated Work Area (Merge)

CVI UTC
MORGAN STATE UNIVERSITY
VirginiaTech Transportation Institute
University of Virginia