Evaluating Work Zone Intrusion Alarm (WZIA) Systems for Inclusion in Standard Traffic Control Plans

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Outline

• Overview
• Selected/Procured WZIA Systems
• Systems Testing/Feedback Procedures
• (Highlights of) General Performance Results of Selected WZIA Systems
• Guidance on Practical Deployment in Standard Traffic Control Plans
• Cost Analysis
• General Recommendations (to Manufacturers)
• Future Research
Overview: Objectives and Introduction

- **Objectives**
  - Evaluate the effectiveness of Work Zone Intrusion Alarm (WZIA) systems
  - Assess practicality of deployment and implementation guidance

- **Introduction - What is a Work Zone Intrusion Alarm (WZIA) system?**
  - Supplement existing work zone (WZ) best practices
  - Complement existing traffic control devices (TCDs) in MUTCD - *not to replace*!

- **Primary types of sensor intrusion and communication system technologies (which can be combined):**
  1. Kinematic – activated by physical impact
  2. Infrared – interrupted beam of light
  3. Pneumatic – air pressure in tube sensors
  4. Microwave – monitors work zone and potential intrusion using microwaves
  5. Radar – monitors work zone and intrusion using radar
     (Radio – communication between sensors and an alarm)
     (Fyhrie, 2016; Marks et al., 2017)
Overview: Project Tasks

• Project Tasks
  – Task 1: Form Project Advisory Panel
  – Task 2: WZIA Systems Assessment and Literature Review
  – Task 3: Selection and Procurement of WZIA Systems
  – Task 4: Development of Testing Plans and Protocols
  – Task 5: Pilot Testing
  – Task 6: Supplemental Testing
  – Task 7: Recommendations and Report
Selected/Procured WZIA Systems: WAS

- **Worker Alert System (WAS)** – Pneumatic tubes to pressure sensor and uses microwave communications to a portable alarm case (PAC) with alarm light and speaker and to a vibrating personal safety Device (PSD)

Source: trafficsafetywarehouse.com, 2017

Selected/Procured WZIA Systems: SonoBlaster

- **SonoBlaster** – Kinematic “system” uses disposable CO\(_2\) cartridges to blow an air horn when traffic cone fitted with device is tipped

Source: Transpo Industries Inc., 2017
Selected/Procured WZIA Systems: Intellicone

- **Intellicone** - Kinematic system uses lamps (lights) with motion sensors that mount on cones and communicate via radio to an alarm unit with auditory and visual alarms when tipped; system can also use web-enabled system with GPS to program a work zone.

Source: transcanadatraffic.ca, 2019
Systems Testing/Feedback

- Closed System Testing & Observations
- Maintenance Staff Survey/Feedback
  1. Pre-Deployment
  2. Deployment
  3. Operation
    - Sound Tests
    - Outcomes Tests (Type I and Type II Errors)
  4. Practicality and Effectiveness

Possible WZIA Evaluation Trial Outcomes

<table>
<thead>
<tr>
<th>Vehicle Intrusion</th>
<th>Alarm Activated</th>
<th>No Alarm Activated</th>
</tr>
</thead>
<tbody>
<tr>
<td>True Positive – Alarm activated as designed.</td>
<td>False Negative – Alarm fails to activate during a vehicle intrusion.</td>
<td>False Positive – Alarm is activated when no vehicle intrusion occurs. True Negative – Alarm at rest as designed (not activated). This is the normal, “ready” operating state.</td>
</tr>
<tr>
<td>No Vehicle Intrusion</td>
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Results – Worker Alert System (WAS)
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• Pre-Deployment
  – Charge alarm unit battery
  – Replace disposable batteries in personal safety device (PSD), pressure sensor, and hand-held remote
  – Easy to transport
  – Accidental activation due to raised buttons on PSD and hand-held remote (removal of batteries during transport recommended)

• Deployment
  – Ease of deployment, minimal worker exposure (survey comments)
  – Pressure sensor should be positioned near the shoulder
  – Multiple trip hoses can connect to transmit signal over a large area providing greater coverage
  – Flexibility of trip hose to be deployed in multiple configurations; openings for maintenance vehicles

(Note: Additional issues were observed with an older-model unit.)
Results – Worker Alert System (WAS)

- **Operation**
  - Audio alarm and visual alert; PSD adds sensory (vibratory) alert and audio (via earbud only)
  - Max. range between trip hose and nearest alarm unit: 225 ft
  - Alarm unit should be deployed 4 ft above ground using base magnet
  - Multiple trip hoses and alarm units can provide adequate sound and detection coverage in work zone
  - **PSD availability is a significant advantage** (75-ft max range in vicinity of alarm unit)
  - **Low sound intensity relative to other systems** (60 dBa); can be remedied by using multiple alarm units, but limited by connection range between units (175 ft)
  - Alarm duration: 5 sec; Speaker on one side (alarm unit orientation is important)
  - Hand-held remote for flagging and manual operation
  - No discernable delay in alarm activation
Results – Worker Alert System (WAS)

- Practicality and Effectiveness
  - “Minimal setup” consists of single trip hose and alarm unit
  - Provides moderate reaction time for workers
  - Assumes vehicle travels in the closure and crosses the one trip hose
  - Additional trip hoses and alarm units could provide greater coverage
  - Overall positive feedback from maintenance staff

<table>
<thead>
<tr>
<th>Vehicle Speed at Trip Hose Impact (miles per hour)</th>
<th>Minimum Reaction Time (seconds) for Workers to React (Using a Minimal Setup*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 (37)</td>
<td>6.1</td>
</tr>
<tr>
<td>30 (44)</td>
<td>5.1</td>
</tr>
<tr>
<td>35 (51)</td>
<td>4.4</td>
</tr>
<tr>
<td>40 (59)</td>
<td>3.8</td>
</tr>
<tr>
<td>45 (66)</td>
<td>3.4</td>
</tr>
<tr>
<td>50 (74)</td>
<td>3.1</td>
</tr>
<tr>
<td>55 (81)</td>
<td>2.8</td>
</tr>
<tr>
<td>60 (88)</td>
<td>2.6</td>
</tr>
<tr>
<td>65 (96)</td>
<td>2.4</td>
</tr>
</tbody>
</table>
Results – SonoBlaster
SonoBlaster – Overall Performance

• Pre-deployment
  – Mechanically operated, no batteries required
  – Approx. 9 lbs. (cone and installed SonoBlaster)
  – Mounting bracket installation required on each cone (approx. 10 - 15 minutes labor installation)
  – Perceived flimsy bracket installation, durability (survey comment)
  – Cannot fit typical Caltrans “cone body truck” in two rows

• Deployment
  – Accidental activation during deployment from cone body truck
  – Slower to deploy, device requires unlocking (survey comments)
  – Could be transported while stacked vertically
  – Increased exposure during slow deployment (survey comments)
SonoBlaster – Overall Performance

• Operation
  – Loudest audio alarm of all devices tested (78 dBA)
  – No visual alert
  – Inconsistent operation - 15 to 90 second alarm duration
  – High probability of “false negatives”
  – Difficulty in proper installation of CO₂ cartridge
  – Some devices broke down after repeated use; should be discarded after first activation
  – Failed to activate in field test by maintenance staff
  – Moisture and freezing issues (maybe of concern in cold weather conditions)

• Effectiveness and Practicality
  – Highly effective in alerting workers when properly activated
  – Overall feedback/comments from maintenance staff were unfavorable
  – If deployed, many devices can achieve maximum coverage and mitigate the possibility of failed activations
Results – Intellicone
Intellicone - Overall Performance

• Pre-deployment
  – PSA requires 24-hour charging
  – Disposable/rechargeable batteries for lamps
  – One person can carry 2-3 alarm units or up to 8 lamps

• Deployment
  – Benefits from simple deployment, single button turn-on (survey comments)
  – Up to 5 minutes of start-up time to acquire GPS and network signals
  – Lamps turn on automatically when placed on cones
  – Most complicated system to learn to deploy
  – Lamps come with 5 different sensitivity levels (using different sensitivities is not recommended)
  – Possible increase in exposure while placing lamps (survey comments)
Intellicone - Overall Performance

• Operation
  – Most consistent operation of all systems tested; audio alarm and visual alert capabilities
  – No “false negative” tests were observed when the system was deployed properly.
  – Max. range distance between single alarm unit and lamp is 100 ft
  – Max. range distance between lamps or between alarm units is 100 ft
  – Range measurements met manufacturer specifications
  – Multiple lamps and PSA units can connect with each other to provide adequate sound and detection coverage in a work zone (more units are required for adequate detection)
  – Low sound intensity (61 dBa)
  – Alarm duration is 32 seconds
  – Three-tone alarm sound is specially designed to be highly effective in alerting workers
  – No discernable delay in alarm activation.
  – Two types of rotating visual alerts, ok during daytime, most effective during nighttime
## Intellicone - Overall Performance

- **Practicality and Effectiveness**
  - Transverse lamp deployment recommended for added coverage
  - Typical deployment layout shown in figure
  - Short setup distances could provide insufficient advance warning
  - Additional lamps and alarm units can provide greater coverage and warning to workers
  - Overall positive feedback from maintenance staff

![Diagram of Intellicone system](image)

<table>
<thead>
<tr>
<th>Vehicle Speed at Cone Impact - miles per hour (feet per second)</th>
<th>Minimum Reaction Time (seconds) for Workers (Cones Impacted 100 feet from Alarm)</th>
<th>Minimum Reaction Time (seconds) for Workers (Cones Impacted 200 feet from Alarm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 (37)</td>
<td>2.7</td>
<td>5.4</td>
</tr>
<tr>
<td>30 (44)</td>
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Guidance on Practical Deployment in Work Zone Standard Control Plans

(Scenario: T-13 Closure)
Guidance on Recommended Deployment in Standard Traffic Control Plans

• Goals
  – Supplement existing Standard Work Zone Traffic Control Plans
  – Provide Detailed Guidance on Practical Deployment in Active Work Zone

• Primary Focus – T13 Caltrans Standard Traffic Control Plan
  – Lower speed work zone deployment preferred given reaction time and sound/noise level concerns
  – Lack of information on reliability/functionality in high speed applications

• Maintenance Staff Feedback/Recommendations Considered
WAS – Recommended Deployment Plans

- **33’ upstream Trip Hoses**
- **225’ max. distance from nearest alarm unit**
- **75’ max distance between Trip Hoses recommended for effective coverage**

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**Typical Lane Closure with Reversible Control**

- **Alarm Location**
- **175’ max. distance between units**
- **Alarm units 4’ from ground on the side of a test vehicle with clear line of sight**

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**Alarm Location (in work area)**
- **Alarm units 4’ from ground on the side of a test vehicle with clear line of sight**

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**33’ Trip Hose**

**PSD within 75’ of any alarm unit**
Intellicone – Recommended Deployment Plans

- Intellicone Lamps
  - 100' max. distance between lamps
  - 100' max. distance between PSA and the nearest lamp
  - 5' max. distance between transverse lamps

- Intellicone PSA Unit
  - 100' max. distance between two PSA units
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Questions?