Early Warning Overheight Vehicle Detection Systems for Falsework in Work Zones: Survey of Practice

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Executive Summary

Background

Currently, the California Department of Transportation (Caltrans) highway system does not have a system in place that will provide the traveling public or commercial vehicle drivers with an early warning that a vehicle load may exceed height restrictions and could impact falsework in an upcoming construction zone. Caltrans is interested in learning about temporary, real-time vehicle detection systems that generate a warning to drivers in advance of the structure under construction and may also warn workers within the work zone that an overheight vehicle is approaching.

Caltrans is seeking information from other state departments of transportation (DOTs) that have experience using overheight vehicle detection systems in work zones. These systems warn drivers that their vehicle load may be overheight and could impact falsework in a construction zone downstream. The focus of this inquiry is on temporary systems used in work zones, not overheight vehicle detection systems associated with permanent low-clearance structures.

To assist Caltrans in this information-gathering effort, CTC & Associates conducted an online survey of state DOTs that examined these agencies' experience with overheight vehicle detection systems. A literature search identified publicly available sources of both domestic and international research and best practices.

Summary of Findings

Survey of Practice

An online survey was distributed to members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Construction who were expected to have experience with overheight vehicle detection in work zones. Twenty-one transportation agencies responded to the survey: 20 state DOTs and the District of Columbia DOT.

Of these 21 transportation agencies, only Arizona DOT reported installing early warning overheight vehicle detection systems in work zones. Respondents from two states—New Jersey and Oklahoma—briefly discussed their agencies' plans to install temporary warning systems in work zones. Six states that do not install early warning systems—Arkansas, Michigan, Nebraska, North Carolina, Virginia and Wyoming—explained why their agencies did not use the warning systems or described alternative approaches.

<u>Users of Overheight Vehicle Detection Systems in Work Zones</u>

Arizona DOT has used a banger-beam system to alert overheight vehicles of the presence of falsework that is temporarily lowering clearance for a bridge under construction. The Arizona DOT respondent noted that banger beams are used on crossroads, not on the highway. Additional details about the system and the agency's experience with system installation, system use and administrative issues related to system operations are summarized below.

System Description

Arizona DOT has used both corrugated metal pipe and I-beams cabled overhead that release on overheight vehicles, preventing them from entering the work zone. The respondent was familiar with three projects in which detection systems had been installed in work zones. The systems did not provide any type of reporting, and the costs were included in the contractors' bids.

System Installation

Agency staff installed the overheight vehicle detection systems. These systems were not installed far enough in advance of the falsework in the work zone to allow a vehicle to exit the highway before encountering the bridge under construction, nor were they installed on the on-ramp just before the falsework in the work zone to prevent an overheight vehicle from entering the highway.

System Use

With these systems, only the driver is alerted when an overheight vehicle is detected, not the workers in the work zone or the agency's traffic management center. The posted speed limit in the specific work zone location where the overheight vehicle detection system is installed is 25 mph. Arizona DOT has not conducted any tests of the warning system, and the respondent was not aware of any false alarms or instances of failed detection with the system.

Administrative Issues

Arizona DOT does not include specifications in construction contracts that address the installation and use of an overheight vehicle detection system in work zones. The agency has not identified the number of accidents that were successfully diverted as a result of the warning system installed in the work zone or the number of accidents that occurred in a work zone location with a properly operating warning system.

Nonusers of Overheight Vehicle Detection Systems in Work Zones

Twenty of the 21 agencies responding to the survey do not currently install early warning systems in work zones to alert overheight vehicles of falsework that is temporarily lowering clearance for a bridge under construction.

Agencies With Plans to Install Overheight Vehicle Detection Systems

New Jersey and Oklahoma DOTs are both planning to install temporary early warning systems in work zones. In New Jersey, specific details of those plans are unknown. The Oklahoma DOT respondent noted that the agency is considering these systems as part of its smart work zone technology expansion plans.

Other Agency Practices

Six states that do not install early warning systems—Arkansas, Michigan, Nebraska, North Carolina, Virginia and Wyoming—briefly discussed agency practices to address temporary clearance issues. These practices were transferring responsibility for warning systems to contractors (Arkansas, Michigan and Nebraska); maintaining the structure's minimum clearance (North Carolina and Virginia); using permanent vehicle clearance signs in temporary construction work zones (Wyoming); notifying other state agencies about the clearance changes (Arkansas); and posting alerts on agency web sites (Wyoming).

Related Research and Resources

A literature search of domestic and international resources was conducted to gather information about overheight vehicle detection systems, with a specific focus on temporary systems used with falsework in work zones. Several publications and resources provide background information about overheight vehicle detection systems in general, including product names and technical details.

State Research and Practices

Publications and guidance from state resources describe both temporary and permanent applications of overheight vehicle detection systems. Among the temporary system application citations is a 2019 Arizona DOT working paper that summarizes various smart work zone solutions implemented by Iowa, Kansas, Michigan and Texas DOTs. The working paper also highlights smart work zone vendors and product information. Additional guidance about smart work zone technology is provided in a 2017 Connecticut DOT guide, 2016 standard operating procedures from Massachusetts DOT and 2018 design guidelines from Texas DOT. Vertical clearance guidance is provided in a 2019 Washington State DOT manual.

Following the resources about temporary system applications is state research describing permanent applications. A 2017 Georgia DOT study identified 22 state DOTs using various warning systems. The report includes a brief discussion of each system. A 2018 North Carolina DOT report describes a warning system that detects overheight vehicles and warns drivers in real time, advising them to use an alternative route. A 2015 Texas DOT presentation provides background information on overheight vehicle detection systems and discusses two demonstration sites.

International Research and Related Resources

International research includes a 2018 journal article that reports on a full validation of a warning system using a constraint-based approach to minimize the number of overheight vehicle misclassifications caused by windy conditions. A 2016 conference paper presents a comprehensive synthesis of the nature and scope of the problem of bridge and tunnel strikes, followed by the current state of practice and current state of research to help bridge owners identify reliable and affordable vehicle detection systems.

Other research is described in a 2017 journal article that features a new method for preventing overheight vehicle strikes. The method uses a single calibrated camera mounted on the side of the roadway to detect overheight vehicles. The accuracy of this method is comparable to existing laser beam systems at a significantly lower cost. A 2014 journal article provides an overview of work zone technologies that enhance safety for road crews and the traveling public.

Vendor Guidance

System and product information is presented for several domestic and international vendors that provide temporary overheight vehicle detection system installations. Among the domestic vendors highlighted are Trigg Industries, ASTI Transportation Systems and Ver-Mac. International vendors include Highway Resource Solutions, with a case study of the UK Highways Agency’s M62 and M1 J39-42 smart motorway project. The overheight vehicle detection system featured in the project is the first temporary road maintenance safety offering that combines modular electronic perimeters with variable message signs.

Gaps in Findings

Only one of the 21 state DOTs responding to the survey installs early warning overheight vehicle detection systems to alert drivers of falsework that temporarily lowers the clearance of structures in work zones. Two other agencies reportedly have plans to install these warning systems, although plans are currently indefinite. Reaching out to agencies not participating in the survey could uncover useful information about other DOT experience and practices with overheight vehicle detection systems in work zones.

Next Steps

Moving forward, Caltrans could consider:

- Reviewing the information provided by Arizona DOT about its banger-beam system for further insight into system installation and operations.
- Remaining in contact with New Jersey and Oklahoma DOTs to stay informed about their efforts to install early warning vehicle detection systems in bridge construction work zones.
- Examining the research reports and guidance cited in **Related Research and Resources**, specifically the domestic and international resources that describe temporary applications of these early warning systems.
- Reviewing the vendor guidance cited in **Related Research and Resources** for appropriate applications and devices.

Detailed Findings

Background

Overheight vehicle detection systems warn the traveling public or commercial vehicle drivers that their vehicle load may exceed the height restrictions of a bridge or other structure ahead. To enhance traffic safety on its highway system, the California Department of Transportation (Caltrans) is exploring the use of temporary early warning systems in work zones to alert drivers of falsework that temporarily lowers the clearance of structures in construction zones. These temporary, real-time vehicle detection systems generate a warning to drivers in advance of the structure under construction and may also warn workers within the work zone that an overheight vehicle is approaching.

Caltrans is seeking information from other state departments of transportation (DOTs) about their experience using overheight vehicle detection systems to warn drivers that their vehicle load may be overheight and could impact falsework in a construction zone downstream. The focus of this inquiry is on temporary systems used in work zones, not overheight vehicle detection systems associated with permanent low-clearance structures.

To assist Caltrans in this information-gathering effort, CTC & Associates conducted an online survey of state DOTs that examined these agencies' experience with overheight vehicle detection systems. A literature search was also conducted to identify publicly available sources of both domestic and international research and best practices. Findings from these efforts are presented in this Preliminary Investigation in two areas:

- Survey of practice.
- Related research and resources.

Survey of Practice

An online survey was distributed to members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Construction who were expected to have experience with overheight vehicle detection in work zones. Survey questions are provided in Appendix A. The full text of survey responses is presented in a supplement to this report.

Summary of Survey Results

Respondents from 20 state DOTs and the District of Columbia DOT responded to the survey:

- Arizona.
- Arkansas.
- Delaware.
- District of Columbia.
- Florida.
- Indiana.
- Kentucky.
- Michigan.
- Nebraska.
- New Hampshire.
- New Jersey.
- North Carolina.
- North Dakota.
- Ohio.
- Oklahoma.
- Pennsylvania.
- Rhode Island.
- Utah.
- Virginia.
- Wisconsin.
- Wyoming.

Of these 21 transportation agencies, one state agency—Arizona DOT—reported that it installs early warning overheight vehicle detection systems in work zones.

Survey results are summarized below in the following topic areas:

- Users of Overheight Vehicle Detection Systems in Work Zones.
- Nonusers of Overheight Vehicle Detection Systems in Work Zones.

Users of Overheight Vehicle Detection Systems in Work Zones

One state agency responding to the survey—Arizona DOT— installs early warning systems in work zones to alert overheight vehicles of the presence of falsework that is temporarily lowering clearance for a bridge under construction. The respondent from Arizona DOT reported that the agency has used banger beams on crossroads—not on the highway—to provide an early warning.

Table 1 below summarizes the respondent's description of the banger-beam system used by Arizona DOT. Additional details are also provided about system installation practices (Table 2), system use (Table 3) and administrative issues related to system operations (Table 4).

Table 1. Arizona DOT Overheight Vehicle Detection System: Description

Topic	Description
System	Banger beams.
System Operations	The agency has used both corrugated metal pipe and I-beams cabled overhead that release on overheight vehicles, preventing them from entering the work zone.
Number of Systems Installed in Work Zones	Three detection systems have been installed in the agency's work zones.
Initial Cost of System	The cost of the system is included in the contractor's bid.
Type of Reporting Provided	None.

Table 2. Arizona DOT Overheight Vehicle Detection System: Installation

Topic	Description
System Installer	Agency staff installs the system.
System Installed in Advance of Falsework to Allow Vehicle to Exit	No. The warning system is not installed far enough in advance of the falsework in the work zone to allow a vehicle to exit the highway before encountering the bridge under construction.
System Installed on the On-Ramp Before Falsework	No. The warning system is not installed on the on-ramp just before the falsework in the work zone to prevent an overheight vehicle from entering the highway.
Other Factors That Determine System Location	The agency has only installed banger beams on crossroads, not on the highway.

Table 3. Arizona DOT Overheight Vehicle Detection System: System Use

Topic	Description
Person/Agency Alerted When Overheight Vehicle Detected	The driver of the overheight vehicle.
Posted Speed Limit	The posted speed limit in the specific work zone location where the overheight vehicle detection system is installed is 25 mph.
System Testing	The agency has not conducted any tests of the overheight vehicle detection system.
False Alarms or Failed Detection	The respondent was not aware of any false alarms or instances of failed detection with the system.

Table 4. Arizona DOT Overheight Vehicle Detection System: Administrative Issues

Topic	Description
Contract Specifications	The agency does not include specifications in construction contracts that address the installation and use of an overheight vehicle detection system in work zones.
Number of Accidents Diverted by System	The agency has not identified the number of accidents that were successfully diverted as a result of the overheight vehicle detection system installed in its work zones.
Number of Accidents That Have Occurred	The agency has not identified the number of accidents that have occurred in a work zone location with a properly operating overheight vehicle detection system.

Nonusers of Overheight Vehicle Detection Systems in Work Zones

Twenty of the 21 agencies responding to the survey do not currently install early warning systems in work zones to alert overheight vehicles of falsework that is temporarily lowering clearance for a bridge under construction:

- Arkansas.
- Delaware.
- District of Columbia.
- Florida.
- Indiana.
- Kentucky.
- Michigan.
- Nebraska.
- New Hampshire.
- New Jersey.
- North Carolina.
- North Dakota.
- Ohio.
- Oklahoma.
- Pennsylvania.
- Rhode Island.
- Utah.
- Virginia.
- Wisconsin.
- Wyoming.

Agencies With Plans to Install Overheight Vehicle Detection Systems

Respondents from two of these states—New Jersey and Oklahoma—provided information about their agencies' plans to install temporary early warning systems in work zones:

> *New Jersey*. According to the respondent, the agency is considering installing these systems but plans are unknown.
>
> *Oklahoma*. Oklahoma DOT has installed a small number of overheight vehicle detection systems in permanent applications, but not in work zones. The respondent reported that the agency is considering these systems as part of its plan to expand its smart work zone technology.

Other Agency Practices

Six states that do not install early warning systems—Arkansas, Michigan, Nebraska, North Carolina, Virginia and Wyoming—briefly discussed the approaches taken by their agencies to address temporary clearance issues. The primary practices cited by respondents were transferring responsibility for warning systems to contractors (Arkansas, Michigan and Nebraska); maintaining the minimum clearance (North Carolina and Virginia); using permanent vehicle clearance signs in temporary construction work zones (Wyoming); notifying other state agencies about the clearance changes (Arkansas); and posting alerts on agency web sites (Wyoming). Survey responses are summarized below by topic:

Contractor requirements:

- *Arkansas*. Most systems used by contractors in Arkansas do not significantly impact vertical clearance. Work platforms rest on the tops of the bottom flanges of the existing girders. However, if the platform does reduce vertical clearance beyond the legal load height, contractors are required to erect appropriate signage.
- *Michigan*. While Michigan DOT does not have plans to install overheight vehicle detection systems, its contractors must obtain agency approval if the planned construction will impede underclearance. Agency specifications include the following requirement:

  > **Vertical Clearance**. The Department defines minimum underclearance as the minimum vertical distance from any point on the pavement, including 24 inches either side of the pavement, to the structure.
  >
  > - Maintain form work above the bottom of beams. If form work must extend below the bottom of beams, obtain the Engineer's approval.
  > - Provide and place advance-warning signs at locations directed by the Engineer before changing the existing structure underclearance.
  > - Provide 10 working days for the Engineer to determine the locations for the advance warning signs.

- *Nebraska*. The agency has not used a notification system for overheight trucks (and doesn't intend to specify one) because of the low incidence of falsework in the state. However, contractors may request that a notification system be used if it is necessary.

Minimum clearance:

- *North Carolina*. When falsework is installed in North Carolina, it must provide minimum clearances, that is, the clearances must be the same or better than existing conditions.

- *Virginia*. The agency does not allow work platforms below 16 feet over Interstate systems. Work is normally completed on mobile platforms that can be rolled out in lane closure operations.

Use of permanent clearance signage:

- *Wyoming*. The agency, which has no plans for adopting overheight vehicle detection systems, changes the permanent vertical clearance signs to account for temporary clearance issues on bridge construction work.

Other practices:

- *Arkansas*. The agency alerts the oversize load permitting section of the Arkansas Highway Police to the temporary changes in vertical clearance.
- *Wyoming*. Height restrictions for the bridge construction work zone are posted on the state web site in addition to the agency's permanent vertical clearance signs.

Related Research and Resources

A literature search of recent publicly available resources identified publications that are organized into the following topic areas:

- State research and practices.
- Related research.
- International research.
- Vendor guidance.

State Research and Practices

This section begins with publications and guidance from state resources that describe temporary applications of overheight vehicle detection systems. Following these citations is research from state sources that describes permanent applications, offering background on system operation and technical details.

Temporary System Applications

Arizona

Nationwide Review of SWZ Technologies, Final Draft Working Paper 1, Smart Work Zone (SWZ) Technical Concept Study, Phase No. 1, February 2019.
https://azdot.gov/sites/default/files/2019/07/swz-study-wp1-nationwide-review-of-swz-technologies.pdf
From the overview:

> As part of Arizona Department of Transportation's (ADOT) Implementation Guidelines for Work Zone Safety and Mobility process review, ADOT is continually looking at ways to expand/enhance existing practices within work zones (WZ). Therefore, ADOT sought assistance to help develop and implement Smart Work Zone (SWZ) operational concepts. These concepts use a combination of intelligent transportation system (ITS) technologies that improve the safety of highway workers and the traveling public by optimizing WZ traffic operations.

This working paper summarizes various smart work zone solutions implemented by Iowa, Kansas, Michigan and Texas DOTs. An overview of smart work zone vendors is also provided and includes solutions offered by ASTI Transportation Systems and Ver-Mac (see **Vendor Guidance**, page 22). Appendix B, which begins on page 157 of the PDF, includes smart work zone guidance from Connecticut, Texas and Washington State DOTs that is cited in this Preliminary Investigation; a Minnesota DOT decision tree for identifying potential ITS scoping needs is also included.

Connecticut

Smart Work Zones Guide, Connecticut Department of Transportation, April 2017.
https://portal.ct.gov/-/media/DOT/documents/dconstruction/WZS_Reviews/STRSWZGuideFINAL20170406withCoverpdf.pdf?la=en
From the executive summary:

> Smart Work Zones (SWZ) are applications of Intelligent Transportation Systems (ITS) in work zones, utilized to help increase safety and mobility. … This guide provides an introduction to SWZ concepts, components, goals, and objectives to be pursued by CTDOT [Connecticut DOT], as well as an overview of different SWZ applications to be used by CTDOT. These applications currently include, but are not limited to, real-time traveler information notifications, performance measurements, queue warning, intrusion detection, excessive speed warning, entering/exiting vehicle notifications, and over height vehicle notifications.

The overheight vehicle application "can be used to provide warnings to drivers of over height vehicles prior to entering areas with low clearance due to construction activity. A typical system includes field sensors along with flashing lights or signs alerting drivers about over-height restrictions, and possibly PVMS [portable variable message signs] to display notification of an alternate route." An overview and sample illustration of this warning system are provided on page 18 of the guide (page 23 of the PDF).

Massachusetts

Smart Work Zone Standard Operating Procedures, Version 1.1, Highway Division, Massachusetts Department of Transportation, February 2016.
https://www.workzonesafety.org/files/documents/SWZ/swz_standard_operating_procedures_MassDOT.pdf
From the introduction:

> Design consultants will use MassDOT's [Massachusetts DOT's] Smart Work Zone Design Standards to evaluate various ITS technology applications to help mitigate the impacts of the road maintenance or construction work.

Among the safety needs discussed in the procedures is clearance warning, which is defined as "[w]arning to over-weight/over-height vehicles of construction-related weight or height restrictions and advise to divert from the route through the construction area." The use of portable changeable message signs (PCMS) and audible warnings is recommended (page 9 of the report, page 13 of the PDF). Testing criteria and required outcomes are summarized on page 19 of the document (page 23 of the PDF). Operating recommendations include posting alternative messages on PCMS when the clearance warning is no longer needed (page 21 of the document, page 25 of the PDF). Data management and archiving practices are provided on page 23 of the document (page 27 of the PDF).

Minnesota

Chapter 5-5.03.19, Warning System—Bridge Height, Traffic Engineering Manual, Minnesota Department of Transportation, June 2015.
http://www.dot.state.mn.us/trafficeng/publ/tem/2015/chapter5.pdf
Chapter 5 of this manual "document[s] currently available Intelligent Transportation System (ITS) technologies and their applications." The definition, purpose and components used in a bridge height warning system are summarized on page 32 of the PDF:

> **Definition**. This type of system detects over height vehicles moving toward obstacles such as bridges, tunnels and other overhead structures and individually warns drivers. A sign is activated when an over height vehicle is detected by the system.
>
> **Purpose and Usage**. The purpose of this system is to detect over-height vehicles and warn the drivers of the impending problem. This will enable them to exit the freeway and avoid the possibility of contact with the bridge.
>
> **Components Used**. Components include:
>
> - Laser detection.
> - Communications.
> - Controller.
> - Power.
> - DMS.

New Hampshire

New Hampshire Work Zone ITS Toolbox: Work Zone ITS Guideline for Smart Work Zone System Selection, 2011 Edition, New Hampshire Department of Transportation, May 2011.
https://www.nh.gov/dot/org/projectdevelopment/highwaydesign/documents/swzman_05102011.pdf
From the introduction:

> The Work Zone (ITS) Toolbox has been prepared as a guideline for selecting an appropriate ITS for existing work zone traffic issues and to mitigate anticipated issues on scheduled projects. … Each WZ [work zone] ITS [intelligent transportation systems] System in the Toolbox is a collection of standard system components which have been combined to produce a useful real-time system. The individual component functions include the collection of data, verifying the accuracy of the data, transmitting the data, storing and managing the data, analyzing the data, and/or providing the data to the motorist.

Vehicle Responsive Systems, one of three categories of ITS systems discussed in the toolbox, "collect and respond to individual vehicle characteristics such as speed, dimensions, and location. When adverse conditions are detected by these systems, motorists need immediate warnings for quick response." This category includes an overdimension warning application (page 15 of the report) with conditions for using this warning system, its benefits and a sample design.

Oregon

Chapter 2.7.1, Overheight Vehicle Warning System (OVWS), Traffic Control Plans Design Manual, 14th Edition, Technical Services, Traffic-Roadway Section, Traffic Standards & Asset Management Unit, Oregon Department of Transportation, January 2019.
https://www.oregon.gov/ODOT/Engineering/Docs_TrafficEng/TCP-Design-Manual-02.pdf
Links to the complete manual and to individual chapters are available at
https://www.oregon.gov/ODOT/Engineering/Pages/TCP-Manual.aspx
This manual provides "an introduction to the standards, practices, devices and technologies that serve as the foundation for the temporary traffic control discipline." The use of overheight vehicle detection systems in construction zones is discussed on page 56 of the report (page 32 of the PDF):

> The OVWS [overheight vehicle warning system] is a warning system used to alert over-height vehicles of an upcoming restricted vertical clearance. The device relies on microwave and infrared technologies to signal a vehicle whose physical height exceeds that of the posted height restriction. The OVWS provides both an audible and visual warning. The PCMS displays instructions as to an alternate route around the restriction.
>
> The OVWS are most effective on high-volume facilities with a significant percentage of truck traffic. Interstate freight routes are prime facilities.
>
> Typically, the request to use this device comes from members of the Project Development Team who are familiar with the construction limitations and the available roadway facilities around the project site. Use OVWS from the QPL [Qualified Products List].

Related Resource:

Qualified Products List, Construction Section, Oregon Department of Transportation, August 2019.
https://www.oregon.gov/ODOT/Construction/Documents/qpl.pdf
Two approved overheight vehicle detection systems are listed on page 27 of the document (page 36 of the PDF):

- **Safety Pass SP-D12** (ASTI Transportation Systems). PCMS devices connected to this device must be from QPL.
- **Trigg Vehicle Detection and Warning** (Trigg Industries International). This is a single or double beam warning device with an audible and visual warning. Attached PCMS must be on QPL.

See **Vendor Guidance**, page 22, for more information about these manufacturers.

Texas

Smart Work Zone Guidelines: Design Guidelines for Deployment of Work Zone Intelligent Transportation Systems (ITS), Texas Department of Transportation, October 2018.
https://ftp.dot.state.tx.us/pub/txdot-info/trf/smart-work-zone-guidelines.pdf
From the introduction:

> This technical report presents TxDOT's [Texas DOT's] recommendations for the basic guidelines for incorporating Intelligent Transportation Systems (ITS) into the TCP [traffic control plan] for roadway construction projects. These guidelines are intended to clarify what ITS Systems are appropriate for "Smart Work Zones" on TxDOT projects, provide general

> design and deployment guidance for these systems, and support state-wide work zone ITS standards and specifications.

Temporary overheight vehicle warning system is one of the six smart work zone systems addressed in this report. This warning system "detects vehicles or loads that are too tall to clear physical limitations such as low bridges in a work zone, and then conveys a warning message to approaching vehicles."

Chapter 2.6 (beginning on page 28 of the report) briefly describes these systems and recommends the following countermeasures:

> In a few cases where traffic is traveling at very low speeds, simple, low-tech horizontal height bars or dangling chains can be used to alert a driver that their vehicle is too tall to navigate under the low structure ahead. For most other cases, an electronic detection system is required to identify vehicle height problems. Twin light beam technology has been used successfully by a number of states as an effective application for detecting these tall vehicles or Over-Height cargo. Dynamic Message Boards or fixed signs with flashing beacons are triggered instantly when any Over-Height detection occurs.

Figure 8 (page 29 of the report) illustrates the use of a temporary warning system in a work zone. Design requirements are presented on page 45 of the report along with three performance metrics:

- Time stamps of equipment stoppages and resumptions per day. (required)
- Total number of Over-Height alerts triggered per month.
- Total number of times the structure was struck by Over-Height vehicles or cargo per week.

A simple decision tree with criteria for selecting a smart work zone overheight vehicle warning system is provided on page 59.

Washington

Chapter 1010: Work Zone Safety and Mobility, Design Manual, Washington State Department of Transportation, September 2019.
https://www.wsdot.wa.gov/publications/manuals/fulltext/M22-01/1010.pdf
Complete manual available at https://www.wsdot.wa.gov/Publications/Manuals/M22-01.htm#Individualchapters
From Chapter 1010.07(5), Vertical Clearance (page 21 of the PDF):

> In accordance with Chapter 720, the minimum vertical clearance over new highways is 16.5 feet. Anything less than the minimum must follow the reduced clearance criteria discussed in Chapter 720 and be included in the temporary traffic control plans. Maintain legal height on temporary falsework for bridge construction projects. Anything less than this must consider over-height vehicle impacts and possible additional signing needs and coordination with permit offices. Widening of existing structures can prove challenging when the existing height is at or less than legal height, so extra care is required in the consideration of over-height vehicles when temporary falsework is necessary. Coordination with the HQ Bridge and Structures Office is essential to ensure traffic needs have been accommodated. Vertical clearance requirements associated with local road networks may be different than what is shown in Chapter 720. Coordinate with the local agency.

From Chapter 1010.07(9), Oversized Vehicles (page 23 of the PDF):

> The region Maintenance offices and the HQ Commercial Vehicle Services Office issue permits to allow vehicles that exceed the legal width, height, or weight limits to use certain routes. If a proposed work zone will reduce roadway width or vertical clearance, or have weight restrictions, adequate warning signs and notification to the HQ Commercial Vehicle Services Office and the appropriate region Maintenance Office is required as a minimum. When the total width of a roadway is to be reduced to less than 16 feet for more than three days, communication with these offices and any other stakeholders is required; include documentation in the Project File. The contract documents shall include provisions requiring the contractor to provide a 30-calendar-day notice prior to placing the restriction.
>
> In the permit notification, identify the type of restriction (height, weight, or width) and specify the maximum size that can be accommodated. On some projects, it may be necessary to designate a detour route for oversized vehicles. An important safety issue associated with oversized loads is that they can sometimes be unexpected in work zones, even though warning and restriction or prohibition signs may be in place. Some oversized loads can overhang the temporary barrier or channelization devices and endanger workers. Consider the potential risk to those within the work zone. Routes with high volumes of oversized loads or routes that are already strategic oversized load routes may not be able to rely only on warning or prohibition signs. Protective features or active early warning devices may be needed. If the risk is so great that one oversized load could potentially cause significant damage or injury to workers, failsafe protection measures may be needed to protect structures and workers. The structure design, staging, and falsework openings may need to be reconsidered to safely accommodate oversized loads.

Related Resource:

Chapter 720: Bridges, Design Manual, Washington State Department of Transportation, September 2019.
https://www.wsdot.wa.gov/publications/manuals/fulltext/M22-01/720.pdf
From Chapter 720.03(5)(a) Vertical Falsework Clearance for Bridges Over Highways (page 5 of the PDF):

> Construction of new bridges and the reconstruction or widening of existing structures often requires the erection of falsework across the traveled way of a highway. The erection of this falsework can reduce the vertical clearance for vehicles to pass under the work area. The potential for collisions to occur by hitting this lower construction stage falsework is increased.
>
> 1. On all routes that require a 16.5-foot vertical clearance, maintain this same clearance for falsework vertical clearance.
>   - On structures that currently have less than a 16.5-foot vertical clearance for the falsework envelope, maintain existing clearance.
>   - On new structures, maintain the falsework vertical clearance at least to those of the minimum vertical clearances referenced below.
>
> 2. Any variance from the above must be approved by the Regional Administrator or designee in writing and made a part of the Project File.

Permanent System Applications

Alaska

Evaluation of the Overheight Detection System Effectiveness at Eklutna Bridge, Final Report, Ming Lee and Dan Moose, Research and Innovative Technology Administration and Fairbanks North Star Borough, March 2013.
https://scholarworks.alaska.edu/bitstream/handle/11122/8817/fhwa_ak_rd_13_01.pdf?sequence=1
Although this report addresses a permanent warning system application, it includes useful information related to products and vendors, system testing and technical details. *From the abstract*:

> The Eklutna River/Glenn Highway bridge has sustained repeated impacts from overheight trucks. In 2006, ADOT&PF [Alaska DOT and Public Facilities] installed an overheight vehicle warning system. The system includes laser detectors, alarms, and message boards. Since installation, personnel have seen no new damage, and no sign that the alarm system has been triggered. Although this is good news, the particulars are a mystery: Is the system working? Is the presence of the equipment enough to deter drivers from gambling with a vehicle that might be over the height limit? Is it worth installing similar systems at other overpasses? This project is examining the bridge for any evidence of damage, and is fitting the system with a datalogger to record and video any events that trigger the warning system. Finally … researchers will test the system with (officially) overheight vehicles. Project results will help ADOT&PF determine if this system is functioning, and if a similar system installed at other bridges would be cost-effective.

Georgia

Note: The report cited below describes survey results that identified 22 state DOTs using various warning systems. The report includes a brief discussion of each system. Additional product information is included in Appendix A (page 89 of the report, page 99 of the PDF) and Appendix B (page 90 of the report, page 100 of the PDF). Technical information about the recommended warning systems is provided in Appendix C (page 105 of the report, page 115 of the PDF). The report also provides survey results from DOTs not using warning systems, including a brief discussion of Connecticut DOT's use of temporary systems.

Warning Systems Evaluation for Overhead Clearance Detection, Marcel Maghiar, Mike Jackson and Gustavo Maldonado, Georgia Department of Transportation, February 2017.
http://g92018.eos-intl.net/eLibSQL14_G92018_Documents/15-21.pdf
From the abstract:

> This study reports on off-the-shelf systems designed to detect the heights of vehicles to minimize or eliminate collisions with roadway bridges. Implemented systems were identified, reviewed, and compared and relatively inexpensive options recommended. Systems for the Georgia Department of Transportation (GDOT) should be able to effectively detect vehicle heights to prevent collisions with low-clearance bridges. Systems were classified in three main categories: passive (rigid or nonrigid), active, or combined. Each system had its own advantages and disadvantages. Since user needs and desired classification results may differ, the authors focused on advantages that specifically serve the interests of GDOT. Some systems have extra functionalities, such as vehicle-type classification, detection of the

vehicle's height and length, and photographic acquisition of license plate information. However, some of the implemented solutions are costly and may not target GDOT's particular needs. Therefore, the study identifies the few adequate, cost-effective, and efficient systems that clearly meet those needs.

Indiana

Synthesis Study: Development of an Electronic Detection and Warning System to Prevent Overheight Vehicles From Impacting Overhead Bridges, Joe Sinfield, Indiana Department of Transportation, July 2010.
https://pdfs.semanticscholar.org/b387/dea3f9fcc0ad1e7f93014e99e20533842c58.pdf
Details of state DOT overheight vehicle detection systems and practices are summarized in this report. Page 19 of the report (page 24 of the PDF) mentions Michigan DOT's use of a warning system during a construction project; the system was removed once construction was completed. *From the abstract*:

> This [s]ynthesis [s]tudy provides a review of solutions that exist to detect and forewarn overheight vehicles and thereby prevent a collision, and specifically examines the breadth of available overheight vehicle detection technologies, the commercial availability of such equipment, and the experience of relevant DOTs with installed and functioning systems. The findings of this study indicate that most states have updated their infrastructure to account for overheight vehicles and permanently avoid collisions. The few states that still actively employ overheight vehicle detection and warning systems (OVD&W) tend to use optoelectronic single- or dual-eye infrared detection systems and report that the devices have decreased the amount of damage occurring to their structures. The initial equipment and installation costs of these systems range from a few thousand to twenty-five thousand dollars based on DOT interviews, and ongoing maintenance appears minimal. Overall, considering that the only other completely effective option to avoid overheight vehicle incidents is to raise the height of affected structures, or lower the roadway surface, an (optoelectronic) OVD&W system is a relatively inexpensive and effective method for decreasing overheight vehicle accidents. With this in mind, this study provides a guide to the site characteristics that influence both sensor selection and overall OVD&W system design. A simple Equipment Selection Tool is presented to guide system choice, and is demonstrated through a case example centered on the I-65 – I-70 merger location in Indianapolis, [Indiana].

New York

"Governor Cuomo Announces Completion of $4.8 Million Over-Height Vehicle Detection System on New York City Parkways," Press Release, Governor's Office, State of New York, November 2016.
https://www.governor.ny.gov/news/governor-cuomo-announces-completion-48-million-over-height-vehicle-detection-system-new-york
This press release announces the installation of overheight vehicle detection systems on the Hutchinson River Parkway in the Bronx and on the Grand Central Parkway in Queens.

Bridge-Vehicle Impact Assessment, Anil K. Agrawal, Xiaochen Xu and Zheng Chen, New York State Department of Transportation, August 2011.
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.250.4396&rep=rep1&type=pdf
From the abstract: This report describes the work done to achieve the following objectives: (i) review and identify major factors contributing to bridge impacts, (ii) provide recommendations to the NYSDOT [New York State DOT] about effective measures for reducing the likelihood of future bridge hits, (iii) provide long term, feasible and economical recommendations to reduce the likelihood of bridge hits, (iv) review and comment on the NYSDOT Collision Vulnerability Assessment Procedure and provide recommended improvements and (v) develop a computer program for analyzing the bridge hits occurrences as new bridge hits data become available.

North Carolina

Gregson Street Bridge Overheight Detection and Alert System, Primer for Improved Urban Freight Mobility and Delivery: Operations, Logistics and Technology Strategies, John A. Volpe National Transportation Systems Center, Federal Highway Administration, May 2018.
https://ops.fhwa.dot.gov/publications/fhwahop18020/fhwahop18020.pdf
From page 37 of the report (page 43 of the PDF): A rail bridge passes just 11 feet 8 inches above South Gregson Street in downtown Durham, [North Carolina]. Due to the low clearance under the bridge, South Gregson Street is not a truck route, and most professional truck drivers avoid the area. However, over time, numerous truck drivers have collided with the bridge. The bridge has even gained social media fame from online videos showing trucks and other types of vehicles striking it. To reduce the frequency of vehicle collisions with the bridge, the North Carolina Department of Transportation (NCDOT) installed a warning system that detects overheight vehicles and warns the drivers in real time that they cannot fit under the bridge and advises them to use an alternative route. The system also triggers a red light at the intersection immediately before the bridge to give drivers more time to observe the warning signal.

South Carolina

"New System Detects, Warns Overheight Trucks on I-85," Bob Kudelka, *The Connector*, South Carolina Department of Transportation, Summer 2015.
https://www.scdot.org/inside/pdf/ConnectorArchives/ConnectorSummer2015.pdf
From page 9 of the newsletter: SCDOT [South Carolina DOT] has installed the state's first detection and warning system aimed at reducing dangerous and costly overheight truck collisions with bridges. The system, which is similar to systems in place on I-95 in North Carolina, consists of sensors that can detect loads that are close in height to the existing bridge clearances.

Texas

Overheight Vehicle Detection System (OVDS), Magdy Kozman and Roma Stevens, Texas Department of Transportation, October 2015.
https://static.tti.tamu.edu/conferences/tsc15/presentations/traffic-ops-2/kozman-stevens.pdf
This presentation from a Texas DOT short course provides background information on overheight vehicle detection systems and discusses two demonstration sites.

Related Research

Below are resources related to temporary and permanent overheight vehicle detection system applications.

"LADAR-Based Collision Warning Sensor to Prevent Over-Height Vehicle Bridge Hits," Abhishek Singhal, Camille Kamga and Anil Kumar Agrawal, *IET Intelligent Transport Systems*, Vol. 12, Issue 7, pages 689-695, September 2018.
Citation at https://ieeexplore.ieee.org/document/8436575
From the abstract: Impacts by over-height (OH) vehicles on bridges, commonly known as 'bridge hits', cause significant risk to safety and preservation of transportation infrastructure in the USA. Currently, available over-height vehicle detection systems (OHVDs) have specific site requirements, extremely high installation costs, and propensity for false alarms, which limit their field deployment to few locations. This study describes a new, enhanced LADAR-based OHVDs (L-OHVDs), which can be installed on the face of a structure to be protected and can measure the height of an approaching vehicle before the safe stopping distance from the structure. Built using off-the-shelf components and a patent pending optical design, it exhibits enhanced features like vehicle detection, actual height measurement, and collision prediction with no reported false alarms. The developed prototype has a detection range of 220 ft [feet] with height measurement accuracy (±0.66 inches) that is better than currently available OHVDs. This system has exceptional precision and is well suited to detect OH trucks and tractor trailers approaching a low vertical clearance bridge. With superior performance and cost-effective installation, the proposed L-OHVDs has the potential to reduce occurrences of 'bridge hits', thereby limiting consequences such as congestion and damages to bridge[s] while sustaining safety of motorists.

"Optimized Parameters for Over-Height Vehicle Detection Under Variable Weather Conditions," Bella Nguyen, Ioannis Brilakis and Patricio A. Vela*, Journal of Computing in Civil Engineering*, Vol. 31, Issue 5, September 2017.
Citation at https://ascelibrary.org/doi/full/10.1061/%28ASCE%29CP.1943-5487.0000685
From the abstract: Over-height vehicle drivers continuously ignore warning signs and strike onto bridges despite the number of preventative methods installed at low clearance bridges. In this paper, the authors present a new method for over-height vehicle strike prevention with a single calibrated camera mounted on the side of the roadway. The camera is installed at the height of the over-height plane formed by the average of the maximum allowable heights across all lanes in a given traffic direction; the error caused by the road gradient is assumed to be negligible and absorbed through the calibration process. At that height, the over-height plane can be safely approximated as a line in the camera view. Any vehicle exceeding this line is consequently over-height. The camera position and orientation are determined through a calibration process proposed. Instances of over-height vehicles are detected through optical flow monitoring. Evaluation of the system resulted in a height accuracy of ±2.875 mm; outperforming the target accuracy of ±5 cm, OH detection accuracy of 68.9%, and classification performance of 83.3%. Although its accuracy is comparable to existing laser beam systems, it outperforms them on cost which is an order of magnitude less because of eliminating the need for new permanent infrastructure.

“Predicting Priorities for Installing Over-Height Vehicle Detection/Warning Systems for Bridges,” Mohammad Neaz Murshed, Imelda Barrett and Randy B. Machemehl, *Transportation Research Board 95th Annual Meeting Compendium of Papers*, Paper #16-1208, 2016.
Citation at https://trid.trb.org/view.aspx?id=1392450
From the abstract: Although collisions of over-height vehicles or vehicles carrying over-height loads with a bridge superstructure may be considered a rare event, occurrences of such events are not uncommon. When such an event takes place, the damage sustained by the bridge superstructure may be substantial—sometimes even leading to total collapse of the bridge. Out of the available solutions to this problem the most promising and attractive one involves the installation of over-height vehicle detection and warning systems, however, such systems have diverse installation costs, effectiveness and longevity. Moreover, yearly budget constraints limit the number of such installations and there is no guideline as to which bridges should be equipped with such devices. In this study a relatively simple but effective method is developed using only two basic items of information about the bridge (minimum vertical under-clearance) and total number of traffic lanes under the bridge to produce a priority ranking based upon the likelihood of the bridge being hit by an over-height truck. Bridge collision datasets were obtained from three state DOTs—New York, Missouri and Texas—and these were used to develop the predictive procedure.

“Creating Smarter Work Zones,” Tracy Scriba and Jennifer Atkinson, *Public Roads*, Vol. 77, No. 5, March/April 2014.
https://www.fhwa.dot.gov/publications/publicroads/14marapr/06.cfm
This article provides an overview of work zone technologies that “in combination with other strategies, help to address specific needs while keeping workers and the traveling public safer.” *From the article*:

> **Over-Dimension Warning**: Work zones may cause temporary minimal width or height clearances for large vehicles using the roadway. Efforts made on behalf of the transportation agency to reroute the affected vehicles may not be effective, so over-dimension warnings give compliance notifications as large vehicles approach the work zone. Potential benefits and outcomes:
>
> - Alerts drivers that their vehicle is over dimension and they need to use an alternate or escape route.
> - Warns drivers about their inability to continue through the work zone, providing sufficient time to use an alternate or escape route.
> - Tells drivers to stop when they fail to use the designated alternate or escape route.

International Research

“Real-Time Validation of Vision-Based Over-Height Vehicle Detection System,” Bella Nguyen and Ioannis Brilakis, *Advanced Engineering Informatics*, Vol. 38, pages 67-80, October 2018.
Citation at https://www.sciencedirect.com/science/article/pii/S1474034617305293
From the abstract: Over-height vehicle strikes with low bridges and tunnels are an ongoing problem worldwide. While previous methods have used vision-based systems to address the over-height warning problem, such methods are sensitive to wind. In this paper, we perform a full validation of the system using a constraint-based approach to minimize the number of over-height vehicle misclassifications due to windy conditions. The dataset includes a total of 102 over-height vehicles recorded at frame rates of 25 and 30fps [frames per second]. An analysis is

performed of wind and vehicle displacements to track over-height features using optical flow paired with SURF [speeded up robust features] feature detectors. Motion captured within the region of interest was treated as a standard two-class binary linear classification problem with 1 indicating over-height vehicle presence and 0 indicating noise. The algorithm performed with 100% recall, 83.3% precision, false positive rate of 0.2% and warning accuracy of 96.6%.

"Understanding the Problem of Bridge and Tunnel Strikes Caused by Over-Height Vehicles," Bella Nguyen and Ioannis Brilakis, *Transportation Research Procedia*, Vol. 14, pages 3915-3924, 2016.
https://core.ac.uk/download/pdf/77413525.pdf
From the abstract: A bridge or tunnel strike is an incident in which a vehicle that is taller than the clearance underneath the structure (over-height), typically a lorry or double-decker bus, collides with the structure causing damage. This can lead to injuries, fatalities and/or, in worst case scenario, train derailments. Bridge and tunnel strikes are costly and expensive. The annual maintenance costs to repair and service the structure have been reported to range in the tens-to-hundreds of thousands (£) while the average cost per strike ranges between £5,000 to £25,000. In this paper, we present a comprehensive synthesis of the nature and scope of the problem of bridge and tunnel strikes, followed by the current state of practice and current state of research. Bridge and tunnel strikes still occur with high frequency, and prevention systems (passive, sacrificial and active) available on the market are often too expensive. Bridge-owners are seeking an affordable yet reliable system that is cheap enough for widespread installation without compromising the accuracy and performance of such a system.

Guideline for Over Height Detection System, VicRoads, June 2015.
https://www.vicroads.vic.gov.au/-/media/files/technical-documents-new/its-technical-guidelines/technical-guideline-tcg-001--overheight-detection-system.ashx
From the scope: This document provides guidelines for the supply and installation of over height detection equipment and associated warning systems for use on main roads, highways and freeways throughout the State of Victoria.

"Over-Height Vehicle Detection System in Egypt," M. A. Massoud, *Proceedings of the World Congress on Engineering 2013*, Vol. II, July 2013.
http://www.iaeng.org/publication/WCE2013/WCE2013_pp1010-1013.pdf
From the abstract: This paper presented a new technique of over-height vehicle detection. This technique was [an] advanced driver assistance system to reduce collisions between motorists and overhead structures. The proposed technique was design by three different methods[:] mechanical, optical, and image processing method. The technique [was] achieved at a real-time operation. This technique consisted of three stages[:] overheight detection, driver alert, and traffic administration unit. License plate recognition (LPR) was used at [the] traffic administration unit. The system was robust and had accurate performance.

Vendor Guidance

The following vendor resources describe temporary applications of overheight vehicle detection system installations.

Domestic

ASTI Transportation Systems Inc., Hill & Smith, Inc., undated.
http://www.asti-trans.com
ASTI Transportation Systems is a Hill & Smith Inc. company. *From* Roads & Bridges *magazine*:

> ASTI manufactures and integrates products to provide a turnkey solution for intelligent transportation systems and their alliance with homeland security. Products include message boards, perimeter security, intrusion detection, overheight vehicle detection, license plate recognition, portable video surveillance and many other items providing safety and security for highways, maritime, ports, buildings, transit and customized applications.

Over Height/Over Width Warning Systems, Road-Tech Safety Services, Inc., undated.
https://road-tech.squarespace.com/over-height-over-width-warning-systems
From the web page: Bridge construction requires false work that reduces clearance heights and widths. Everyone has seen video of trucks crashing into low bridges and false work. Static signs often don't get their attention. These systems pair a sensor with a message board and/or flashing lights to warn drivers when they must exit. They work well, especially in areas with a high volume of cross country truck traffic.

Road-Tech has experience with a wide variety of sensors including over height, over width, flood detection, ice sensors, fog sensors and even wind sensors. The key in every case is good locations for both the sensors and the warning devices and a distance between them resulting in timely warnings that drivers respect and obey.

Overheight Vehicle Detection and Warning Systems Overview: Typical Installations, Trigg Industries, LLC, undated.
https://www.triggindustries.com/ohvds-application-notes/typical-installations.html
System overview available at https://www.triggindustries.com/overheight-vehicle-detection-systems.html
This brief summary of overheight vehicle detection system installations includes an illustration of the system used with temporary falsework in a bridge construction work zone.

Related Resources:

> **Over Height Vehicle Detection and Warning Systems (OHVDS)**, Trigg Industries, LLC, 2015.
> https://www.triggindustries.com/overheight-vehicle-detection-systems/ohvds-powerpoint.html
> Typical overheight vehicle detection system installations referenced in this presentation include temporary falsework.
>
> **Overheight Detection**, Trigg Industries, LLC, undated.
> https://www.triggindustries.com/
> *From the web page*: Trigg Industries LLC offers overheight detection solutions utilizing LED based detection systems or Over Height Vehicle Detections Systems (OHVDS). We provide project document review, advanced planning support, best-fit equipment recommendations

and on-site testing procedures and consultation as specified. Trigg Industries also offers an array of warning devices and accessories for alerting and warning drivers and nearby workers of over-height vehicles.

JamLogic—Smart Work Zone Solutions, Ver-Mac Inc., undated.
https://www.ver-mac.com/en/jamlogic-software/smart-work-zones
From the web page: Utilizing overheight detection sensors, the system automatically alerts drivers in advance of an alternate route or to stop if they have passed the route. The benefit is preventing collisions to structures that cause significant damage and delays.

International

Overheight Vehicle Detection System Protects Highway Workers, Highway Resource Solutions, undated.
https://www.highwayresource.co.uk/highways-safety-technology-news/overheight-vehicle-detection-system-protects-highway-workers
From the web site: A new temporary overheight vehicle detection system is protecting BAM Morgan Sindall joint venture (bmJV) construction crews that are working on the UK Highways Agency's M62 and M1 J39-42 smart motorway project.

The bmJV group leased the temporary system shortly after its launch in September by Mobile Visual Information Systems Ltd (MVIS) and its partner, Highway Resource Solutions Ltd (HRS), creators of the Intellicone temporary work zone safety system. The overheight detection system is part of the partnership's new work-zone safety portfolio, and is the first temporary road maintenance safety offering that combines modular electronic perimeters with variable message signs (VMS). The MVIS/Intellicone overheight detection system was launched alongside the Safelane automated traffic management system, which [combines] Intellicone products with MVIS' VMS to facilitate safer work-zone traffic management by fewer personnel. The partnership will launch further safety applications in 2015.

One element of the bmJV's 'smart motorway' project involves the suspension of scaffolding beneath a bridge. The road remains periodically open to road-users, and therefore personnel operating from the scaffolding require protection from errant oncoming high-sided vehicles. Signs in advance of the bridge direct high-sided vehicles away from the structure. An Intellicone Sentry Beam detects overheight vehicles, activating a message on MVIS' VMS-A variable message sign, alerting drivers to their breach and enabling them to turn round and find an alternative route. Simultaneously, an audible Intellicone Portable Site Alarm on the scaffolding warns workers of the breach, allowing them sufficient time to reach a position of safety. While the MVIS/Intellicone temporary detection system was originally designed to protect workers from vehicles in ground-based worksites, the customer identified its potential to protect bridge personnel from high-sided vehicles during its smart motorway project.

Stores manager from bmJV, Chris Hunter, who commissioned the system in September, said, "Historically, BAM and Morgan Sindall have warned drivers of overhead obstructions via goalposts or 'hangman' and clatterboard constructions. Neither were as effective as the MVIS/Intellicone solution at halting errant high-sided vehicles, and neither simultaneously alerted overhead personnel of safety breaches. The new solution has quickly proved its worth; within the first week, there were three breaches, all of which were quickly remedied, as the drivers were instantly alerted and able to turn around and find an alternative route.["] On behalf of the MVIS and HRS partnership, MVIS managing director, Pat Musgrave, commented, "We are pleased that our new temporary overheight detection solution has been so quickly embraced by the transport management market, and that it is already demonstrating its ability to promote worker safety."

Related Resources:

"Safelane Automates Work Zone Perimeter Guarding," *ITS International*, May/June 2014.
https://www.itsinternational.com/categories/detection-monitoring-machine-vision/features/safelane-automates-work-zone-perimeter-guarding/
From the article: Workers on the M62 smart motorway upgrade deployed a temporary overheight detection solution to protect personnel working on scaffolding suspended beneath a bridge above live traffic. The system combines Safelane with a sentry beam set at the required height and positioned some distance from the bridge. An overheight vehicle heading towards the bridge will break the beam, automatically triggering flashing VMS signs and the Intellicone alarm which gives workers time to vacate the potential impact area before the vehicle arrives.

Chris Hunter, stores manager for the BAM Morgan Sindall Joint Venture, said: "Within the first week there were three breaches, all of which were quickly remedied as the drivers were alerted and able to turn around and find an alternative route."

Highway Resource Solutions (HRS), Highway Resource Solutions, undated.
https://www.highwayresource.co.uk/
From the web page: HRS protects workers and the travelling public during the maintenance, repair and renewals of our roads, railway and utilities infrastructure. This includes:

- Digitally enabled traffic management equipment allows remote road closure monitoring.
- Advance warning systems that provide an instant alert to the workforce in the case of a breach via road closure and works access points.
- Intuitive customer facing systems to inform and deter the traveling public from entering restricted work zones, significantly reducing unauthorised incursions into worksites.

Mobile Visual Information Systems Ltd (MVIS), MVIS, United Kingdom, undated.
https://www.m-vis.co.uk/
From the web page: Mobile Visual Information Systems (MVIS) is an industry leader in the delivery of temporary ITS products and integrated solutions for hire across the UK. Driven by the very latest communication technology, our highly versatile products and solutions are used in the highways, events and construction sectors as well as at ports and airports across the UK.

Bam Morgan Sindall Joint Venture, MVIS, undated.
https://www.m-vis.co.uk/case-studies/customer-bam-morgan-sindall-joint-venture/
This case study summarizes the construction project cited above.

Contacts

CTC contacted the individuals below to gather information for this investigation.

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Appendix A: Survey Questions

The following survey was distributed to members of the AASHTO Committee on Construction to gather information from other state agencies about their experience using early warning overheight vehicle detection systems to alert drivers of falsework that temporarily lowers the clearance of structures in work zones.

Use of Overheight Vehicle Detection Systems in Work Zones

(Required) Does your state install early warning systems in work zones to alert overheight vehicles of the presence of falsework that is temporarily lowering clearance for a bridge under construction?

- No (directs respondent to **Nonusers of Overheight Vehicle Detection Systems in Work Zones**)
- Yes (directs respondent to **Overheight Vehicle Detection in Work Zones: System Description**)

Nonusers of Overheight Vehicle Detection Systems in Work Zones

Does your agency have any plans to install early warning overheight vehicle detection systems in work zones?

- No
- Yes (please describe your agency's plans)

Overheight Vehicle Detection in Work Zones: System Description

1. Please provide the name of the early warning overheight vehicle detection system(s) used in your agency's work zones and the vendor providing the system(s).
2. Please briefly describe system operation.
3. Approximately how many of these detection systems have been installed in your agency's work zones?
4. What is the initial cost of a single system?
5. What type of reporting does the system provide?

Overheight Vehicle Detection in Work Zones: System Installation

1. Who installs the overheight vehicle detection system?
    - Our agency staff members install the system.
    - The contractor's staff installs the system.
    - The vendor providing the system installs it.
    - A specialized contractor installs the system.
2. Is the warning system installed far enough in advance of the falsework in the work zone to allow a vehicle to exit the highway before encountering the bridge under construction?
    - No
    - Yes

3. Is the warning system installed on the on-ramp just before the falsework in the work zone to keep an overheight vehicle from entering the highway?
    - No
    - Yes
4. Please describe other factors that contribute to the decision of where to place overheight vehicle detection systems to alert drivers to the presence of falsework in work zones.

Overheight Vehicle Detection in Work Zones: System Use

1. Who is alerted when an overheight vehicle is detected? Select all that apply.
    - The driver of the overheight vehicle.
    - Our agency's traffic management center.
    - Workers in the work zone (please respond to **Question 1A** below).
    - Other (please describe).

    1A. Please describe how workers in the work zone are alerted when an overheight vehicle is approaching falsework in the work zone.
2. What is the posted speed limit in the specific work zone location where the overheight detection system is installed?
3. Has your agency conducted any tests of an overheight vehicle detection system in operation in a work zone?
    - No
    - Yes (please describe the testing conducted)
4. Are you aware of any false alarms or instances of failed detection with the systems installed in your agency's work zones?
    - No (directs respondent to **Overheight Vehicle Detection in Work Zones: Administrative Issues**)
    - Yes (please respond to **Question 4A** below)

    4A. Were there any legal consequences associated with the failed detection/failure to activate the warning?
    - No
    - Yes (please describe these legal consequences)

Overheight Vehicle Detection in Work Zones: Administrative Issues

1. Does your agency include specifications in construction contracts addressing the installation and use of an overheight vehicle detection system in work zones?
    - No
    - Yes (please describe the specifications and/or provide a copy of them)
2. Has your agency identified the number of accidents that were successfully diverted as a result of overheight vehicle detection systems installed in your agency's work zones?
    - No
    - Yes (please provide this number)

3. Has your agency identified the number of accidents that have occurred in a work zone location with a properly operating overheight vehicle detection system?
    - No
    - Yes (please provide this number)
4. Do you have any documentation you can share regarding your agency's experience with overheight vehicle detection systems for falsework in work zones (other than what you've already provided)? If available, please provide links to documentation or send any files not available online to carol.rolland@ctcandassociates.com.

Wrap-Up

Please use this space to provide any comments or additional information about your previous responses.