U.S. Department of Transportation
Federal Highway Administration

Global Benchmarking Study

Countermeasures for Preventing Bridge and Tunnel Strikes from Oversized Vehicles:

A Review of Best Practices in Ireland, the Netherlands, and the United Kingdom

March 2026

Cover image: Source FHWA. Over-height warning sign on Irish Rail bridge at Amiens Street, part of a suite of over-height detection and warning signs along the approach to this bridge.

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-HPL-25-002	N/A	N/A

4. Title and Subtitle	5. Report Date
Countermeasures for Preventing Bridge and Tunnel Strikes from Oversized Vehicles: A Review of Best Practices in Ireland, the Netherlands, and the United Kingdom	March, 2026
	6. Performing Organization Code
7. Author(s) Carrasco, Bernie; Cempel, Erik; Chiarito, Vincent; Harper, Jennifer; Lamba, Naveen; Purdy, Jeffrey.	8. Performing Organization Report No.
9. Performing Organization Name and Address Guidehouse 1676 International Dr, McLean, VA 22102	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. 693JJ322F00365N
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Highway Administration 1200 New Jersey Ave, SE Washington DC 20590	13. Type of Report and Period Covered
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Bridge strikes are one of the leading causes of damage to bridges and resulting disruption to traffic. Oversized trucks, or the inadvertently raised portions of cargo such as dump beds or crane booms, frequently strike bridges and tunnels, causing considerable damage to infrastructure, traffic delays, and rerouting of traffic to remove the truck and repair damage. At worst, bridges can fail, potentially resulting in deaths and injuries and costly economic and quality of life impacts for entire regions until the facility can be reopened to traffic. After a review of best practices globally in prevention of bridge and tunnel strikes, the study team visited the United Kingdom, Ireland, and the Netherlands. This report presents the range of countermeasures observed in these countries and insights and lessons learned.

17. Key Words	18. Distribution Statement
Bridge Strikes; Tunnel Strikes; Countermeasures; Driver Behavior; Enforcement; Over-height Vehicles	This document is available to the public

19. Security Classification. (of this report)	20. Security Classification. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	95	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized.

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List of Acronyms

Acronym	Description
AI	Artificial Intelligence
BASt	Bundesanstalt für Straßenwesen
CDL	Commercial Driver's License
CMS	Changeable Message Sign
CPC	Certificate of Professional Competence
DfT	Department for Transport (UK)
DOT	Department of Transportation
DVSA	Driver and Vehicle Standards Agency (UK)
EU	European Union
FHWA	Federal Highway Administration
GPS	Global Positioning System
HFST	High Friction Surface Treatments
IR	Irish Rail
ITS	Intelligent Transportation Systems
LED	Light Emitting Diode
LIDAR	Light Detection and Ranging
MUTCD	Manual on Uniform Traffic Control Devices
NAPCORE	National Access Point Coordination Organisation for Europe
NBSI	National Bridge Strike Initiative (UK)
NH	National Highways (UK)
NR	Network Rail (UK)
NTSB	National Transportation Safety Board
OBB	Osterreichischen Bundesbahnen
OHV	Over-height Vehicle
ORR	Office of Rail and Road (UK)
PIARC	Permanent International Association of Road Congresses
RDW	Netherlands Vehicle Authority
RFID	Radio Frequency Identification
RSSB	Rail Safety and Standards Board (UK)
RWS	Rijkswaterstaat
SAAQ	Société de l'assurance automobile du Québec
TfL	Transport for London
TII	Transport Infrastructure Ireland
UK	United Kingdom
US	United States
USDOT	United States Department of Transportation

Executive Summary

Study Context and Approach

Bridge strikes are one of the leading causes of damage to bridges and resulting disruption to traffic. Oversized trucks, or the inadvertently raised portions of cargo such as dump beds or crane booms, frequently strike bridges and tunnels, causing considerable damage to infrastructure, traffic delays, and rerouting of traffic to remove the truck and repair damage. In dire circumstances, bridges and tunnels can fail, which may result in injuries and loss of life. There may also be costly economic and quality of life impacts for entire regions until the facility can be reopened to traffic.

After a review of best practices globally in prevention of bridge and tunnel strikes, the study team visited the United Kingdom (UK), Ireland, and the Netherlands for in-person visits.

Countermeasures and Supporting Processes and Systems

Countermeasures identified in the visited countries included:

- **Physical countermeasures.** Physical countermeasures have a long history and precedent of use to prevent bridge and tunnel strikes or reduce the impact of strikes. One physical countermeasure type is a collision beam, a beam that absorbs collision impacts in lieu of the structure itself. The utilization of collision beams may still result in operational and potential safety impacts since closing and inspecting the bridge is still required. Various hanging devices, such as chains or bells, are other low-cost physical countermeasures that are easy to install. However, the hanging devices are not always effective since they may go unheard. Such devices, if heard, may startle drivers. The countries visited recommended using these tools along with other countermeasures.
- **Roadside technology.** The examples observed in the visited countries represent sophisticated applications of advanced, interconnected technology. Typically, redundancy is built in, with multiple sensors, warnings, or preventative measures – with increasing severity – when approaching a bridge or tunnel. Together, these roadside technologies are effective in reducing bridge and tunnel strikes. However, they are unique to each structure, and are likely to be applied to high risk, high impact assets.
- **In-vehicle technology.** Various in-vehicle devices have been developed to alert drivers of potentially dangerous vertical clearances ahead. These devices are often linked to roadside technology, external databases, or other tools. Often components of these systems and devices also rely on manual driver input. Navigation and routing for trucks is also a common issue that leads to bridge and tunnel strikes. Most publicly available guidance systems do not incorporate truck restrictions or low clearances into their data and routing algorithms; and even if they do, the system may not link to a particular truck and load's height that day to properly route the vehicle and alert it of any potential strikes. Several systems and approaches have been developed to solve these challenges.
- **Training, education, and driver behavior.** The agencies in all three visited countries identified driver behavior as their leading cause of bridge and tunnel strikes. As a result, they identified strategies focused on impacting driver behavior as most critical. Through public sector and private sector training, key facets include:

    - Consistency in training.
    - More driver awareness of strikes, the dimensions of their vehicle, and the potential personal and social consequences of a strike (safety, legal and monetary).
    - Constant reiteration of key messages, e.g., measuring one's vehicle.
- **Marketing and communication.** Representatives from each country expressed the need to balance enforcement and prosecution with positive engagement. Several examples highlight multifaceted marketing campaigns, short online videos, and multilingual tools to better communicate with truckers.
- **Law and regulation.** Laws and regulations underpin many of the countermeasures identified across the three countries, allowing approaches that previously had not been authorized. They also can drive agencies to innovate to meet new requirements. When applied at a national, or in the case of the European Union (EU) a multinational, scale, they help to ensure consistency and effectiveness of approaches.
- **Liability and claims.** Both the UK and Ireland utilize claims as a means of ensuring liability is assigned to appropriate parties after a bridge or tunnel strike and that financial compensation can be received. These claims can flow both into and out of an agency. In other words, a bridge owner could submit a claim to a trucking company for damages and lost time due to a bridge strike the trucking company caused (known as a green claim). Conversely, a rail or truck operator could submit a claim to the bridge owner if the owners' actions resulted in lost time or damages (a red claim). This standardized process for assigning and pursuing financial liability has led to greater incentives for agencies, trucking companies, and drivers to find ways to reduce bridge and tunnel strikes.
- **Operations and process.** Operations and processes complement and integrate with the countermeasures found throughout the three visited countries. These include approaches to collaboration, issuing permits, and standardizing procedures.

Each agency in each visited country also utilizes various risk assessment and prioritization approaches to identify where countermeasures are needed and what countermeasures are most appropriate.

Findings and Noteworthy Practices

Other countries identify many of the same bridge and tunnel strike challenges and themes as those in the US. Just as the causes of the problem are multifaceted, so too are the most effective examples of overseas countermeasures: these countries report that there is no silver bullet, and a system of countermeasures, from physical measures to advanced roadside and in-vehicle technology, to effective training and education, to targeted enforcement are necessary. Some are inexpensive and quickly implemented, while others require substantial investment, planning, and an ongoing effort to operate and maintain. A combination of countermeasures can also provide redundancy and help to address the multitude of critical events that can lead to a crash. Some countries have attempted to address all these facets through structured, formal, and informal collaboration across many agencies and industry organizations.

A summary of the key findings and noteworthy practices includes:

- **There is no silver bullet.** Every countermeasure identified was documented as having advantages and disadvantages. As a result, agencies with the most robust approaches to preventing bridge and tunnel strikes combine systems of countermeasures and practices. This is clearly articulated through the UK's Network Rail 4Es: Education, Engineering, Enablement, and Enforcement.
- **Understand risk and appropriate countermeasures for the situation.** Similarly, the exact application of a suite of countermeasures may differ across the network. An agency selects the right countermeasure or countermeasures for the right structure, location, likelihood of a strike, potential impact of a strike, and set of specific causes. The agencies in the three visited countries used a combination of risk assessments, evaluation sheets, and standards to help determine this.
- **Focus on prevention.** The agencies across the three countries indicated qualitatively or quantitatively a positive return on investment for the countermeasures they implemented. Due to the direct costs to the agency of a damaged structure, along with myriad societal costs associated with a strike and its aftermath, the upfront costs are minor: as one participant indicated, "a little money saves a lot of money."

  In particular, the agencies gravitated towards preventative countermeasures instead of protective or sacrificial countermeasures, though both were used for redundancy.
- **Involve the private sector.** Overseas successes in reducing bridge and tunnel strikes often resulted from strong involvement from and coordination with the private sector. The inclusion of trucking companies and firms with large fleets, both directly and through trade organizations, was seen as essential. Ports and insurance companies were also involved.

  In the case of the UK, the involvement was driven through a regular working group on bridge and tunnel strikes. The collaboration led to significantly improved understanding of the risks, costs, and causes of bridge and tunnel strikes to all parties. This in turn catalyzed better training, communication, and in-vehicle technology.
- **Driver behavior is key.** Driver behavior was the most cited challenge across the three countries for preventing bridge and tunnel strikes. It is difficult to control for and predict. Even a high-clearance structure can be struck by a careless or distracted driver with fully extended construction equipment on a trailer or an accidentally raised dump bed. Drivers also find ways to get around roadside sensors and warning devices. Agencies had the greatest ability to affect change through education and training. Some of this is required for licensing and certifications. Sometimes companies implement training voluntarily, though with incentives and disincentives in the law. Recent in-vehicle technology attempts to remove driver error from the equation: one UK software solution has Radio Frequency Identification (RFID) tags on all cabs and trailers that automatically warns the driver of any approaching low-clearance structures. Enforcement is the final line of defense for controlling driver behavior.
- **Control for blind use of Global Positioning System (GPS) navigation.** It is easy and familiar for most people in 2025 to use freely available mobile applications for route planning and navigation; truck drivers are no different. However, such publicly available, free applications, as well as standard in-vehicle GPS navigation systems, usually do not contain truck restrictions or low-clearance data. Even if they do, they are not in any way

linked to vehicle height, and so the systems cannot create a route and navigate an over-height vehicle safely.

Several solutions were observed across the three countries:

- The first solution is to ensure drivers are aware of this, and through repeated education, messaging, and habitual measuring and documenting of their vehicle height, ensure that despite the GPS navigation, they are aware of their height and watch for low-clearance structures.
- The second solution is a requirement of specialized in-vehicle navigation systems for trucks which include data on clearances linked to vehicle height. Several companies in the UK require this for their fleets, with strict procedures around their use and any unplanned deviations. Some companies created their own custom software.
- The third solution is through legislation and resulting standards, such as the EU's regulation requiring member countries to develop a common data standard for items such as truck restrictions. These data will then be required to be used by GPS navigation applications.

- **Provide a harmonized database on bridge and tunnel heights and other traffic regulations.** According to the European experience in the National Access Point Coordination Organisation for Europe (NAPCORE) project, roadway databases can be harmonized across jurisdictions and providers. Information on traffic regulations can be digitized by the relevant road authorities and then made findable and accessible via common data standards and access mechanisms, such as through the EU's National Access Points. These include common data standards and quality assurance practices, requiring cooperation between data stakeholders and governance structures. This also encourages standard mapping and guidance platforms to use the databases.
- **Enforcement and financial liability drive more interest in compliance and technology development.** Regulations in the UK include a strict process around financial liability related to bridge strikes; costs go beyond asset repair to include delay and other costs to operators and the public. Drivers, managers, and their companies can lose licenses, certifications, and the ability to operate their fleet. These provisions encourage companies and drivers to pay greater attention to avoiding bridge and tunnel strikes. This includes a robust ecosystem of UK-developed in-vehicle systems for routing or warning drivers, and robust procedures and training for drivers at large companies.
- **Use progressive stages of sensors, warnings, and enforcement prior to major tunnels and bridges.** Each country used a series over-height sensors and warning signs on approaches to major tunnels (and in one case, a bridge). The intent was to provide a sensor and warning early enough on an approach to both allow the driver to exit on the last regular exit and alert the traffic control center of a potential over-height vehicle. In the cases of the tunnels, when the last sensor is triggered, a gate is lowered, and the tunnel is closed. At this stage, Rijkswaterstaat (RWS) inspectors remove the vehicle via a service road and, if the vehicle is over-height, they fine the driver. In London, drivers have an escape ramp at the tunnel that they are forced down, but no fine is given. In Ireland, drivers are escorted off the facility, without a fine. Each country used slightly different types of signs and sensors, placed at differing margins of safety relative to tunnel clearance. Some tunnels use a hybrid of different sensors and induction loops. This

technology is applied for high-risk, high-impact structures, such as major, heavily traveled tunnels on strategic roadways.

- **Remind drivers to measure vehicle height.** All three visited countries focused a considerable amount of messaging, marketing, communication, education, and training on reminding drivers to measure their vehicle height before each run. Additionally, several companies in the UK and the Netherlands incorporated this messaging into their own training and communications; companies in the UK created strict processes of height measurement and documentation as part of standard, required procedure.
- **Educate elected officials, law enforcement, and other key stakeholders about the problem.** Outside of those who manage bridges and tunnels, most people are not aware of the risks and associated impacts of strikes from over-height vehicles. They may not know the potential return on investment of various countermeasures. The countries visited have elevated the seriousness of the problem within their agencies and amongst decision-makers. Educated law makers and decision-makers can craft legislation and provide support for these efforts, as was noted in the UK and Netherlands; they can also help encourage other organizations and private industry to be engaged. Often this is a precursor to being able to apply many of the countermeasures in this report. Engaged law enforcement was also identified in the three countries as very necessary in the reduction of bridge and tunnel strikes.
- **Provide focused law enforcement for over-height vehicles.** Law enforcement is overburdened, with many competing priorities. The Netherlands granted special, limited authority to RWS – their national DOT – providing the ability to pull over and fine over-height vehicles. The resulting RWS inspectors have similar training and oaths as standard police, and they have a strict process to follow before issuing a fine. The inspectors are closely linked to RWS traffic control centers and tunnel detection and warning systems: when a potential over-height vehicle is identified and stopped before a tunnel, RWS inspectors are called out to intercept them.

  Special staff at Transport Infrastructure Ireland (TII) tolled tunnels in Ireland also have the authority to escort vehicles off the road if they are over-height. Alternatively, the Metropolitan Police in London carved out a special commercial vehicle division, which includes enforcing vehicle height violations.
- **Centralize monitoring by linking data and information to a traffic center.** All the roadside technology examples are linked to and monitored and controlled through a centralized traffic control center. These centers also tie in law enforcement and emergency services.

1. Introduction

Background and Objectives

This study was undertaken by the Federal Highway Administration (FHWA), an agency of the United States Department of Transportation (USDOT). It was conducted under the FHWA's Global Benchmarking Program, which serves as a tool for accessing, evaluating, and implementing proven foreign innovations that have the potential to significantly improve highway transportation in the United States (US).

The purpose of the study was to gather information on countermeasures, emerging practices and research plans, and technologies successfully used in other countries to reduce the incidence and consequences of oversized trucks striking bridges and tunnels. The goal of the study was to understand effective mechanisms used to deploy these strategies and bring this information to States to advance the US state of the practice. In addition, the study examined data collection and connection frameworks to aid in better decision-making.

For this study, oversized trucks were defined as:

- Vehicles and loads beyond legal size limitations that should operate under oversized load permits.
- Vehicles with loads that have shifted or inadvertently raised above legal height limitations.
- Standard-size vehicles and loads that for reasons related to operator actions or improper routing are traveling on a roadway with a low-clearance bridge or tunnel that does not have sufficient vertical or lateral under clearance for the vehicle.

Study Context/US State of the Practice

In the United States, bridge and tunnel strikes are one of the leading causes of damage to bridges and tunnels, resulting in disruption to traffic (Figure 1). Oversized trucks, or the inadvertently raised portions of cargo such as dump beds or crane booms, frequently strike bridges and tunnels, causing considerable damage to infrastructure, traffic delays, and rerouting of traffic to remove the truck and repair damage. In dire circumstances, bridges and tunnels could fail, which may result in injuries or cause loss of life. There may also be costly economic and quality of life impacts for entire regions until the facility can be reopened to traffic.

An early study in Maryland from 2004 reported that around 20 percent of the bridges in Maryland were hit by an over-height vehicle[1]. They also polled other States and found that most States consider over-height collisions a major problem. New York State DOT conducted a Bridge-Vehicle Impact Assessment Report in 2011 that included a bridge strike survey of State DOTs across the Nation, investigated New York bridge strikes, and proposed recommendations for reducing bridge strikes in New York.

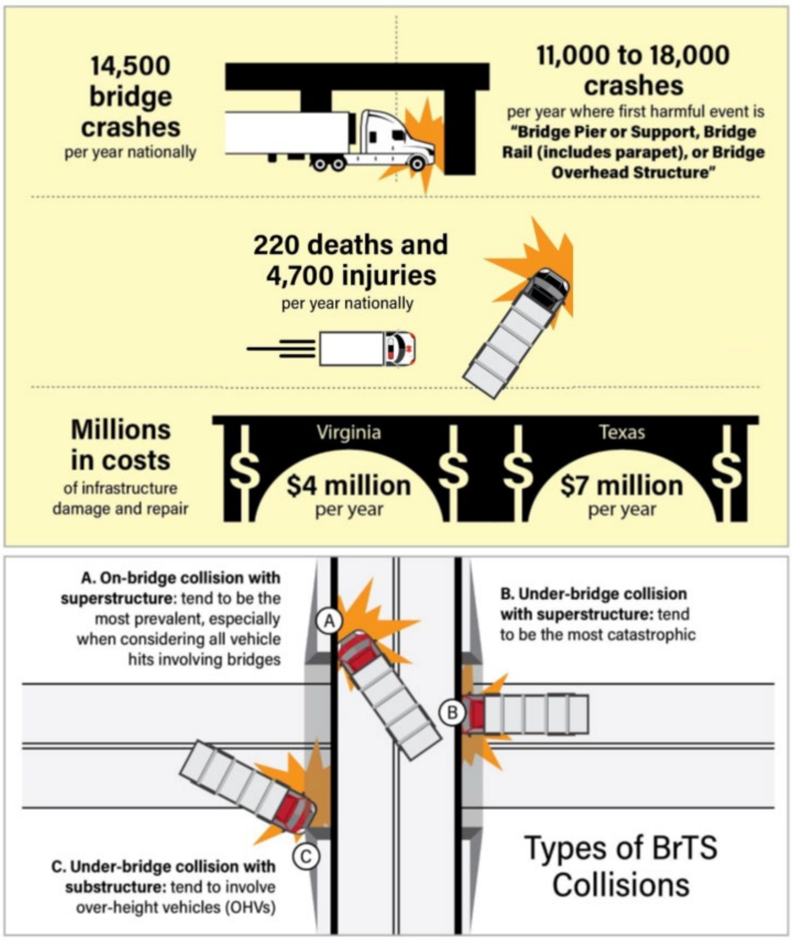
Engineering strategies for mitigating bridge and tunnel strikes, such as modifying bridge and tunnel dimensions, can be very effective but are costly and not immediately feasible on a system-

[1] Overheight Vehicle Collisions with Highway Bridges. *Transportation Research Record: Journal of the Transportation Research Board*, *1865*(1), 80-88. https://doi.org/10.3141/1865-12

wide scale. Other measures such as signing and active warning devices can be more economical but may not be as effective. This is particularly true if the messaging is unnoticed or unclear to the truck drivers or too close to the structure to allow the driver to reroute. Laser and infrared detection technology are currently more widespread in the US, but false alarms diminish the effectiveness of these systems. FHWA is continuing to explore cost-effective solutions.

There are several mitigation strategies to address the operation and routing of oversize loads, including policies and procedures related to the vehicle permitting process, oversize vehicle routing systems, carrier equipment, pilot car escort guidance, and technology. Challenges related to these operational strategies include noncompliance or improper use of existing procedures and guidance. Human factors-specific practices like training, or the use of pre-departure checklists can address common root causes of strikes. While there are numerous options available to mitigate strike risk, any individual strategy will have strengths and limitations.[2]

Figure 1: Magnitude of Bridge and Tunnel Strike Issue in the US



Source: Adapted from NCHRP 08-139 - A Guide for Identifying and Mitigating the Risk of Bridge and Tunnel Strikes

Common countermeasures such as these in practice now in various places across the US are shown in Table 1. These can be grouped into:

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[2] NCHRP 08-139 - A Guide for Identifying and Mitigating the Risk of Bridge and Tunnel Strikes, [NCHRPRep1132_Training_Strategies.pdf]

- Passive countermeasures, which improve driver awareness and include warning signs.
- Sacrificial countermeasures, which absorb impacts of strikes to protect a bridge or tunnel.
- Non-physical countermeasures, such as education, processes, policies, and outreach.
- Active countermeasures, such as detection- or location-based warning systems.[3]

Table 1: Overview of Common Countermeasures

Passive	**Non-Physical**
• MUTCD Compliant Curve Warning Signs • Changeable Message Signs (CMS) • Flashing Signs/Beacons • Bridge and Tunnel Fascia Treatments • Hanging Chains/Strips/Bells/Bars • Enhanced Lateral Clearance • Enhanced Tunnel Lighting • Enhanced Bridge and Underpass Lighting • Transverse Rumble Strips • High Friction Surface Treatments (HFST)	• OHV and Axle Load Restrictions • OHV Permits • Route Surveys • Pilot Car/Escort Vehicle Policies • Road Atlas • Commercial GPS Policies and Applications • Training and CDL Certification
Sacrificial	**Active**
• Crash Beams • Portal Frames	• Routing Systems • Early Warning Detection Systems • In-Cab Technology

Source: NCHRP 08-139 - A Guide for Identifying and Mitigating the Risk of Bridge and Tunnel Strikes

In addition, the National Transportation Safety Board (NTSB) has recommended the development of a guide for States to prevent bridge strikes by over-height vehicles, including a framework for collecting bridge strike data, communicating data among the State agencies responsible for bridge inspections and issuing oversized load permits, and using data to support operational changes and develop bridge strike countermeasures.[4]

Development of a centralized database for bridge and tunnel strikes in the US is critical, as there is a great deal of variability between States for tracking bridge and tunnel strikes. In general, such crashes are under-reported, and minor strikes are often not reported until the damages are identified during routine bridge inspections. Bridge and tunnel strikes also tend to be spread across the network as opposed to being clustered at specific locations. The small sample sizes and low crash density make it challenging to identify and prioritize locations for further diagnosis and potential treatment. A centralized database would help with gathering a larger sample size. There are also data quality issues, including the accuracy and completeness of location coding, contributing factors, and specific strike impact points. This makes it difficult to accurately assign a given crash to a specific bridge or tunnel and to diagnose the factors that contribute to a crash.[5]

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[3] NCHRP 08-139 - A Guide for Identifying and Mitigating the Risk of Bridge and Tunnel Strikes
[4] NTSB Report: Collapse of the Interstate 5 Skagit River Bridge Following a Strike by an Oversize Combination Vehicle, Mount Vernon, Washington May 23, 2013, NTSB/HAR-14/01
[5] NCHRP 08-139 - A Guide for Identifying and Mitigating the Risk of Bridge and Tunnel Strikes

Methodology

The study began with a desk review that involved researching, compiling, analyzing, synthesizing, and documenting current information on noteworthy innovations, practices, and advances in other countries related to preventing bridge and tunnel strikes by oversized vehicles. The desk review focused on the following areas:

- Proven or emerging countermeasures used in other countries to reduce the incidence and consequences of oversized vehicles striking bridges and tunnels. These may include:
  - Driver-based programs, including driver training, permitting processes, vehicle route guidance, pilot car escort guidelines, and enforcement.
  - Detection of noncompliant vehicles before any bridge strike.
  - Passive systems (crash beam, hanging chains, signs, energy absorbing devices);
  - Active ITS technology (sensors, cameras, in-vehicle notifications, signage systems) used for driver warning at low-clearance bridges.
  - Vehicle-to-infrastructure connectivity for oversized loads to provide warnings on bridge clearance, including vehicle-based technology to obtain structure profile measurements, and
  - Strategies for rapid response and incident management.
- Deployment strategies used in other countries to implement these.
- Processes used for bridge and tunnel strike reporting and tracking, including data collection and data management practices.
- Transferability of this information to States and localities to advance the state of the practice.

Given the wide variety of topics and the relatively short time in which to collect information, the desk review did not act as an all-inclusive study of global activities, but it provided concrete quantitative information to help the team select the most appropriate countries to focus on and visit. The research began with identified examples of Federal and State reports from the FHWA. Bridge and Tunnel Strikes by Oversized Vehicles: A PIARC Special Report, provided by the FHWA, was another starting point for potential examples from other countries.[6] From there the study team used a combination of internet-based review and outreach to overseas contacts to compile the desk review.

A summary of desk review findings is provided in Table 2.

Based on desk review findings, the study team selected the United Kingdom, Ireland, and the Netherlands for the in-person visits. This decision was based on the following considerations/criteria:

- Countries with moderate to high maturity in dealing with bridge and tunnel strikes.
- A blend of state of the practice examples that included both bridges and tunnels.

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[6] Bridge and Tunnel Strikes by Oversized Vehicles: A PIARC Special Report, 2022, https://www.piarc.org/en/order-library/36928-en-Bridge%20And%20Tunnel%20Strikes%20By%20Oversized%20Vehicles

- A blend of examples that included different roadway classifications, such as limited access highways as well as arterials or local roads.
- Proximity of countries to each other to minimize travel time and increase study time.

Prior to the in-person visits, a study coordination document that included a comprehensive list of focus questions was developed and sent to the host countries to help ensure their understanding of the type of information the team was hoping to obtain within the broader topic area (Appendix A). In addition, several virtual meetings were held between the team and host country subject matter experts. Much information was learned through these meetings, and key documents shared, allowing the team to optimize its limited time overseas.

Table 2: Summary Assessment of Countries for Determining Study Visits

Country	In-Vehicle Tech	Roadside Tech	Sacrificial Tech	Reg. and Enforcement	Marketing and Comm.	Deployment Extent	Data Collection/ Monitoring	Transferability	Notes
UK – Network Rail, National Highways	1	5	2	5	5	5	5	5	Many examples driven by robust regulations, incentives
UK – Transport Scotland	1	1	1	1	3	1	1	5	Campaign
UK – Other Tech	5	5	1	1	1	1	1	3	Many examples, driven by robust regulations, incentives
Rep. of Ireland	1	3	1	3	3	3	4	4	GIS-based data; campaign; focused roadside tech
Netherlands	1	5	1	3	1	3	3	4	Tunnel tech; data sharing with traffic centers; enforcement
Germany	3	1	1	1	1	1	1	5	Tech manufacturing
Finland	4	1	1	1	1	1	1	5	Tech manufacturing
Italy	4	1	1	1	1	1	1	5	Tech manufacturing
Austria	1	1	4	1	1	2	1	5	Sacrificial beams
Canada (Quebec)	3	5	1	4	1	5	1	4	Regs for in-vehicle tech
Australia (Vic.)	1	5	1	1	1	2	1	4	Impact sensors, multifaceted tech approach
Australia (NSW)	1	5	1	1	1	2	1	3	Hologram on water curtain
New Zealand	1	5	3	3	4	3	1	4	Multifaceted tech approach
EU	5	1	1	5	1	5	5	5	GPS navigation standards, mobility data coordination

Table Key:

- 5 = identified extremely robust examples

- 4 = identified very robust examples
- 3 = identified some examples
- 2 = identified limited examples
- 1 = no examples identified

The US study team met with public sector representatives from the national and regional level, as well as private sector stakeholders, in the United Kingdom, the Republic of Ireland, and the Netherlands from June 24-28, 2024. In addition to meetings, the hosts led the study team on site visits to observe bridge and tunnel strike prevention or warning systems in operation.

The primary host organizations who organized the meetings and site visits are in Table 3. A list of all the organizations that presented or participated in meetings during the visits is in Appendix B.

Table 3: Primary Host Organizations

Country	Organization
Netherlands	Rijkswaterstaat (RWS)
United Kingdom	Network Rail
	National Highways
	Transport for London (TfL)
Republic of Ireland	Irish Rail
	Transport Infrastructure Ireland (TII)

Team Composition

Study team members included:

- Jeffrey Purdy, AICP, PTP (Team Lead) – Freight Programs Team Leader, Office of Operations, FHWA
- Vincent P. Chiarito, PE, M.ASCE, F.SEI - Senior Bridge Engineer - Security and Safety, Office of Infrastructure, FHWA
- Jen Harper, PE, PMP – Research Director, Missouri Department of Transportation
- Bernie Carrasco, PE - Bridge Management Section Director, Texas Department of Transportation
- Erik Cempel, PE, PMP (Report Lead) – Guidehouse Team, President, Cempel International Transportation Consulting

Full team member bios are in Appendix C.

Report Structure

The report is organized into the following sections:

- **Key country characteristics:** This section presents brief overviews of each country and primary agency to provide some context on their respective issues and areas of focus within bridge and tunnel strike countermeasures.
- **Processes for prioritizing structures and countermeasures:** This section summarizes high level policies and risk assessment approaches that the countries and agencies use to identify where countermeasures are needed and what countermeasures are most appropriate.
- **Countermeasures:** This section presents the countermeasures themselves, what they are, where and why they are used by overseas agencies, information on benefits and challenges with each, and lessons learned. Countermeasures are categorized by:
    - Physical countermeasures
    - Roadside technology
    - In-vehicle technology
    - Training, education, and driver behavior
    - Marketing and communication
    - Law and regulation
    - Liability and claims
    - Operations and process
- **Data management:** This section presents how countries approach data collection, sharing, distribution, and updating in relation to bridge and tunnel strikes.
- **Findings and noteworthy practices and implementation:** This section synthesizes the overarching lessons, key themes, and conclusions, as well as suggestions for implementation in the US.

2. Key Country Characteristics

Netherlands

The Netherlands Rijkswaterstaat (RWS) (Ministry of Infrastructure and Water Management) is responsible for the design, construction, management, and maintenance of the main infrastructure facilities in the Netherlands. Across its 3,100 km roadway network, the agency has 28 tunnels, 13 built between 1960 and 2000, with an average age of about 40 years; 792 bridges, with an average age of about 50 years; and 2,927 viaducts on its roadway network. Before the 2013 design standards were introduced, there were no regulations for minimum vertical clearance of tunnels; therefore, most tunnels have over-height protection or detection in some form. Detection systems are not required for newer tunnels that have vertical clearances over 4.7 meters (m), or 15.4 feet, as the European Union (EU) maximum vehicle height is regulated at 4m (13.1 feet).

RWS extensively leverages technology to detect and warn over-height vehicles before its tunnels. However, RWS indicates strikes still occur due to challenges with drivers ignoring warnings or due to communication challenges with the diversity of languages across the EU and beyond.

United Kingdom

The United Kingdom's **Network Rail (NR)** owns, develops, and repairs the railway infrastructure in England, Scotland, and Wales. Many of the agency's bridges are old, 19th century masonry arch bridges that do not comply with modern clearances; in total, about 9,000 are considered at-risk for bridge strikes. They also review and evaluate structures owned by other entities that cross their right-of-way.

In the 1970s there were several serious bridge strikes resulting in subsequent derailments that caused the UK to take action to prevent bridge strikes. Since then, there has been a general downward trajectory of strikes, with around 1,800 per year on NR bridges.

Regarding impacts of strikes, NR is concerned about the structure itself, the displacement of rail over the bridge (if it is a rail overbridge), or the falling of debris on the tracks (if it is a rail under-bridge, with the roadway going over the bridge) or onto the roadway. They have numerous bridges that are skewed diagonally relative to the roadway, which creates a greater risk of the striking vehicle tipping onto other vehicles or sidewalks. Buses occasionally hit their low bridges, which poses a much higher risk of injury. NR identifies most contributing factors to bridge strikes as outside the control of operating agencies.

The UK's **National Highways (NH)** manages and improves England's motorways and major roads. As a modern system, most structures exceed the minimum vertical clearance standard of 5m (16.5 feet) (these structures do not need to be signed as low clearance with height restrictions). Except for NR bridges, NH is responsible for any structure that crosses their network. Of their approximately 60 documented bridge strikes per year, most are due to fast-moving vehicles with construction equipment on low loaders.

Transport for London (TfL) is the integrated transport authority that runs the day-to-day operation of London's public transport network and manages London's main roads. This includes 580 kilometers (360 miles) of roadways, which constitute 5 percent of the network but 30 percent of traffic, and all traffic signals in the city. They also manage the city's congestion pricing. TfL has many wholly owned subsidiaries and some private franchisees to operate the system.

TfL owns and operates 12 tunnels in London; some of these date to the 19th century and have clearance challenges. London Underground, part of TfL, also has low-clearance masonry arch bridges throughout the city. The focus of TfL on bridge and tunnel strikes is mostly on the disruption to quality of service for the system users.

Ireland

A subsidiary of Córas Iompair Éireann, Irish Rail (IR), or Iarnród Éireann, provides passenger and freight rail services as well as operating Rosslare Europort. Like the UK, the rail infrastructure is on average much older than the highway network, with some masonry arch bridges almost 200 years old. Ireland currently has a 4.65m (15.3 feet) maximum vehicle height. Dublin, which has many of IR's low height bridges, also has an axle restriction; combined with the opening of Dublin's port tunnel, this helps to remove many heavy trucks from Dublin's streets and reduce bridge strikes.

IR had a fatal accident involving a train derailment due to a bridge strike in the 1980s, which led to action to prevent bridge strikes. Numbers on bridge strikes rose through the early 2000s. They found several trends with their strikes:

- Ten bridges account for 28 percent of strikes.
- Trends are seasonal and strikes peak in the summer, due to greater travel activity or due to temporary drivers covering for workers on vacation.
- Construction traffic can result in temporary increases in bridge strikes, both from increased construction equipment movement itself and from truck traffic being diverted to other routes.
- Strikes in dense urban areas have greater impacts both to the rail network and the road network, with large delays. However, in rural areas, it takes much longer to get inspectors to bridge strike sites.

Transport Infrastructure Ireland (TII), or Bonneagar Iompair Éireann, was established through a merger of the National Roads Authority and the Railway Procurement Agency under the Roads Act 2015. TII's primary function is to provide an integrated approach to the future development and operation of the national roads network and light rail infrastructure throughout Ireland. This includes several tunnels.

Ireland has more road miles per capita than the Netherlands or UK. Compared to the rail network, bridge and tunnel strikes on the much newer national roads network are rarer as most structures do not have low clearance. As part of the EU, they must at least reflect EU regulations. Previously, Ireland had a 4.25m (13.9 foot) maximum vehicle height restriction; this was rescinded, but then reinstated at a 4.65m (15.3 foot) maximum vehicle height to be consistent with the newer tunnel heights. However, trucks that were purchased during the unrestricted period that may exceed 4.65m (15.3 feet) still exist on Irish roads. TII indicates that most strikes that do occur at their bridges or tunnels are due to irregular loads, such as construction equipment, or overseas drivers with over-height trucks coming through the port.

3. Processes for Prioritizing Structures and Choosing Countermeasures

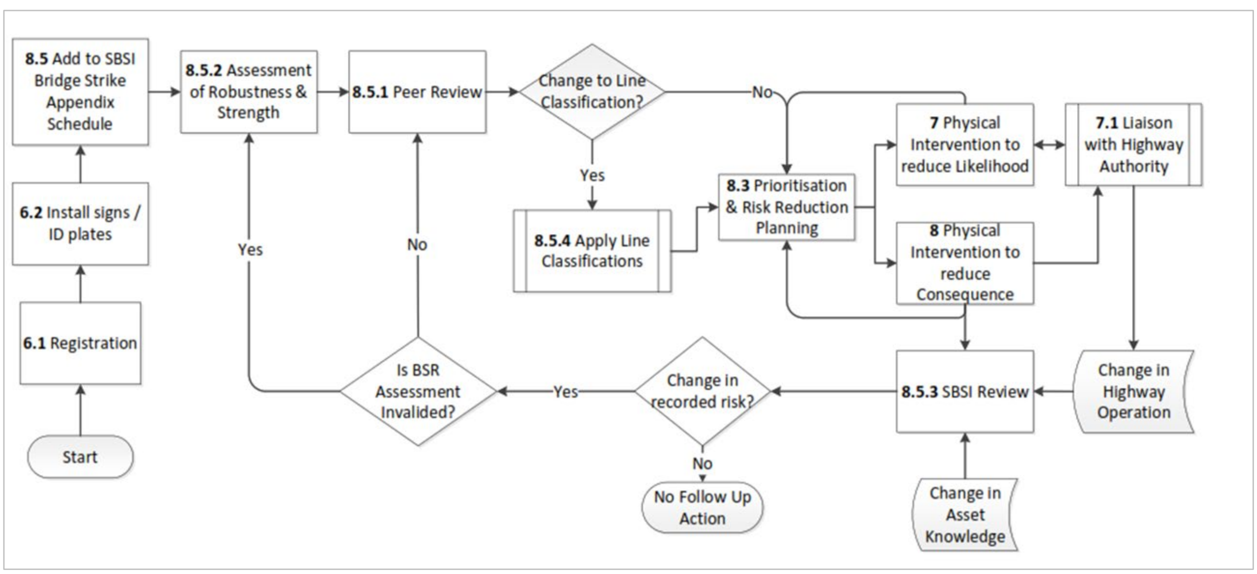
With limited resources and competing needs, agencies cannot apply all countermeasures to all bridges and tunnels. The visited agencies all used some form of risk assessment to understand the most at-risk structures or desired system-level outcomes. Then appropriate countermeasures are selected based on some type of assessment of return on investment.

The UK's NR applies Rail Safety and Standards Board (RSSB) guidance and complies with Office of Rail and Road (ORR) regulatory standards to reduce and manage bridge strikes. The ORR monitors progress and can push for more demanding measures if needed. The RSSB, at the same time, provides continuous research and recommendations.

NR is also directly penalized (financially) through the Schedule 8 payment process (see Law and Regulation section in Countermeasures) for outside parties striking their infrastructure; therefore, their methods and behaviors have been shaped to manage bridge strikes. Through the National Bridge Strike Initiative (NBSI), NR evaluates how they can continue to keep trains moving following a bridge strike, limit the minutes delayed while ensuring the safety of the infrastructure, and apply countermeasures to bridges that have a high risk of bridge strikes (Figure 2). This is guided by two key documents:

- NR/GN/CIV/202 Management of the Risk of Bridge Strikes, and
- NR/L3/CIV/076 Management of the Risk of Bridge Strike from Road Vehicles and Waterborne Vessels.

Figure 2: Network Rail Bridge Strike Risk Management Process



Source: Network Rail (UK)

Through the NBSI process, NR performs numerical calculations to see what effect a strike has on the bridge globally (e.g., will the bridge lift upwards or slide due to the impact) and locally (e.g., can the bridge still support loading with predetermined loss of section to the main structural members). This quantitative and qualitative assessment template is shown in Appendix D.

The outcome of the NBSI is a color-coded rating:

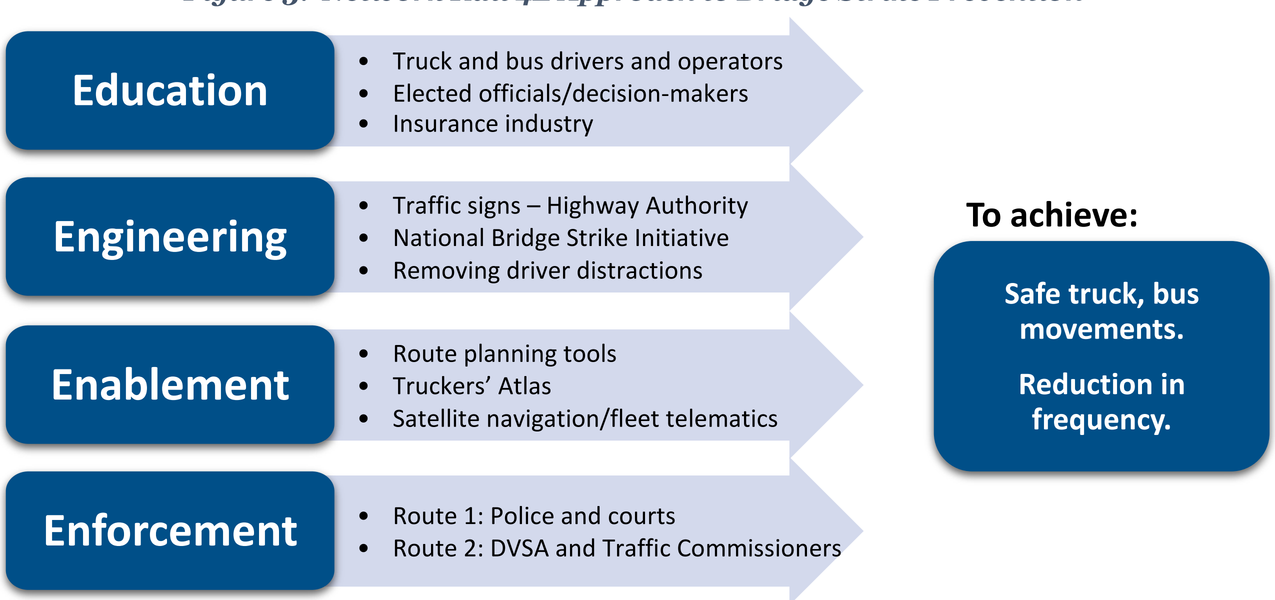
- **Red.** All train movements are stopped until a bridge examiner or engineer can give approval for train movements to resume.
- **Amber.** First train goes over the bridge at 5mph and reports back to the signaler whether they felt any defects on the track. If not, subsequent trains can travel over the bridge at 20mph until the bridge examiner or engineer gives approval to open back up to line speed.
- **Double amber.** First train goes over the bridge at 5mph and reports back to the signaler whether they felt any defects on the track. If not, subsequent trains can travel over the bridge at line speed unless instructed not to by the bridge examiner or engineer.
- **Green.** No action required and trains continue to run at line speed unless instructed not to by the bridge examiner.

More specific criteria that tie the assessment to each of these ratings is shown in Appendix E.

After being notified of a strike, NR checks the table to identify the bridge category. The purpose of this NBSI rating is to keep trains moving while the bridge is awaiting a bridge examiner inspection, which depending on the location of the bridge can take several hours.

NR's bridge database includes data related to past strikes, such as train minutes lost, and other metrics that help NR understand the total cumulative costs of bridge strikes over time at specific bridges. From this NR can identify high-risk, high-cost bridges for which a business case can be made for application of countermeasures. Appendix F provides a checklist of types of solutions that are explored. Broadly, NR using the 4E approach to solutions for bridge strikes (Figure 3).

Figure 3: Network Rail 4E Approach to Bridge Strike Prevention



Source: Network Rail (UK)

Once specific solutions are identified for a high-risk bridge, those solutions are compared through a benefit-cost analysis. The analysis primarily considers the cost of the solution and reduction in delay costs (considering Schedule 8 requirements) based on an estimated reduction in strike frequency or NBSI reclassification.

Irish Rail updates its Bridge Strike Management Strategy every 5 years. It is based on the adoption of the following principles:

- Application of developments in technology and safe systems.
- Risk-based prioritization.
- Engagement and enforcement.
- Standardization.

These principles have given rise to five key strategic areas designed to provide a complete and consistent framework for the management of bridge strikes:

- To develop and implement technological solutions at high-risk bridges.
- To work with stakeholders through the RSA Road Safety Strategy.
- To reduce the risk of collisions and near misses at bridges.
- To improve the safety culture and awareness both of internal and external stakeholders.
- To develop standardized approaches to our infrastructure.

To achieve these objectives, IR will develop and implement a specific plan for each; assign accountable owners to each; and follow the "plan-do-check-act" process.

Building on the NR approach, IR created its own multi-dimensional risk assessment process for vulnerable bridges. The process utilizes one-page score sheets, with items related to clearance, alignment, and traffic levels ranked on a one-to-ten scale (see Appendix G). The score is then used for identifying locations that warrant countermeasures, and for budgeting for priority projects. It is used to fairly justify investment across country.

Instructions are provided defining the differences in ranking and meaning for each item. While different people might score differently, IR leadership has found relative rankings to be consistent. At the organization level, IR can roll up this information for the entire network and understand if risk for the network has gone up or done over time. IR has found these score sheets to be simple but effective tools. After being in place for 10 years, acceptance of the process across the organization varies; but those who understand the process have realized that the score sheet is a powerful tool for promoting necessary bridge improvements in their regions.

Following a significant bridge strike that resulted in the loss of a bridge span, NH developed guidance to assess the risk of bridge strikes to allow targeted strengthening solutions. As a result, the Chief Highways Engineer provided guidance on conducting a triage exercise to determine bridges requiring a more detailed assessment. This approach included grouping structures into different priority tiers based on headroom and the resistance to collision on the deck (Figure 4):

- Group 1 Particularly at Risk: Immediate action required.

- Group 2 Medium Risk: To be rectified at the next suitable major maintenance project.
- Group 3 Low Risk: To be managed in accordance with risk assessment.
- Group 4 Very low Risk: No immediate action

The guidance provides a consistent means to identify particularly at-risk structures to be prioritized for some form of mitigating actions when funding is available. The evaluation also considers two items: that older structures on the network have not been built to current standards and that vehicles continue to get bigger and heavier.

Once a bridge has been placed into a group, there are several factors that could move the bridge up or down a group:

- Bridge is known to have a history of strikes.
- Location of low headroom does not coincide with a critical point of impact.
- There is adequate resistance to prevent the deck being removed from the support under collision.

Figure 4: NH Risk Assessment and Prioritization of Structures into Groups

Over-Bridges and Under-Bridges

Headroom	% collision load on a superstructure that can be resisted			
	< 33%	34%–66%	67%–99%	>100%
> 5.30m + S	Group 2	Group 3	Group 4	Group 4
5.03m + S – 5.30m + S	Group 1	Group 2	Group 3	Group 4
< 5.03m + S	Group 1	Group 1	Group 1	Group 1

Where S = Sag Curve Compensation in accordance with TD27/05

Foot-Bridges

Headroom	% collision load on a superstructure that can be resisted			
	< 33%	34%–66%	67%–99%	>100%
5.41m + S – 5.70m + S	Group 3	Group 3	Group 4	Group 4
5.03m + S – 5.41m + S	Group 1	Group 2	Group 3	Group 4
< 5.03m + S	Group 1	Group 1	Group 1	Group 1

Where S = Sag Curve Compensation in accordance with TD27/05

Source: National Highways (UK)

The Netherlands RWS did risk analysis of its tunnel system in 2012. As a result of this analysis, the Netherlands revised its tunnel safety law in 2013. RWS updated design and retrofit standards to meet these criteria.

When building tunnels for RWS in the Netherlands, contractors must use the RWS risk analysis model, which includes a threshold below which they must stay.

4. Countermeasures

Physical Countermeasures

Physical countermeasures have a long history and precedent of usages as a means of preventing bridge and tunnel strikes or reducing the impact of strikes. Collision beams absorb collision impacts in lieu of the structure itself, but still result in operational and potential safety impacts as a strike has still taken place. Various hanging devices, such as chains or bells, are low cost and easy to install, but may go unheard or, if heard, startle drivers. The countries visited recommended using these tools in conjunction with other countermeasures.

Collision Beams

Collision beams range from simple steel beams placed in front of bridges or tunnels to more advanced energy absorption devices. The UK's NR has installed steel collision beams in front of several high-risk sites with multiple recorded strikes and high impacts. NH's design standard for collision beam recommends they be on the same foundation as the structure and therefore part of the structure itself. The standards further recommend that the beam follow the direction of the bridge (e.g., angled or straight). This also ensures NH is not legally held responsible for building an additional and separate low-headroom obstruction in front of the bridge.

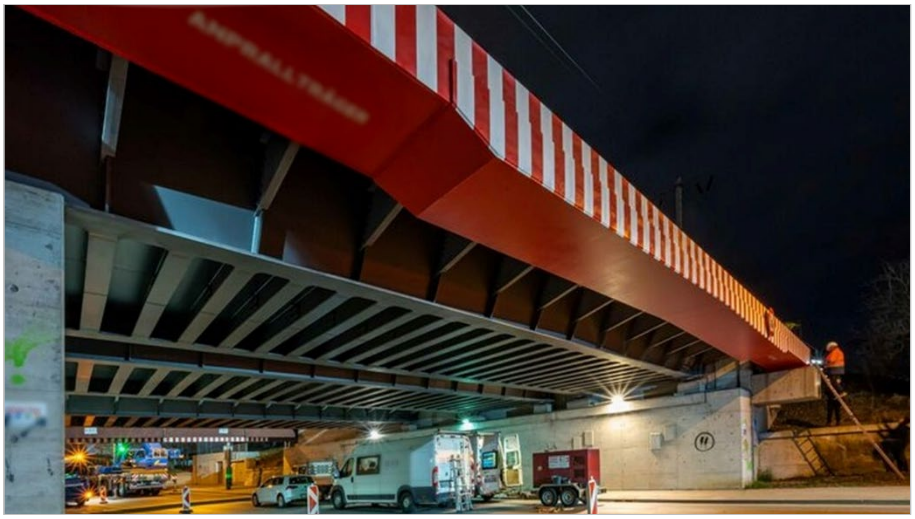
While IR cites their traditional use of collision beams, many of which are still in place and will remain, they are intentionally reducing their use of this countermeasure. IR cites several downsides of collision beams:

- If a beam is hit, the process of identifying the strike, closing the bridge, and inspecting the bridge still takes place, resulting in similar operational consequences for the transportation system.
- The beam will need to be repaired or replaced.
- A falling beam, or a truck that gets tipped or loses its load due to hitting a beam, can injure other drivers or pedestrians under the structure, and
- The core problem remains.

While not observed in the countries visited, Austria was identified in the desk review as a country advancing their collision beam technology. Osterreichischen Bundesbahnen (OBB), Austria's national rail company, has begun adding steel strike absorption shields in front of bridges to reduce disruptions to rail service due to bridge strikes from over-height vehicles on the roadways below. The impact of a bridge strike is absorbed by the shield itself, a long beam placed before the bridge, protecting the bridge from severe damage (Figure 5). The first demonstration shield weighs 18 metric tons (19.8 US tons) and is 22m (72 feet) long. The shields are placed as far away from the bridge as space allows and are equipped with white and red markings as a clear warning to road users. The shields are being prioritized on those bridges with the highest frequency of strikes and the greatest potential impacts to rail operations.

The rollout of the bridge strike shields follows a successful trial conducted in 2020, in which trains crossing the shielded bridge were not subject to any bridge-strike-related disruption. "Following the successful implementation on the busiest route in Austria, the Wiener Schnellbahn, other hotspots are gradually being planned for retrofitting. The focus is on those [bridges] where a strike has a particularly significant impact on train operations," explained Christian Nagl, Head of Route Management and Facility Development at ÖBB-Infrastruktur.[7]

Figure 5: Austrian Rail Bridge Absorption Shield



Source: *https://traktuell.at/news/oebb-baut-schutzschilde-fuer-eisenbahnbruecken/*

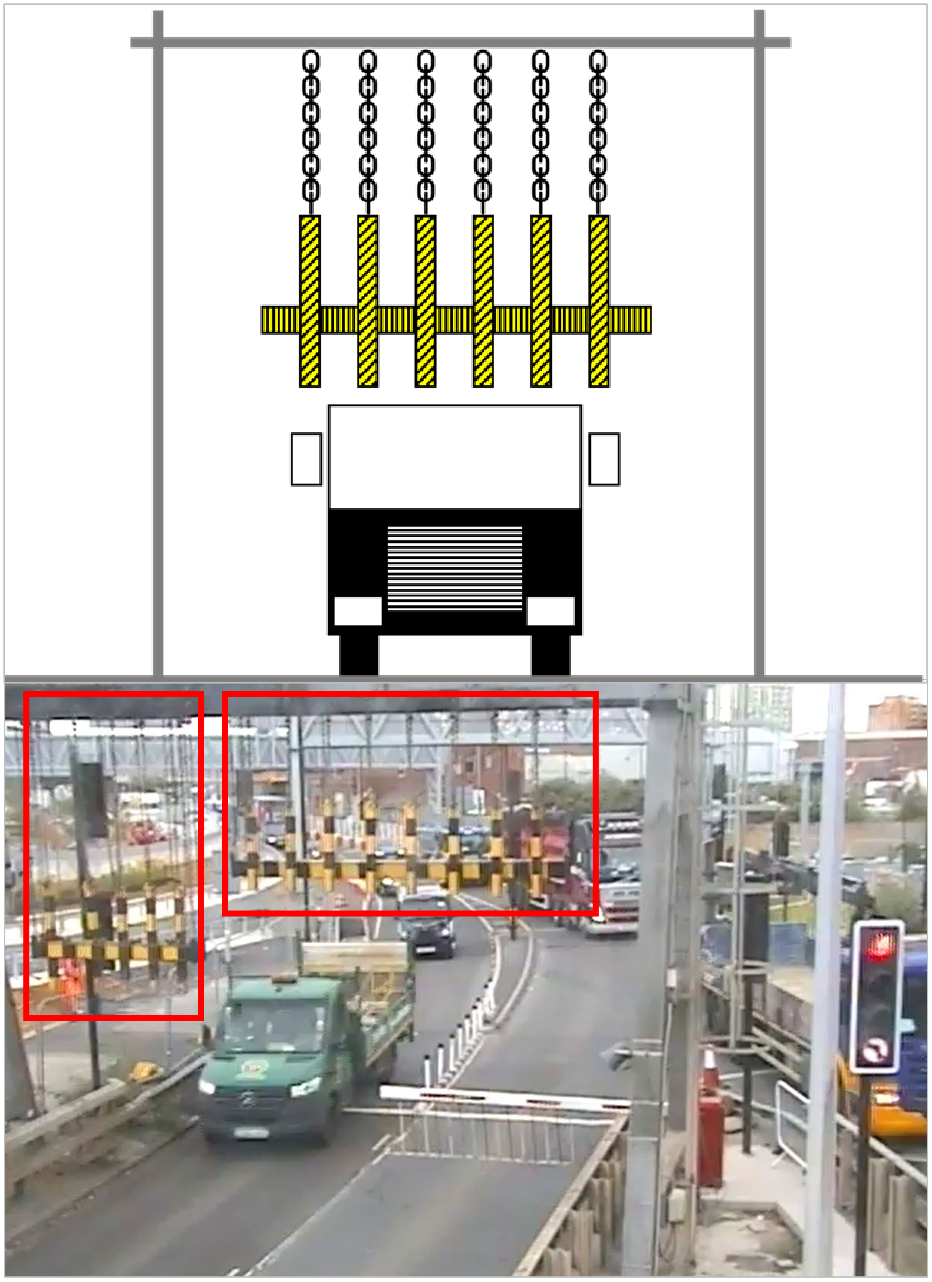
Chains, Bells, and Bars

Chains, bells, bars, and other devices hanging over a roadway at the permitted height are countermeasures seen in use across the countries. These countermeasures work by physically hitting an over-height vehicle and making a sound to alert the driver.

The UK uses bells or chains at multiple tunnels or low-clearance bridges (Figure 6). At a tunnel near Haarlem, Netherlands, RWS has a steel bar in place; it is regularly hit, and RWS has to regularly move it back into position. RWS has also used hanging devices such as ropes or a series of hinged triangles hanging from a pole, but they are taking them out of service (Figure 7).

[7] https://trans.info/bridge-strike-shields-297959

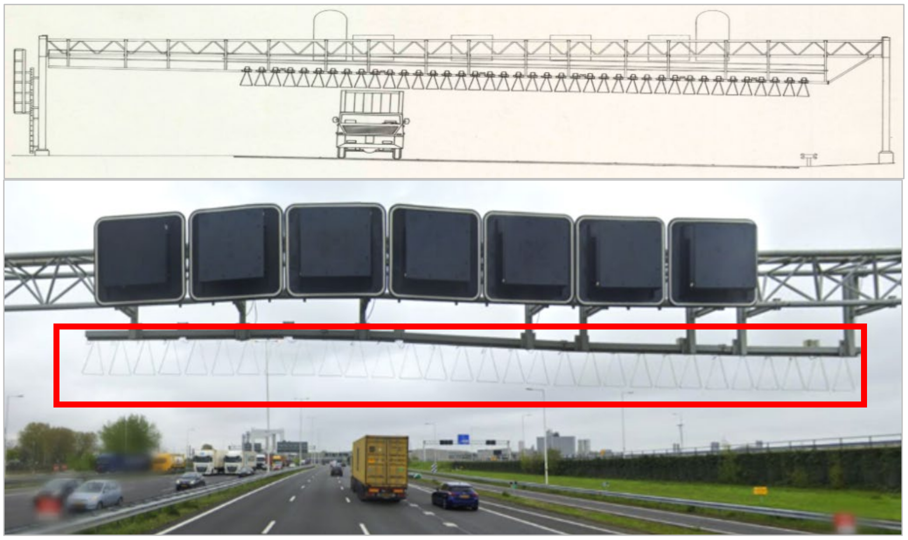
Figure 6: Hanging Bells at Tunnel Entrance



Source: FHWA (top) and TfL (bottom)

Authorities in the three visited countries indicated that these types of countermeasures – on their own – may have limited effectiveness. Many drivers do not hear them due to other noise and distractions, or they hear them but do not realize what they are or what the sound signifies. IR expressed concern that these devices – when heard – can have a startling effect on the driver, thereby causing further safety issues.

Figure 7: Hanging Hinged Triangles at Tunnel Entrance



Source: RWS (Netherlands)

Other Physical Measures

The visited countries identified several other physical infrastructure-based measures:

- **Moving ventilation (or other equipment in the tunnel) outside the tunnel.** The Netherland's RWS added 20 centimeters, or 7.9 inches, of clearance by moving ventilation outside some tunnels while retaining the efficacy of the fans (Figure 8).
- **Raising the structure.** In Ireland, IR worked with TII to raise a frequently struck bridge, after which no strikes were recorded. RWS raised a tunnel by 5 cm (2 inches) and reduced over-height vehicle detections by 50 percent.
- **Reconstructing a structure.** With the age of many railroad bridges in the UK and Ireland, newer construction can allow for assorted designs and thinner decks. However, in the case of railroad bridges near stations, this can be difficult; further, the UK and Ireland have many historic bridges that cannot be removed or reconstructed.
- **Traffic calming.** Slowing vehicles under bridges and tunnels can help drivers be more aware of their surroundings and give them more time to react, and reduce crash severity.

Figure 8: Ventilation Moved Outside Tunnel Entrance

Source: RWS (Netherlands) and FHWA

Roadside Technology

Each application of roadside technology is tightly integrated with a set of agency processes and protocols, regulations, and enforcement. The examples observed in the visited countries represent sophisticated applications of advanced, interconnected technology. Usually redundancy is built in, with multiple sensors, warnings, or preventative measures – with increasing severity – when approaching a bridge or tunnel. Together, these roadside technologies are effective in reducing bridge and tunnel strikes. However, they are specific to a single structure, and are likely to be applied to high-risk, high-impact assets.

While all three visited countries used similar types of roadside detection and warning systems, different agencies used several types of sensors, had different ways of layering this technology with other countermeasures, and had different philosophies around prevention and enforcement.

Irish Rail Over-height Detection with Time-Delay Warning Signs

Ireland's Amiens Street bridge, built in the 1850s, carries one of Irish Rail's mainlines into Connolly Station over a busy arterial roadway in central Dublin. Despite slightly exceeding the regulatory height below which bridges are considered low clearance (4.65 m, or 15.3 feet), the bridge experienced 46 strikes in 10 years, and 3 major strikes in a 6-month period. The last strike, involving a non-over-height vehicle carrying over-height construction equipment, came close to hitting pedestrians under the bridge.

IR considered several approaches, including raising or replacing the bridge; however, when considering capital and ongoing maintenance costs, IR chose a suite of technology to prevent future strikes. In 2020 Irish Rail installed systems on the approaches north and south of the bridge that sense vehicle height and activate signs that flash and alert the vehicle (Figure 9). The system has several components:

- Dual sensors detect over-height vehicles: both must be broken to activate the system to prevent false positives from birds and snow.
- When the system is activated, a lighted but static message sign prior to the first intersection indicates "Low Bridge Ahead – Overheight Vehicle Turn Right" with an arrow.
- At the last intersection before the bridge, a second, similar sign directs the driver to turn left. This sign is activated on a time delay to account for estimated travel time from the first sign (there is no second sensor at this location, so the second sign is always activated).
- Along with this sign, a large LED video marketing display on the bridge over the roadway transitions to a sign that says "Warning! Over-Height Vehicle Detected."
- The second sign and video marketing display get automatically activated one more time, as a precaution in case the over-height vehicle was delayed reaching this point.

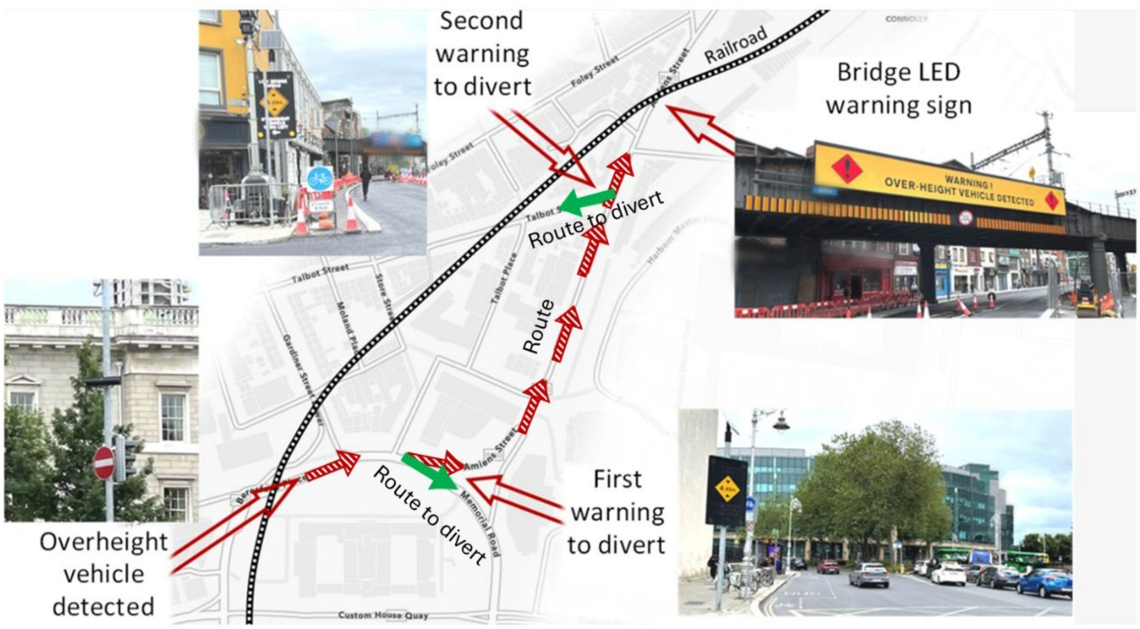
IR had several technical specifications and concerns they considered:

- The technology needed to be cost effective and easy to install.
- A reliable power supply, and they selected solar with battery backup for the signs.

- The density of the curb and sidewalk space created challenges for placing equipment and finding a good line of sight for drivers without impacting other structures, signals, and signs.
- Bridges in denser urban areas have many approach options – the signage needs to be far enough from the bridge to allow for vehicles to exit the path towards the bridge, but still close enough that it is not triggered by vehicles not traveling towards the bridge.

As of June 2024, there had not been a single collision since the 2020 installation, though there were numerous activations. Irish Rail, funded by the National Transport Authority, paid for the system, which was installed in cooperation with the local authority.[8] Irish Rail plans to install this type of system at other bridges that are frequently struck and that experience high impacts to rail service due to bridge strikes, but that are suitable for the system.

Figure 9: Irish Rail Amiens Street Bridge Detection and Warning Sign System



Source: FHWA

Netherlands Tunnel Over-height Detection and Warning Systems

For RWS tunnels, there are three phases of intervention when an over-height vehicle is approaching a tunnel (Figure 10):

1. **Advisory Phase:** Roadside sensors detect an over-height vehicle. A static road sign with flashers, tunnel height, and the next exit (the last regular exit before the tunnel) indicated is triggered. It is upon the driver to exit or adjust the truck's load.

[8] https://dublininquirer.com/2023/07/05/three-dublin-railway-bridges-are-among-those-most-often-hit-by-drivers-says-irish-rail/

2. **Warning Phase:** After the last publicly available regular exit, another set of sensors detect an over-height vehicle that failed to exit. An overhead sign displays a lowered speed limit of 70 kilometers per hour (kph) (43.5 miles per hour (mph)).
3. **Red Phase:** If the vehicle continues, the traffic control center reduces the speed to 50 kph (31.1 mph), and then to 0 kph, and closes the tunnel using signals and a barrier. They will send an RWS inspector who manually identifies the offending vehicle, directs the vehicle down a service road, measures the vehicle, and issues a fine or sends the vehicle back to the facility (see Law and Regulation section for more information about RWS inspectors).

The following is the Netherlands' tunnel standard for tunnels with vertical clearance under 4.7m (15.4 feet):

Two pairs of double beam laser sensors are used at each measurement location to reduce false positives due to snow, birds, tarps, or other similar elements. The last location also has detection loops in the pavement. Detection methods are applied to all traffic lanes, including the shoulder. Mobile LIDAR is used to measure the lowest clearance in the tunnel; heights of the sensors that trigger the warnings are based on that clearance height plus a factor of safety. That factor gets smaller at each successive set of sensors (i.e., the height of the sensors gets closer to the actual tunnel height).

The advisory phase warning sign was supplemented by a sign that displays a picture of the over-height truck back to the driver in a test at the Velsertunnel. The number of over-height vehicles on the road to the tunnel was reduced by 20 percent, and the number of vehicles that had to stop at the tunnel was reduced by 40 percent.

Sometimes false positives, such as snow, tarps blowing in the wind, tilted trailers, or differences in tire pressure, still trigger the systems. Sometimes after viewing the vehicle, the officer cancels the alarm. The process can take 15 to 20 minutes, but timing is extremely variable. If a vehicle is fined, the process could take an hour.

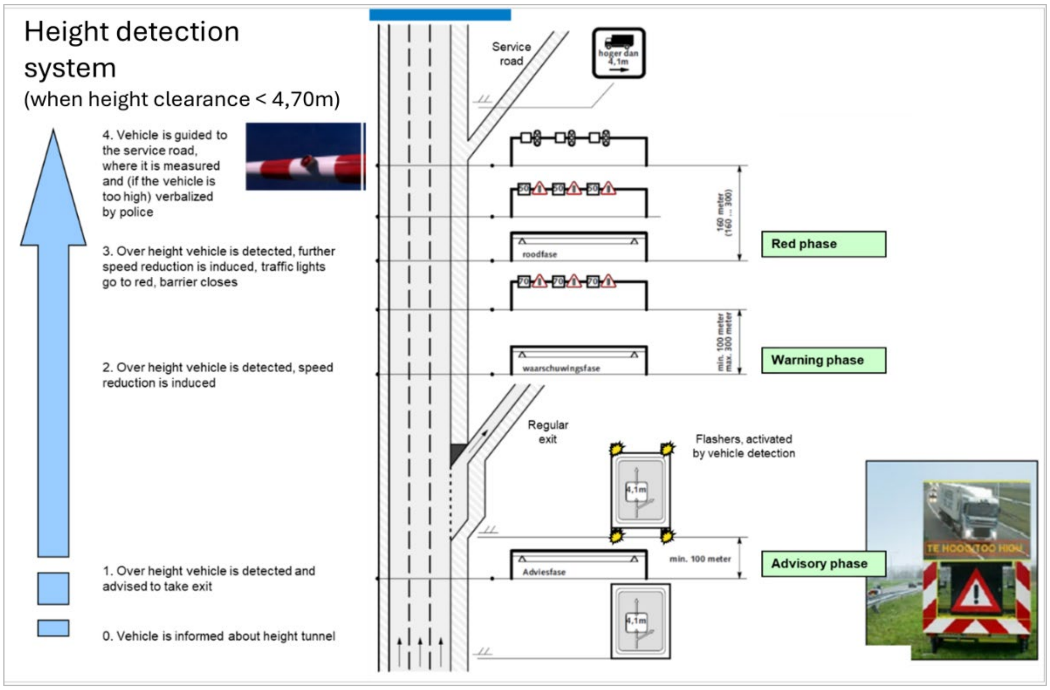
RWS indicates that 80 percent of the time when an alarm goes off, the truck still drives through. Of the 20 percent who stop, 10 percent are too high. Usually there are no strikes in these tunnels: there are only 1 to 2 cases of damage per year in one of RWS' 12 tunnels with a vertical clearance under 4.50m (14.8 feet).

RWS' traffic control centers are a key part of the success of the tunnel countermeasures. The main tasks of the traffic control centers are to ensure safety and traffic flow through:

- Incident management: coordinating, securing and handling incidents.
- Asset operation: Operating and monitoring tunnels, bridges and other assets.
- Traffic management: Directing and guiding traffic flows and coordinating and supporting road construction.
- Informing: Providing information to road users.

The centers ensure close coordination with RWS inspectors, emergency services, and others.

Figure 10: RWS Tunnel Over-height Detection and Warning System



Source: RWS (Netherlands)

Ireland Tunnel Approaches with Laser and LIDAR Detection

TII uses systems of lasers, LIDAR, license plate recognition cameras, CMS, and signals and gates to prevent tunnel strikes from over-height vehicles. These use a set of 2 laser beams for each detection point, requiring an over-height vehicle to break both beams in the direction of travel: this reduces triggers due to birds or weather. Loop detectors combined with these lasers further reduce false positives by confirming a vehicle is passing the sensors.

Similar to examples in London and the Netherlands, TII uses several sets of these detectors at points leading up to a tunnel entrance, each combined with CMS that first indicate that an over-height vehicle has been detected and should exit, and then – if the vehicle has not left the facility – that the vehicle must stop (Figure 11). This is combined with traffic signals prior to the tunnel, as well as an actual barrier that can be deployed. TII's license plate recognition cameras can capture information from vehicles that do strike a tunnel but flee the scene; one tunnel displays the license plate of the over-height vehicle on the CMS. Off-the-shelf over-height vehicle sensors on one of TTI's tunnel approaches is shown in Appendix H.

Figure 11: Transport Infrastructure Ireland Tunnel Over-Height Warnings and Closure

Source: TII (Ireland)

At one tunnel, TII has installed LIDAR as an additional means of detecting over-height vehicles. It provides greater detail of the vehicle, and it also includes detection of which lane the vehicle is traveling in. TII indicated that a hybrid solution of sensors – rather than relying on a single type of sensor, such as lasers or LIDAR – along with loop detectors was used to try to provide better information to control centers, protect tunnels, and reduce false positives.

However, TII found that LIDAR detection can be more sensitive to things such as the slope of the road or even the color of the vehicle. The new system has resulted in an increase in false positives and tunnel closures. Although these are still relatively few compared to the 70,000 vehicles per day that pass through the tunnel, TII recently stopped their use of LIDAR at this tunnel.

London Tunnel Over-height Detection and Warning System, with Escape Ramp

Like other agencies in the visited countries that operate tunnels, TfL uses a variety of detection and warning devices to prevent tunnel strikes; this is particularly critical as some of their tunnels are old with low clearances. Also like those agencies, TfL uses a progression of detection stages and warnings, leading to a red signal and closure of the tunnel. These systems are all tied back to the traffic control center.

TfL's approach is not intended to be punitive: it is intended to prevent the strike and remove the vehicle from the traffic flow quickly to avoid additional delays. At one critical tunnel TfL added an escape ramp, along with a public address system placed at the red signal and gate where an over-height truck would stop. The ramp allows for the stopped truck to leave the roadway and brings them to the other direction of travel on the same roadway. If the truck does not move, then the control center can speak to the driver via the public address system. The driver is not fined, unless the driver attempts to beat the gate and red signal at the last phase and enters the tunnel. The tunnels also have CCTV that can be recorded to support police investigations and claims.

TfL found these countermeasures to have a high return on investment. The tunnel with the system above, including the escape ramp, used to be damaged every few weeks; now it has not been damaged for 3 years. It has saved costs from damage, closures, delay, staff time, and claims.

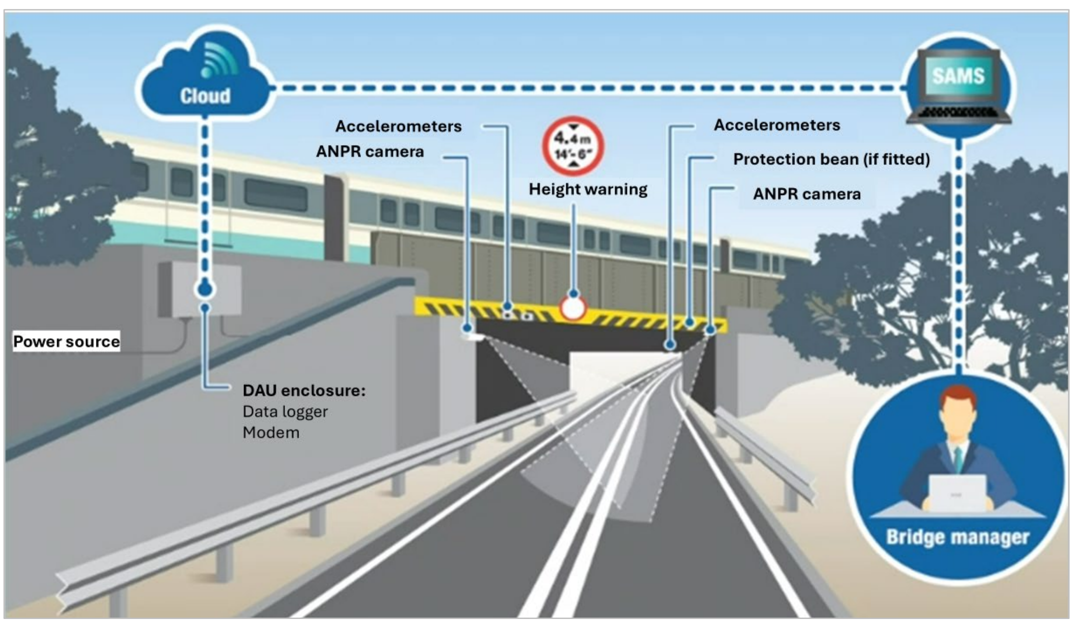
Remote Cameras and Sensors

Cameras and sensors on structures allow monitoring in real-time. This can help to immediately identify a bridge or tunnel strike, instead of a longer duration when reported through traditional means or may go unreported. It also can help experts observe the level of damage to a structure immediately and to take appropriate safety measures.

Irish Rail, for example, has cameras under and over key bridges. The cameras allow staff at a computer to give an initial clearance after a strike, as inspectors may take time to arrive at the scene. The cameras also have helped with prosecution of offenders. IR stressed the importance of being aware of data protection rules. Accelerometers attached to bridges detect movement in the components to which they are attached. IR is developing a platform for accelerometer monitoring of bridges for bridge strikes and other potential stressors.

Since 2021, a UK company installed its bridge strike detection system on 11 London Underground bridges along above ground segments of the network. The system includes cameras, accelerometers, and a series of algorithms that connect with a control center via a dashboard and emails to inform London Underground of bridge strikes and their impacts real time (Figure 12).

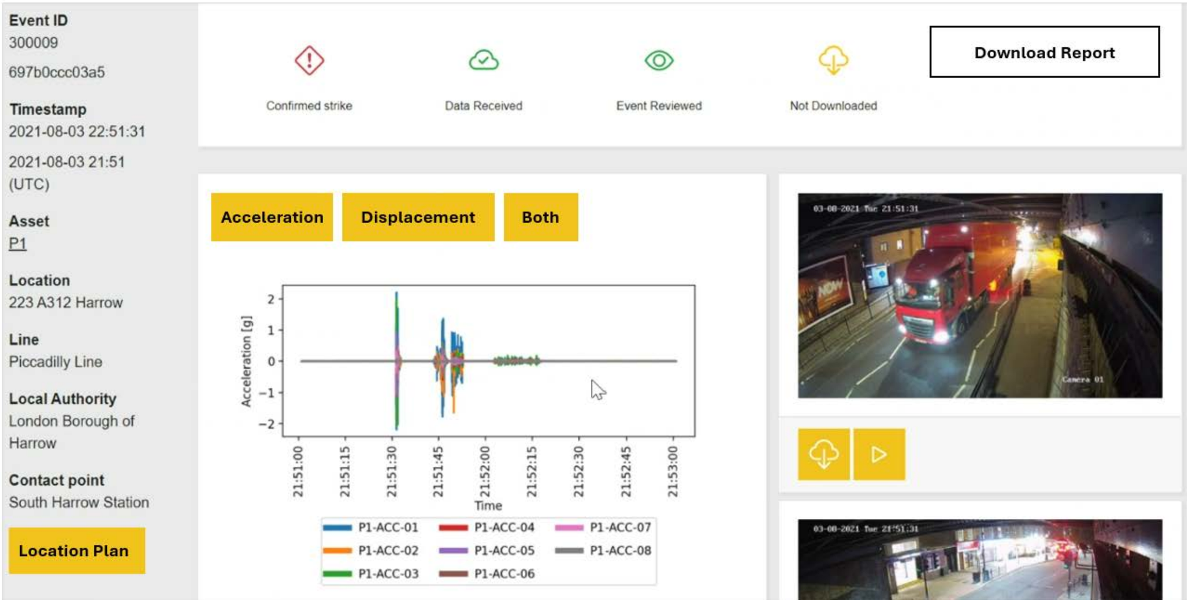
Figure 12: London Underground Bridge Strike Detection System Schematic



Source: BES

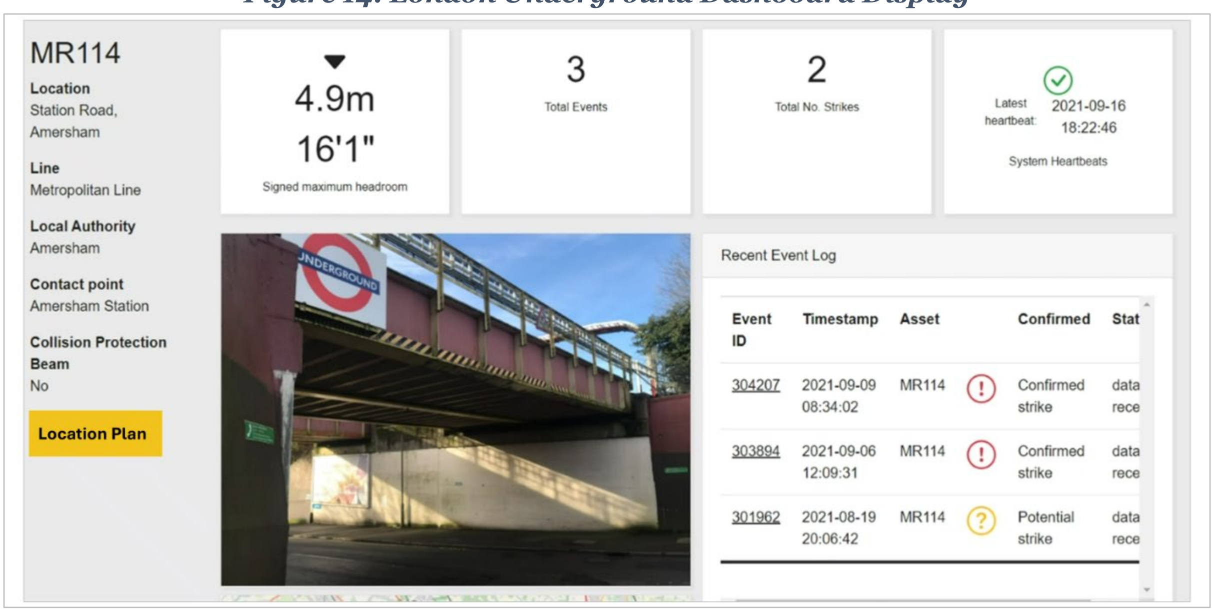
When the accelerometers detect a movement beyond regular operations, the video capture is triggered from the live cameras both immediately before and after the event. Video capture, accelerometer readings at critical positions, location, time, and other key data are emailed and made available on the system dashboard (Figure 13). This allows staff to make decisions on the severity of a strike and measures to be taken, and over time it allows the agency to track trends across their bridges (Figure 14).

Figure 13: London Underground Display of Potential Bridge Strike Event



Source: BES

Figure 14: London Underground Dashboard Display



Source: BES

When London Underground gets notified by the system, they observe the data and footage. While procedure still requires them to visit the site and fill out required paperwork, they now may not need to get there immediately. The agency reports many more bridge strike notifications since the system was installed, implying that prior strikes may have gone undetected.

Tunnel Speed Standstill System

The Netherlands' RWS uses a speed standstill system for its tunnels. This system monitors the speed and direction of traffic and reports to the road traffic controller in the traffic control center if the speed falls below set values or if the direction of travel is against traffic; this could be a result of regular congestion, or it could be an indication of a crash or tunnel strike. The road traffic controller can then take prescribed safety measures, such as calling emergency services and, in extreme cases, closing the tunnel.

However, the current system generates many notifications to controllers that do not imply any safety issues or require action. RWS is currently experimenting with three different companies in different tunnels on improving these systems using various combinations of:

- Cameras inside and outside tunnels.
- Radar.
- Induction loops, and
- Smarter software algorithms for error correction and reporting.

Once RWS arrives at a preferred solution, the Netherlands will adjust the national tunnel legislation (described in the Law and Regulation section) and apply the standard to any future tunnels or renovations of existing tunnels. While the technology will be off-the-shelf, the algorithm and process will be specific to RWS.

In-Vehicle Technology

Warnings and alerts external to a vehicle, like those described in the previous sections, may not always catch the attention of drivers, who are focused on the many needs related to driving a heavy truck. Various in-cab devices have been developed to alert drivers of potentially dangerous vertical clearances ahead. These devices are often linked to roadside technology, external databases, or other tools. Often components of these systems and devices also rely on manual driver input.

Navigation and routing for trucks is also a common issue that leads to bridge and tunnel strikes. Most publicly available guidance systems do not incorporate truck restrictions or low clearances into their data and routing algorithms; and even if they do, the system may not link to a particular truck and load's height that day to properly route the vehicle and alert it of any potential strikes. Several systems and approaches have been developed to solve these challenges.

Systems designed specifically for trucks face challenges with driver buy-in. It is important for drivers to trust the system and not ignore it, which can be undermined through false warnings.

In-Vehicle System for XPO Logistics

XPO Logistics UK contracted a UK company to develop custom in-vehicle technology that uses telematics to automatically warn a truck driver when a low bridge poses a strike risk along the route. Rather than use existing solutions, XPO requested a new product for several reasons:

- **Human error:** Other solutions and tools that rely on drivers to input vehicle heights before each journey create more uncontrolled risk.
- **Excessive alerting:** Geofenced-based solutions result in false positives and excessive alerting, resulting in less driver trust in the warnings.

- **Different tractor and trailer combinations:** Across trips, drivers may pull trailers of different heights, which could cause existing systems to use incorrect data.
- **Inadequate reporting:** A detailed audit of information surrounding an actual strike is critical for the company and authorities.
- **Liability, legality, and reputation:** Due to several prior strikes, XPO was asked by the UK Traffic Commissioner to identify its countermeasures to reduce future strikes.

For the purposes of XPO's specific needs, the technology provider considered and eliminated several technologies:

- Bluetooth had signal strength concerns, pairing issues, and too many devices to pair and communicate with.
- Artificial intelligence (AI) cameras require clear visibility, have complex installation procedures, and are expensive.
- Geofencing's level of accuracy has the potential for false positive alerts to drivers.
- Lasers were deemed too expensive, and potentially dangerous from a moving vehicle.

Ultimately, they decided to use Radio Frequency Identification (RFID) tag and reader solution suitable for tractor and trailer linkages. RFID provides them with an inexpensive, easily integrable solution with a strong signal strength (adjusted to a range of 5m, or 16.4 feet, so as not to accidentally pick up other tags). It enables both trailers and tractors to have a height attached to them at installation, with the highest part of the vehicle used by the system.

No driver input is needed: vehicle heights are input during installation. Since heights are fixed once input, and not based on any real-time detection, a fleet manager has ownership of the input heights and may adjust to the highest level a trailer could be. The device can be configured remotely. It detects every low bridge in the UK, as well as other height restrictions such as parking garage barriers, through a live database that is updated by a third party. If a road is resurfaced, the appropriate government body is required to change the road signage, which updates the database from which the system uses information.

The system's algorithm takes into consideration direction of travel, current speed, live traffic status, live average road speed, and ability to physically access a bridge. These features reduce false positives and therefore reducing the number of alerts. It scans every seven seconds, and alerts drivers if they are within 60 seconds' live drive time of a low structure. The alert consists of an in-cab audio message. While the standard message is "Warning Low Bridge in Area", this message can be pre-programmed as desired. Alerts will only stop being played in-cab when the vehicle is no longer within 60 seconds' live drive time of a low structure, or the vehicle is no longer travelling in the direction of the low bridge. On average, each driver is alerted 3 times before they take action to avoid the low bridge.

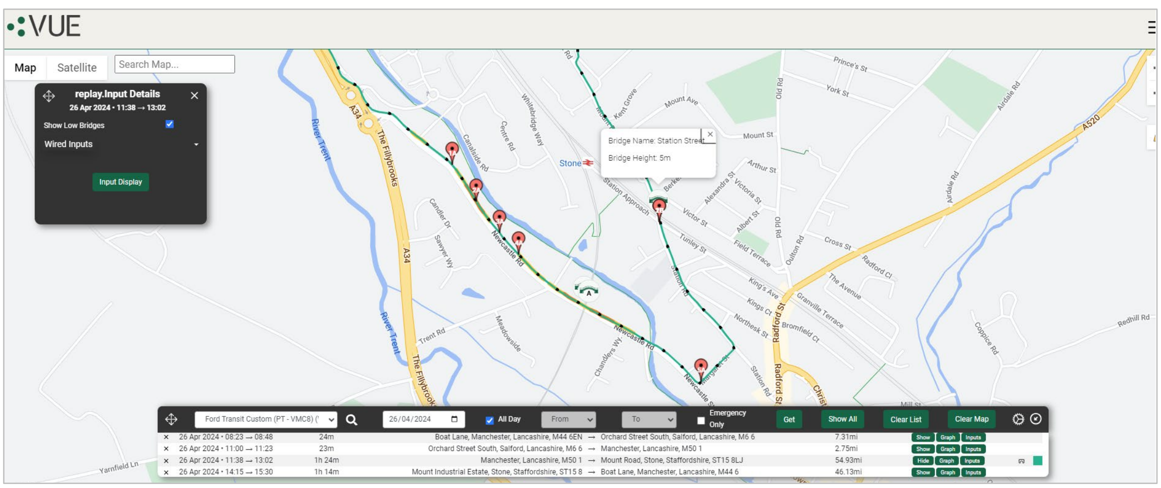
During the testing phase, an LED light was added to indicate when a mobile data connection is lost (i.e., the system is not functional). To further highlight this risk, the provider added a data layer of cellular blackspots to the mapping interface, overlayed with bridge locations. As shown in Figure 15, the device provides comprehensive reporting that allows companies to view alerts on a map to see an audit of exactly when and where drivers were alerted, including:

- Location and timestamp of scan.
- Whether an alert was played.
- Bridge name and address.
- Height of the bridge and of the vehicle.
- Direction vehicle was facing.
- Distance to bridge.

It also stores data histories of alerts that can be accessed for training and documentation purposes. The system does not have to be manufacturer installed and costs are dependent on kit requirements. It is currently only available in the UK due to the databases that are used.

XPO Logistics first evaluated the in-cab truck technology during day and night distribution runs from its Bury St Edmunds, Suffolk depot, expanding to the rest of the vehicles at that depot in September 2022. These initial trial runs allowed for adjustments while working with drivers, further strengthening their buy-in. As of June 2024, the system is expanding to the rest of the fleet, and it has alerted the drivers of 650 vehicles over 1 million times. Since implementation, no outfitted vehicles have been involved in a strike.

Figure 15: XPO Logistics UK In-Vehicle System Reporting Interface



Source: VUE

Various In-Vehicle Technologies for TESCO Trucks in the UK

TESCO, a UK grocer, provides for the purposes of this study a selected example of a UK company with a large fleet that has implemented several process, training, and education countermeasures to reduce bridge strikes for its fleet; these are described in the Training, Education, and Driver Behavior section. The company also incorporates or is developing a variety of in-vehicle technologies:

- In-house route guidance software, including approaches to both, planned and off-route guidance.
- Automated measuring devices with digital signage.
- GPS-linked in-cab warning devices

- GPS-linked devices with AI sign-reading software.
- Routing technologies automatically linked to vehicle height.
- Back-up systems for automated trailer levelling.
- Advanced driver assistance systems which connect vehicle brakes to routing technology.

Key to their current in-vehicle technology is their in-house route guidance. TESCO provides its drivers 100 percent of their end-to-end route guidance through this system, and drivers are not allowed to deviate from this or use other products.

Other In-Vehicle Technology

Several other in-vehicle products for reducing bridge and tunnel strikes are under development or already on the market in the visited countries:

- One UK-based product uses **GPS location data, mapping services, and geofencing to warn drivers via LED-enhanced alerts and an audible warning system** of upcoming low bridges. The supplier states that this system does not require driver input if the height of the load does not vary, with the height and width of the vehicle set at the point of installation. It is pre-programmed with a database of up to 3,750 bridges in the UK and Ireland. Visual and audible alerts are generated automatically, with multiple attempts to advise the driver to stop the vehicle. This can be used as a standalone product, powered by the vehicle's auxiliary power outlet (cigarette lighter socket), or alternatively it can be deployed as part of the company's On Demand online platform. That online platform provides operators with instant remote alerts and on-demand access to their fleet, at all times.
- The UK's DfT is creating a framework that can be used to **link connected vehicles to road signage** via in-vehicle navigation systems and mobile phones, thereby including information from such signage in real-time routing (see Section 5 – Data Management).
- The EU is developing data standards across member countries to ensure **consistency in data for GPS navigation systems**; specifically, they are developing standards for including traffic restrictions, such as truck restrictions and bridge or tunnel height restrictions (see Section 5 – Data Management).
- In-cab **visual and audio warning systems for raised dump beds** or other raised equipment are readily available; more about these systems and related regulations in the UK and Quebec are in the Law and Regulation section.

Training, Education, and Driver Behavior

The agencies in all three visited countries identified driver behavior as their leading concern as the cause of bridge and tunnel strikes. In the UK, NR's research revealed that 43 percent of truck drivers do not check the height of their vehicle before heading out, and 52 percent of truck drivers do not consider low bridges when planning their journeys. A 2011 survey indicated that drivers believed causes of bridge strikes include drivers not knowing vehicle height (32 percent); poor route planning (22 percent); drivers not understanding signs (15 percent); poor information about low bridges when planning a route (11 percent); inadequate signing (9 percent); and drivers not believing signs (8 percent).[9]

As a result, the countries visited believe that strategies focused on impacting driver behavior are most critical, beyond any other design and safety standards already in place. Examples of driver behavior-related bridge and tunnel strikes often related to driver distraction. Sometimes drivers were simply unaware of their actual vehicle height, including their load. Occasionally, drivers were both aware of the issue and their height but attempted to get around regulations. Sometimes the perceived value to a driver or operator of carrying a slightly greater load outweighed – in their view - the risks of damages and fines. Agencies cited examples of drivers attempting to pass a low tunnel or bridge by driving slower (or faster), lowering their suspension temporarily to miss sensors, or tying bamboo sticks above their cabs and seeing where the sticks broke off driving under a structure to test the structure's actual (as opposed to posted) height.

> *Excavation equipment on the back of a truck was raised; the driver clipped a bridge on the highway, pulled over due to the noise, but thought he was fine. As he started moving off the shoulder, he passed under a pedestrian bridge, and due to the lower clearance near the shoulder, he completely took down the bridge.*
>
> *- National Highways*

As a result, agencies in the three countries emphasized the importance of building driver and manager habits through:

- Consistency in training
- More driver awareness, including the dimensions of their vehicle, and the potential personal and other consequences of a strike (safety, legal and monetary)
- Reiteration of key messages, e.g., measuring one's vehicle.

The importance of training and education of elected officials and law enforcement was also evident. As their support is critical for reducing bridge and tunnel strikes, it is important for them to be aware of the seriousness of the problem, monetary costs, transportation impacts, and potential safety concerns. The UK's NR cited the need to create a culture where everyone in the transport system, from drivers to logistics managers, takes bridge and tunnel strike prevention seriously. This includes working with industry groups, insurance companies, and the public to raise awareness and change attitudes about safety.

Company Training

TESCO indicates that preventing bridge strikes is a priority because:

- Bridge strikes are very high profile with transportation regulators and formal action against the companies' licenses to operate in the UK are a high risk: The Traffic Commissioner has the authority to "grind operations to a halt" within the UK's regulatory framework (see the Law and Regulation section).
- Safety culture comes from the top down.

[9] https://www.networkrail.co.uk/wp-content/uploads/2020/11/Bridge-Strikes-Risks-Consequences-and-Costs-2020-accessible.pdf

- Operational impacts to others, including customers, are a key business concern.
- Brand damage is adversely affected when a company truck is involved in a strike or major crash is significant.

As a result, TESCO has several routine actions in place as part of bridge strike prevention:

- A regularly reviewed policy related to bridge and tunnel strikes.
- Height stickers on vehicles and trailers.
- In-cab height indicators, with heights documented.
- Managers' gate checks.
- Driver training at onboarding and ongoing over time.
- Training for managers and clerks.
- Mandatory route guidance adherence, with drivers calling in if diverted.
- Analysis of bridge strike causes.

TESCO uses a variety of collaboration, technology, and driver awareness and education countermeasures (Table 4).

The company has found that driver awareness is the most important of the three and is what has most impacted bridge strike numbers. The company found that if all the drivers get the same training, then they get the same results. Drivers are trained to:

- Check their height.
- Conduct a set pre-trip routine.
- Use the in-cab height meter.
- Input their information into a handheld tablet (Figure 16).[10]

TESCO provides complete end-to-end route guidance, using their own in-house guidance system that incorporates low-clearance structures. Drivers are not allowed to deviate from that guidance. If there is an unforeseen detour, drivers are trained to stop the vehicle, call the company, and receive step-by-step instructions on an updated route.

[10] https://vimeo.com/tailwindgroup/review/745022545/0ec3f7d3ec. This video was created by an outside entity and is included in this report for illustrative purposes only. The views and opinions expressed in this video are the outside entity's and do not necessarily reflect those of FHWA or the U.S. Department of Transportation (USDOT). The contents do not necessarily reflect the official policy of the USDOT.

Table 4: TESCO Approach to Reducing Bridge and Tunnel Strikes

Driver Awareness	**Technology** (in use and under development)	**Collaboration**
• Near miss procedure • Debrief discussion • Posters • Routing feedback process • E-learning module • Letter to home addresses • Pre-brief reminder • Engage trade union leaders • Bridge strike video • Questions on in-cab device • Quarterly refresher training	• In-house route guidance software, for planned and off-route guidance • Automated measuring devices with digital signage • GPS-linked, in-cab warning devices (radial and predictive) • GPS-linked devices with AI sign-reading software • Routing technologies automatically linked to vehicle height • Back-up systems for automated trailer levelling • Advanced driver assistance systems which connect vehicle brakes to routing technology • Discussions with European New Car Assessment Programme	• Reviewed vehicle defects with Driver and Vehicle Standards Agency (DVSA) safety team • Part of Network Rail's bridge strike prevention group • Member of the Earned Recognition scheme • Regular formal meetings with NH, TfL, and transport operators • Bridge strike prevention included in contractual terms • Attending transport conferences throughout the year • Working with trade associations (Logistics UK) • Chairing the Road Freight Council • Contributing to policy development and influencing Government lobbying efforts

Source: TESCO

TESCO's bridge and tunnel strike numbers went up after the introduction of new high-sided vehicles in 2019. The height of the new vehicles, combined with unexpected diversions due to accidents and construction, were the leading causes of strikes or near misses. After introducing the procedures identified above, bridge and tunnel strikes decreased in 2023 and 2024.

Figure 16: TESCO Company Driver Training Video

Source: https://vimeo.com/tailwindgroup/review/745022545/0ec3f7d3ec

Disclaimer: This video was created by an outside entity and is included in this report for illustrative purposes only. The views and opinions expressed in this video are the outside entity's and do not necessarily reflect those of FHWA or the U.S. Department of Transportation (USDOT). The contents do not necessarily reflect the official policy of the USDOT.

Approaches for education and improving driver behavior at other firms with large fleets include:

1. Having management on-site to talk to drivers throughout the day and night.
2. Exit gate checks and walk-arounds with drivers.
3. Billboards and posters around facilities, reminding drivers to measure trucks.
4. Putting bridge strike prevention messaging on company folders, papers, stickers, and other items in the vehicle.
5. Banning personal GPS navigation systems and applications and confirming at the exit gate that they are using an appropriate system.
6. Communicating the consequences of bridge strikes to drivers, including examples of drivers being banned after causing a strike.

Required Training and Certification

Every five years truck drivers in the UK must take 35 hours of training to renew their Certificate of Professional Competence (CPC). UK's NR has a module for the CPC training relating to bridge strikes as part of awareness training. Information is available on the NR website that can be used to prepare for the CPC training. The Senior Traffic Commissioner, who regulates the industry (see the Law and Regulation section), issued a reminder to the industry in 2020 of its obligations and consequences: regulatory action for operators and drivers who fail to act appropriately to prevent bridge strikes. Several UK organizations offer this training, including Logistics UK, an industry group representing 20,000 members. They inform members about regulatory requirements and compliance; provide legal advice; share information; and lobby on behalf of their members to government. They work with agencies like NR and NH on reducing bridge and tunnel strikes.

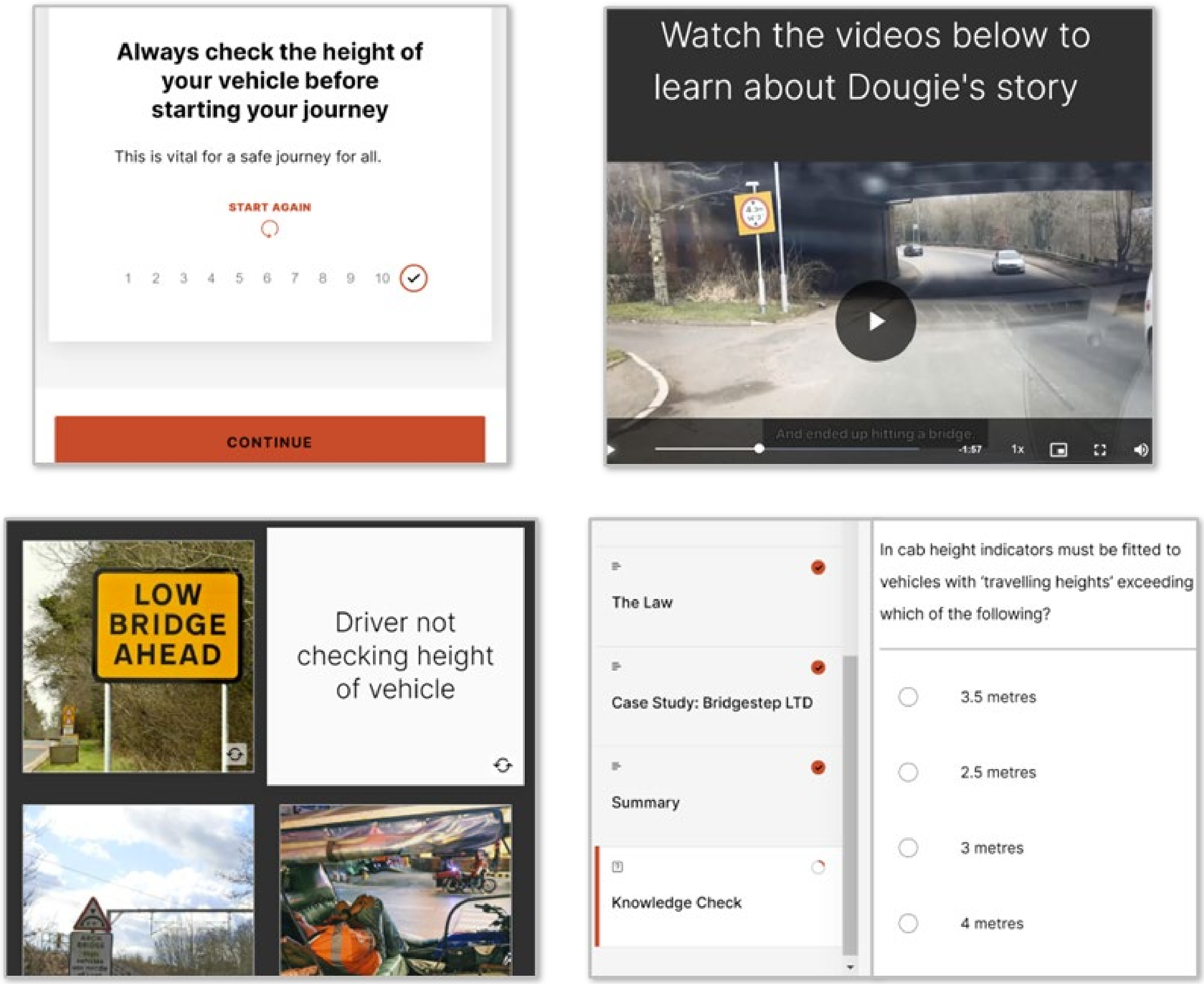
Logistics UK worked with NR to develop an eLearning package and with NH on a half-day driver CPC course. Its training approach is based on the way its participants most effectively learn. This includes characteristics such as gamification, use of an avatar, and team exercises. The training includes case studies, videos, and quizzes. The CPC module on bridge strikes aims to:

- Remind drivers of the importance of safety for themselves and their organizations.
- Highlight the importance of route planning and driver checks.
- Identify causes of bridge strikes and provide advice on how they can be prevented.
- Raise awareness of the risks and consequences of bridge strikes.

The training walks drivers through:

- Operator responsibilities.
- Causes of bridge strikes.
- Consequences and costs, including relevant laws.
- Prevention, including actions before and during a journey.
- Actions in the event of a bridge strike, including relevant laws (Figure 17).

Figure 17: Elements of Driver Certificate of Professional Competence Training



Source: Logistics UK

For preventative countermeasures, the training recommends the following actions for operators:

- An operator's health and safety policy statement should include the management of bridge strike risks.
- Training programs should include the prevention of bridge strikes. Ensure bridge strike avoidance is included within driver onboarding and CPC training programs.
- Ensure all drivers are provided with a copy of Network Rail's *Prevention of bridge strikes - a good practice guide for professional drivers* and briefed on its contents; it includes a driver checklist (Figure 18).
- Conduct gate checks to ensure vehicle heights correspond to in-cab height indicators.
- Check all routes are risk assessed. Communicate risks and controls to staff and drivers.
- During a journey, communicate to drivers any unplanned or emerging situations arising from road closures. Provide drivers with guidance and assistance on alternative routes or actions to be taken to avoid low bridges when advised of road closures.

- Ensure drivers have access to equipment, information, and training to ensure height indicators are accurate prior to commencing their journey (DVSA may conduct roadside checks to ensure that vehicle heights correspond to in-cab height indicators).
- Ensure GPS navigation software is suitable for heavy trucks.
- Maintain communication with drivers and communicate traffic alerts.[11]

Drivers must check:

- The security and safety of the load.
- The width of the vehicle including mirrors.
- The height of the cab.
- The height of any trailer, its load, and equipment.
- That the correct maximum height is displayed in the cab.
- The height of the vehicles and the load before every journey: the suspension mechanism of a truck can decompress with lighter loads and alter the expected vehicle height.[12]
- During the journey, they should know their height, width, route, and obey traffic signs.

[11] Logistics UK Driver CPC Training Module
[12] Logistics UK Driver CPC Training Module

Figure 18: UK Network Rail Professional Drivers' Route and Vehicle Check

Date		Driver's name	
Vehicle no.		Trailer fleet / Serial no.	
Route	From	To	Via
Load type	☐ Box	☐ Container	☐ Curtainsider
	☐ Plant & Machinery	☐ Skip	☐ Waste
	☐ Car transporter	☐ Other (specify):	

Route and vehicle check	
Have low bridges on your route been identified?	☐ Yes ☐ No
What is (are) the location(s) of the lowest bridge(s) on the route?	
What is the limit on vehicle height under bridges on your route?	.... ft .... ins .... metres
Is the load and equipment properly secured and safe?	☐ Yes ☐ N
What is the maximum travelling height of your vehicle?	.... ft .... ins .... metres
Is the maximum height of your vehicle less than the limit on vehicle height under bridges on your route?	☐ Yes ☐ N
What is the maximum width of your vehicle?	.... ft .... ins .... metres

Know your vehicle height and width.
Know your route. Obey traffic signs.
Don't hit and run.

Source: https://assets.publishing.service.gov.uk/media/5a79d4b0ed915d042206b591/bridgestrikestransmanagers.pdf

Manuals and Guidebooks

UK's NR has worked closely with public and private sector partners to create and disseminate guidebooks for drivers, transport managers, highway managers and bridge owners, audits, inspections, rankings, and other purposes. Some guides are endorsed by the Parliamentary Under Secretary of State for Transport. These guides are publicly available online:

- **Transport managers guide**. This guide includes the recommended system for signing high risk bridges; safety inspections, including the condition of traffic signs at and in advance of low bridges; and road maintenance to consider the reduced clearance for vehicles at these bridges. NR produced this guide in conjunction with organizations representing the freight and construction plant transport industry, including:

  - Department for Transport
  - Freight Transport Association
  - Road Haulage Association
  - Construction Plant-hire Association
  - Associations of Chief Police Officers

- **Professional drivers' guides for trucks and passenger vehicles.** These short guidebooks describe the consequences of strikes, how to prevent strikes, how to interpret relevant signage, and what to do in the event of a strike.
- **Guide for passenger vehicle operational staff.** This guidebook describes the law and related consequences for bridge strikes, actions that staff can take to prevent strikes, training that can support that, and what to do if a strike occurs. [13]

Philosophies to Posting Bridge and Tunnel Clearances

Each country visited exhibited different philosophies around signage for bridge and tunnel clearances, and whether to officially post actual measured clearances or clearances with a margin of safety. The philosophy was driven by an attempt to anticipate driver behavior and reduce bridge strikes. When margins of safety were incorporated into official posted clearances, agencies assumed that drivers would not include their own margin of safety when comparing their height to the height of a structure; further, they would not account for change in tire pressure, shifting loads, shocks, or other items affecting the truck's exact height. This strategy carried over to the height at which sensors were placed before a structure. Countries reported, however, that drivers often found ways to discover that measured clearances were different from posted clearances.

Agencies that post measured clearances are concerned that if posted clearances include a margin of safety, and drivers discover this, then there will be reduced credibility in the accuracy of low bridge and tunnel warnings and signs in general. Further, if a driver learns that there is a margin built into a particular posted clearance, that driver may assume the same margin in all posted clearances and will make clearance decisions based on that assumption; if margins are different across structures, then that could increase bridge and tunnel strikes.

Marketing and Communication

Representatives from each country expressed the need to balance enforcement and prosecution with positive engagement. Beyond specific educational or licensing-related efforts described above, several examples highlight multifaceted marketing campaigns, short online videos, and multilingual tools to better communicate with truckers.

Videos, Campaigns, and Targeted Outreach

The Netherlands' RWS developed a brief informational video in English and Dutch, posted on YouTube, that reminds drivers of the EU 4m (13.1 feet) height standard, the importance of

[13] https://www.gov.uk/government/publications/prevention-of-bridge-strikes-good-practice-guide

measuring their trucks, and the consequences of being over-height (Figure 19). IR also produced a video which outlines the dangers posed to road users when a bridge is struck.

Figure 19: Rijkswaterstaat Informational Video

Source: [*https://www.youtube.com/watch?v=jkUwWyZJ-go.*](https://www.youtube.com/watch?v=jkUwWyZJ-go)

Disclaimer: This video was created by an outside entity and is included in this report for illustrative purposes only. The views and opinions expressed in this video are the outside entity's and do not necessarily reflect those of FHWA or the U.S. Department of Transportation (USDOT). The contents do not necessarily reflect the official policy of the USDOT.

The UK has had multiple marketing campaigns targeted towards truck drivers and managers. In addition to a national advertising campaign that includes trucking magazines, there are social media campaigns, guides for drivers, along with closer links between NR, Traffic Commissioners, DVSA, British Transport Police, and the local police forces on enforcement. NR's campaigns have included its 'Lorries Can't Limbo' and 'Wise Up, Size Up' campaigns (Figure 20). The campaigns, originally launched in 2018, was created to remind drivers and operators of their obligations to prevent bridge strikes from occurring. Campaign posters and visual information were publicized at 'hot spots' such as truck stops, highway service stations, fuel pumps, and in bathrooms at service stations. When NH attends events to provide information to drivers on bridge strikes, they focus on three key messages: know your height, plan your route, and secure your loads.

When NH goes to events to give information to drivers on bridge strikes, they focus on three key messages: know your height, plan your route, and secure your loads.

Figure 20: Network Rail Wise Up, Size Up Campaign

Source: https://www.networkrail.co.uk/communities/safety-in-the-community/railway-safety-campaigns/wise-up-size-up/

Disclaimer: This video was created by an outside entity and is included in this report for illustrative purposes only. The views and opinions expressed in this video are the outside entity's and do not necessarily reflect those of FHWA or the U.S. Department of Transportation (USDOT). The contents do not necessarily reflect the official policy of the USDOT.

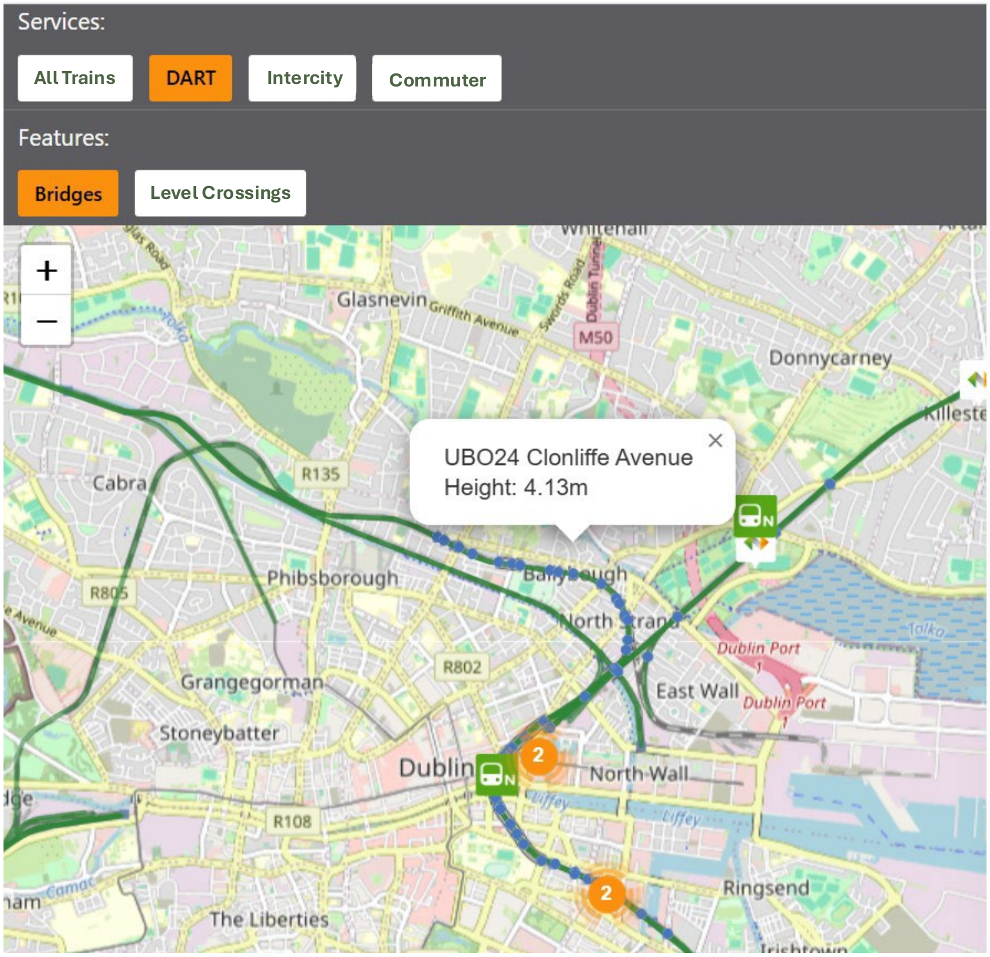
NR's regional Bridge Strike Champions raise awareness with truckers and visit and present at leading logistics companies, bus and coach companies, and major trade bodies. Another part of the process is encouraging drivers to be aware of vehicle dimensions and checking the height with a measuring pole (an inverted 'L' that can reach across, for example, to an excavator arm in the middle of a trailer) as part of the walk-round routine before beginning their journey.[14]

Interactive Maps

In Ireland, IR and TII have encouraged truck drivers to download maps showing the heights of bridges and tunnels around the country (Figure 21). They originally engaged with commercial companies to develop and maintain the platforms, but due to liability these companies stepped back. Now the agencies develop their own APIs and distribute them to truck drivers via various agencies and trade organizations.

[14] https://www.networkrail.co.uk/wp-content/uploads/2020/11/Bridge-Strikes-Risks-Consequences-and-Costs-2020-accessible.pdf

Figure 21: Irish Rail Interactive GIS Map of Rail Network with Bridge Heights



Source: https://www.irishrail.ie/en-ie/train-timetables/dart-live-map

Laws and Regulations in the Three Countries Visited

Laws and regulations underpin many of the countermeasures identified across the three countries, allowing approaches that previously had not been authorized. They also can drive agencies to innovate to meet new requirements. When applied at a national, or in the case of the EU a multinational, scale, they help to ensure consistency and effectiveness of approaches.

Tunnel Safety Regulations and Standards

EU Directive 2005/54/EC provides minimum safety requirements for tunnels in the trans-European road network. The Netherlands implemented this in their own national legislation in 2006; however, the minimum safety requirement of the Netherlands tunnels was already significantly higher than required by the EU directive. The Netherlands maintained the more restrictive requirements in order to prevent an unwanted decline of safety and to prevent regional or national traffic disruptions caused by tunnel incidents.

The Netherlands national legislation was evaluated in 2012 and revised in 2013, primarily because of discussions between RWS and local authorities regarding the required safety level and equipment standards for tunnels. The law requires:

- A uniform, legally required safety level (based on societal risk), to be verified with a risk model.
- Standard principles for incident management and emergency response operating processes in tunnels.
- Standard equipment for (new) state owned road tunnels, with a limited list of equipment, including performance requirements.

From the legislation stems more detailed tunnel standards, guidelines, and processes within RWS.

The standardization of equipment does not include the design of the equipment. The exact brands or companies for equipment are not designated. The appearance or characteristics of the tunnel structure, including length, alignment, cross section, number of tubes, or number of lanes per tube also remain site and tunnel specific. The focus is on the type of equipment, required dynamic behavior of the equipment, and the performance requirements for that equipment.

RWS identified several benefits of standardization:

- Increased efficiency, reduced cost, and reduced risk through repetition.
- Better project management, with predictable costs and schedules.
- More structured maintenance and change management.
- Better recognition for operators, emergency services, and road users.
- Streamlined discussions with stakeholders.

Vehicle Height Restrictions and Minimum Clearance Standards

The countries visited have different vehicle height restrictions, as well as minimum height standards for new structures and under which older structures must be signed.

Netherlands tunnel legislation and RWS tunnel standards are at the EU standard of 4m (13.1 feet) for legal maximum vehicle height. Higher vehicles require a permit with a designated route.

Before 2013 there were no regulations for the minimum height of tunnels in the Netherlands. Tunnels now must be built at 4.7m (15.4 feet) or higher now; tunnels below this height require a height detection and warning system (this constitutes most RWS tunnels). Fixed low clearance warning signs are required when vertical clearance is less than 4.5m, or 14.8 feet (for each lane in case the height varies).

Ireland has a 4.65m (15.3 feet) vehicle height limit. Historically, the vehicle height limit was 4.25m (13.9 feet); then the government briefly removed the height restriction entirely. When the government chose to reinstate the height limit, 4.65m (15.3 feet) was chosen as it is consistent with the height of TII's tunnels. However, higher trucks that were purchased during the period with no height limit are still on the roads today.

The UK has no legislation limiting maximum overall height. Height – unlike weight, width, and length – is a notifiable attribute rather than reportable. Therefore, vehicles exceeding typical bridge and tunnel clearances technically do not need to notify authorities or apply for a permit. There are Traffic Regulation Orders (TRO), however, restricting over-height vehicles from roads with low clearance bridges. There are also provisions for vehicle dimensions in Construction and Use Regulations, which, for example, require vehicles with overall traveling height exceeding 3.66m to have a notice in the cab indicating the height.

UK's Traffic Signs Regulations require a highway authority to sign a low-clearance bridge if the minimum clearance is less than 5.03m. If the low clearance bridge is properly signed and an over-height vehicle strikes the bridge, the driver can be cited for driving without due care and attention.

UK Schedule 8 Financial Liability

NR, which owns and manages the railway infrastructure in England, sells access to the railway network to operating companies. Schedule 8 is a mechanism for ensuring that both NR and the operating companies are held financially responsible for delays that they cause to each other and hence encourages initiatives to improve train performance. The rates of payment or penalty are set by the Office of Rail and Road (ORR), which is the independent regulator. If a bridge strike occurs on the rail network that leads to disruption to the operating companies, NR is liable for the Schedule 8 payments. Where vehicle and driver details are known, NR pursues the recovery of all costs, including Schedule 8 related costs, through the vehicle insurers (see the Liability and Claims section).[15]

NR does claim back the cost of Schedule 8 payments from insurers. Truck drivers now must declare accident history for five years, similar to the requirement for automobile drivers. This has led to some truck drivers self-insuring.

Fines and Enforcement

RWS Inspectors and Dutch Law

Dutch law allows for limited enforcement authority by the RWS. Specially trained RWS inspectors can write fines for height violations, driving in a lane marked with an overhead red "X", and for shoulder riding. However, this is not RWS' core business, and it is usually under the jurisdiction of the Ministry of Justice. There are only 100 RWS inspectors who are authorized to cite over-height vehicles. Recertification and training for RWS inspectors occurs every 5 years, similar to the police. In 2019 they started fining over-height trucks, citing just 17; in 2022 that increased to 96.

A vehicle cannot be fined without being stopped and measured by the police or an inspector. RWS inspectors have specially calibrated measuring devices (Figure 22). The inspector must show the driver the measured height.

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[15] https://www.networkrail.co.uk/wp-content/uploads/2020/11/Bridge-Strikes-Risks-Consequences-and-Costs-2020-accessible.pdf

Figure 22: Rijkswaterstaat Vehicle Height Measuring Device

Source: FHWA

As discussed earlier, RWS tunnels have three phases of intervention when an over-height vehicle is approaching a tunnel with the first two phases advising the driver to exit the roadway. If an over-height vehicle is stopped by the final red phase sensor and gate at the entrance of a tunnel, an RWS inspector is dispatched to intercept the vehicle. The inspector will manually identify the offending vehicle, direct the vehicle down a service road, measure the vehicle, and issue a fine or send the vehicle back to the roadway if no violation is recorded (Figure 22).

EU law allows for a maximum vehicle height of 4m (13.1 feet). Dutch law allows for a 1cm (0.4 inch) margin for regular vehicles and a 5cm (2 inch) margin for vehicles with cargo (not box trucks).

The fines in the Netherlands for the holder of the vehicle are 500 euros for the first 10cm (3.9 inches) over the limit, 800 euros for up to 20cm (7.9 inches) over the limit, and 1,200 euros beyond 20cm (7.9 inches) over the limit, along with a 9-euro administration fee. Other European countries will have different fines. In addition to the fine, the driver is immediately banned from driving the vehicle until the size is reduced to 4m, or 13.1 feet (with no margin), or until Netherlands Vehicle Authority (RDW) has issued a permit for the oversized load. Drivers from out of the Netherlands are required to pay on the spot. If unpaid, the vehicle is prohibited from moving and the trailer is left at the location.

Figure 23: Rijkswaterstaat Inspector Escorting Potential Over Height Vehicle

Source: FHWA

In the Netherlands, all trucks need liability insurance. Insurance companies are responsible for paying damages caused in bridge and tunnel strikes. Insurance companies incentivize good behavior through a discount if drivers participate in educational courses. They have also created a contest for the "best driver in the Netherlands."

Irish Tunnel Operator Ability to Remove Vehicles

Ireland's TII has contractor staff at tunnels with certain legal authority that comes from operating a tolled facility. Those staff have the authority to remove vehicles from the road. After over-height vehicles trigger the second sensors and CMS, staff are called out to intercept them. Staff can escort them off an escape ramp. The drivers are not fined. This is similar to the IR scheme at the Amiens Street Bridge, where the goal is to prevent bridge strikes, and no fines are given unless a strike occurs.

London's Specialized Commercial Vehicle Police Unit

TfL funds the Commercial Vehicle Unit of the London area's Metropolitan Police. The unit has 50 staff that focus on items such as tunnel policing, freight compliance, and oversize loads. In addition to enforcement, they may also meet with trucking companies if their drivers are consistently violating the rules. In addition to potential Schedule 8 payments for causing damage to a structure, drivers can be prosecuted for contravening a height limit and failing to display a height marker in their vehicle as required.

Consequences resulting from prosecution include fines and the addition of points to their license. The truck drivers could also lose their commercial driver's license. A company could be restricted in the number of trucks it is able to operate. Transport Managers, positions required by law at trucking companies, could require recertification. The Metropolitan Police can recommend the course of action for prosecution, which subsequently goes to the Traffic Commissioner for adjudication.

UK Office of the Traffic Commissioner

The UK's Office of Traffic Commissioner has judicial authority over prosecutions related to bridge and tunnel strikes. They can review and revoke commercial drivers' licenses; review, curtail, or revoke operator licenses, causing the loss of reputation and certification of transport managers and trucking companies. Operators and transport managers can be called to a public inquiry.

In the UK, the regulatory authority influences private companies to be proactive in reducing bridge and tunnel strikes. The Traffic Commissioner cannot fine a company, but in can stop operations.

Use of License Plate Data

While cameras are used to monitor vehicles in the Netherlands, RWS is not allowed to save and register license plates, which would require permission from the Ministry of Justice. If a truck strikes the tunnel, RWS can detain the person responsible. RWS can hold the driver and company responsible for standard liability.

Ireland and the UK can capture license information – with data and personal privacy conditions in place – to fine drivers and pursue claims when structures are struck.

Raised Equipment Warning System Regulations

The UK Road Vehicles (Construction and Use) Regulations require vehicles with high level equipment more than 3 m (10 feet) to be fitted with a device that gives a visible warning to the driver if the equipment is raised while being driven unless the equipment can be fixed in position by a locking device.

While not visited by the Study Team, the Province of Quebec, Canada, provides an interesting example of raised dump warning system regulations. The provincial government amended the Provincial Highway Safety Code requiring a raised dump body light and sound warning system, effective as of September 1, 2020. This regulation was instituted as amendments to the Provincial Highway Safety Code. Offenders face a fine of Canadian $350 to $1,050.[16, 17] The sections below provide more detail on these regulations.

Vehicle and Dump Body Definitions

All heavy vehicles (trucks, trailers, tractor-trailers) that have a dump body, and with a height that exceeds 4.15m (13.6 feet) when the dump body is raised at its highest position are subject to the regulation. Combinations of road vehicles with a gross combination weight rating of 4,500 kilograms (9,921 pounds) or more, such as a smaller truck pulling a trailer, are also subject to the regulation.[18, 19]

Any permanent or temporary equipment or accessories that may cause the total height of the vehicle to exceed 4.15m (13.6 feet) when the dump body is lifted must be considered. Removable dump bodies, designed to be rolled on and off, are subject to the regulation because they are

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[16] https://saaq.gouv.qc.ca/blob/saaq/documents/publications/frequently-asked-questions-dump-body-safety-devices.pdf
[17] https://saaq.gouv.qc.ca/en/vehicle-registration/mechanical-inspection/raised-dump-body-light-sound-warning-system/
[18] https://saaq.gouv.qc.ca/blob/saaq/documents/publications/frequently-asked-questions-dump-body-safety-devices.pdf
[19] https://saaq.gouv.qc.ca/en/vehicle-registration/mechanical-inspection/raised-dump-body-light-sound-warning-system/

equipped with a lifting system allowing the container to be raised.[20, 21] Any vehicle operating in Quebec, independent of where it is registered, is subject to the regulation if they are on public roads.

Technical Specifications of Warning System

The regulation's technical specifications provide specifics on the type and location of visual and audio warnings, and how they are to be triggered. First, the warning must activate as soon as the dump body is being raised, regardless of speed; it may turn off after 5 seconds. It must switch on again as soon as the truck begins moving or its speed reaches 12 kph (7.5 mph).[22, 23]

Weather conditions or going through a tunnel can disturb the functioning of certain technologies. Any loss of the signal used to measure speed, or any other sensor malfunction, must cause the warning signals to switch on if the dump body is not completely lowered.[24, 25]

Audible warning devices must emit a continuous sound or an intermittent sound at a frequency that is between 60 and 120 times per minute, and it must emit a sound sufficiently high to be easily audible by the driver of the vehicle in any situation. For example, the warning device must be audible in the driving compartment when the truck's engine is on in a workplace environment, such as on a construction site.[26, 27]

The flashing red warning light must:

- be placed on the dashboard as close as possible to the vehicle driver's line of sight.
- have a flash rate between 60 and 120 times per minute.
- have a light intensity sufficient to be easily visible by day.[28, 29]

Many different companies supply raised dump warning systems, some of which are readily available online for less than $100.

[20] https://saaq.gouv.qc.ca/blob/saaq/documents/publications/frequently-asked-questions-dump-body-safety-devices.pdf
[21] https://saaq.gouv.qc.ca/en/vehicle-registration/mechanical-inspection/raised-dump-body-light-sound-warning-system/
[22] https://saaq.gouv.qc.ca/blob/saaq/documents/publications/frequently-asked-questions-dump-body-safety-devices.pdf
[23] https://saaq.gouv.qc.ca/en/vehicle-registration/mechanical-inspection/raised-dump-body-light-sound-warning-system/
[24] https://saaq.gouv.qc.ca/blob/saaq/documents/publications/frequently-asked-questions-dump-body-safety-devices.pdf
[25] https://saaq.gouv.qc.ca/en/vehicle-registration/mechanical-inspection/raised-dump-body-light-sound-warning-system/
[26] https://saaq.gouv.qc.ca/blob/saaq/documents/publications/frequently-asked-questions-dump-body-safety-devices.pdf
[27] https://saaq.gouv.qc.ca/en/vehicle-registration/mechanical-inspection/raised-dump-body-light-sound-warning-system/
[28] https://saaq.gouv.qc.ca/blob/saaq/documents/publications/frequently-asked-questions-dump-body-safety-devices.pdf
[29] https://saaq.gouv.qc.ca/en/vehicle-registration/mechanical-inspection/raised-dump-body-light-sound-warning-system/

Results

While no data currently are available on the impacts of the regulation, Société de l'assurance automobile du Québec (SAAQ) notes that various trucking associations have shared this information with their members.[30]

Several agricultural organizations have written to the Quebec Minister of Transport to request exemptions for dump bodies registered as farm trailers, which was granted.

Rental trailers may cause a vehicle combination to exceed the 4,500 kg (9,921 pound) limit; however, the trailers may not be equipped with the warning devices.[31]

Although rare, some light dump trailers can exceed 4.15m (13.6 feet) in the raised position; those manufacturers are considering modifying those heights in the future rather than providing warning devices. [32]

Liability and Claims in the UK and Ireland

Both the UK and Ireland utilize claims as a means of ensuring liability is assigned to appropriate parties after a bridge or tunnel strike and that financial compensation can be received. These claims can flow both into and out of an agency. In other words, a bridge owner could submit a claim to a trucking company for damages and lost time due to a bridge strike they caused (known as a green claim); conversely, a rail or truck operator could submit a claim to the bridge owner if the owners' actions resulted in lost time or damages (a red claim). This standardized process for assigning and pursuing financial liability has led to greater incentives for agencies, trucking companies, and drivers to find ways to reduce bridge and tunnel strikes. In the UK, this has led to truckers having to declare crash history for five years and has led to some truckers self-insuring to cut their premiums.

In the UK, NH and other infrastructure agencies manage claims in-house, by regional teams. Each team has an inspector, who helps determine what it would take to make the structure safe and what the repair process would entail. Damages are assessed by reference to the reasonable cost of repairing the highway asset and legal precedent. The inspector examines the value of the asset at the time of the incident (these are updated annually by NH) and the decline in asset value due to the incident. The repair costs do not need to be lowest cost, but they do need to be reasonable. If standards have been updated since the time of original construction of the asset, resulting in the need to rebuild the asset to a higher standard and incurring greater costs, NH is technically entitled to recover costs to the new standard; however, in practice they find a reasonable middle point for the cost. Traffic management costs can be claimed when the incident happens and during repair. Ireland has a similar process for assigned financial liability for a bridge or tunnel strike.

This process encourages good record keeping in NH regions, or the agency might not recover costs. NH works with claims across a variety of issues and assets, but bridge strike claims tend to be more expensive, more complex, take longer to settle, and often lead to litigation. Insurers and loss adjusters will often push back on certain costs and negotiate. While they have a 95 percent recovery rate for simpler claims, the recovery rate for bridge strike claims is 80 percent. NH also

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[30] Email exchange with SAAQ
[31] Email exchange with SAAQ
[32] Email exchange with SAAQ

must be able to identify who to pursue for a claim in the first place, which could be challenging in the case of a hit and run, unless their cameras were able to capture license plate information.

Incidents can be reported in a variety of ways to TfL to start the claims process. TfL has a response desk. The traffic control center may have viewed the incident. However, if they cannot identify the offender and the license plate, then TfL contacts the Metropolitan Police (as CCTV must be at the right location, working, and pick up the registration number at speed to be able to identify the offender, TfL relies on the police about 30 to 50 percent of the time).

Like NH, after a strike, inspectors collect information. Contractors may also be involved, and they need to be collecting the right information on the damages, costs, and other relevant information to support the claim as they determine how to fix the structure. This process could take between 2 to 60 days. Also, like NH, TfL's claims department first deals with insurers; if there are disputes, such as due to the inclusion of additional overtime costs or the costs of pursuing the claim in the first place, then the case may be litigated. TfL recovers about 80 percent of their expenditures.

TfL typically pursues larger claims, unless key information is missing; small ones (e.g., under 250 pounds) may not be worth the cost. TfL cannot include costs of improving the structure, such as the costs of a full bridge replacement and upgrade, even if it was planned before the bridge strike.

NR has claims that fall under Schedule 4 – planned disruptions – and Schedule 8 – unplanned disruptions.[33] Schedule 8 is a mechanism for ensuring that both NR and the train operating companies are held financially responsible for delays that they cause to each other and hence encourages initiatives to improve train performance. The rates of payment or penalty are set by the Office of Rail and Road (ORR), which is the independent regulator. If a bridge strike occurs on the rail network which leads to disruption to the operating companies, NR is liable for the Schedule 8 payments. Where vehicle and driver details are known, NR pursues the recovery of all costs including Schedule 8 through the vehicle insurers.[34]

NR is legally obligated to pay operators 100 percent of costs within a month. However, changing travel patterns and many individuals working from home has made cost estimation for operator training difficult. The costs to the operators are theoretically lower, but the formulas are only recalculated every three years. There have been legal challenges to the formula. NR's claims process is executed at the regional and central level: the central office provides guidance to each region, and each region manages minor claims. Recovering costs is incentivized through bonuses.

Operations and Process

Operations and processes complement and integrate with the countermeasures found in the three visited countries. These include collaboration, issuing permits, and standardizing procedures.

Interdisciplinary Working Groups

The UK's NR chairs the Bridge Strike Prevention Group, in collaboration with National Highways and the DVSA. This group consists of numerous public sector and private sector stakeholders, including rail agencies, roadway agencies, safety agencies, police agencies, logistics organizations,

[33] https://www.networkrail.co.uk/industry-and-commercial/information-for-operators/payments-for-disruption-on-the-railway/
[34] https://www.networkrail.co.uk/wp-content/uploads/2020/11/Bridge-Strikes-Risks-Consequences-and-Costs-2020-accessible.pdf accessed Nov 2023.

truck driver organizations, and many others. The group meets every six months to share data and best practices and to collaborate on ways to reduce bridge strikes.

Other Private Sector Coordination

The Port of Rotterdam – the busiest port in Europe – has facilities where drivers can check their heights prior to embarking on their journey. While the company that runs the harbor is private, and there is no requirement for them to have such a facility, the RWS has a good relationship with the port. There is much communication between the entities, and it is in everyone's interest to have good, uninterrupted transportation facilities. Some private companies in the Netherlands also voluntarily provide places for drivers to check their heights and ask their drivers to do so.

Permitting Processes and Tools

Prior to 2006 in the Netherlands, truck drivers were required to communicate with each road agency managing every segment of roadway along a route to get permits. Currently, RDW, a Dutch agency with vehicle licensing, safety, and permit issuance, in the US, provides a centralized and online process. RDW uses an online portal, DWO.rdw.nl, for storing data provided regularly from agencies on a digital road map; this portal is then used for permit applications and approvals.

RDW uses a five-step process for permitting:

1. The truck driver researches the route on DWO and creates a potential viable route on DWO. The applicant provides details on the vehicle, dimensions, weight, and cargo, and applies for the exemption (if the request matches a previously approved request on the same route, the permit can be automatically approved).
2. RDW reviews the application and determines if the proposed route is viable; if not, they create a viable route. They then forward the application to the road agency or agencies who manage the infrastructure in question (e.g., RWS).
3. The road agency reviews the route, screening for traffic safety, traffic flow, infrastructure preservation, and fairness between various applicants. The agency also checks for ongoing or planned construction and adjusts the route and associated guidance as needed. The road agency will then either formally agree to the route, which may include any reasoning behind deviating from standard policies, or it will disagree and substantiate the rejection.
4. If the road authority rejects the route, RDW will either determine a different route and repeat the process, or completely reject the trucker's application. If the authority approves the route, then RDW issues an exemption permit. This permit will be issued electronically and may be valid only until a specific date. The truck driver does not need to confirm receipt of the permit.
5. The truck driver receives RDW's decision, and the trucker will review this through the DWO portal. It is the responsibility of the trucker to check the route in advance to ensure that it will accommodate the load; the trucker can input the permit number into DWO and confirm the route is viable.

As a result of this process and tool, 80 percent of permit decisions are determined within five working days, with 97 percent determined within ten working days. RDW indicates that the process goes well, and errors (and therefore strikes) rarely occur. If a driver does come to an unexpected low-clearance structure, the driver usually stops and calls. However, RDW does not track whether an issued permit has been used or whether the vehicle followed the permitted route.

In considering clearances, the system automatically deducts 15cm (5.9 inches) from the lowest height measured. The system does not differentiate heights between lanes, but RDW has this information in their archives, and that data can also be obtained from the road agency.

Permit requirements for oversized loads vary by country in the EU. The Netherlands requires that the pilot driver and truck driver must be able to communicate in the same language. Nationals of other countries can work in the Netherlands and drive a permitted truck, but they cannot drive a pilot vehicle unless specifically certified in the Netherlands.

There are emergency exemptions for police regarding permits: if an emergency requires an oversized vehicle, the police must determine this and contact the RDW, who in turn will contact the appropriate road agencies.

Through the permitting process, drivers can determine the true heights of structures (since degrees of safety are built into posted heights), which may encourage them to change their behavior and drive vehicles under structures where their measured heights exceed the structures' posted heights. Also, sometimes truckers will take measures to secure the route that should be managed through RDW, such as removing signals that may block the route.

Standardized Post-Strike Processes

In the UK and Ireland, bridge owners have a standardized process for reporting bridge strikes, either by the truck driver or by encouraging members of the public to report the strikes. For example, Irish Rail invests in marketing and communications to encourage the public to report strikes. Calls from the public go to a centralized traffic control. A bridge can be identified by a numbered plate on the bridge, which is standardized across the country for both IR and locally owned bridges). IR is currently collaborating with the national police to ensure that such information is eventually and consistently reported to the police for future prosecution.

NR also has standardized bridge identification plates. After a strike is called in, NR checks its color-coded risk table to see if the bridge is listed as red, double amber, amber, or green to determine next steps (see Section 2 – Processes for Prioritizing Structures and Choosing Countermeasures). Following all recorded bridge strikes, an examiner inspects the bridge to ensure it is safe to continue to operate trains and record any defects that may need rectifying. All incident details are recorded by the examiner, such as drivers' names and vehicle registration. This record is subsequently entered into NR's safety management systems and used to pursue the recovery of costs.

IR has found it difficult to get bridge examiners to a bridge strike site in dense urban areas in a timely manner, not only due to general traffic congestion, but also due to the queues caused by the strike itself. IR now provides e-bikes to examiners in Dublin as a means of getting bridges examined faster, thereby greatly reducing transportation impacts on the road and rail networks.

Finally, in the UK, TfL has used accelerometers to remotely detect bridge strikes and remotely determine the degree of impact (see the Roadside Technology section).

5. Data Management

The agencies in each of the visited countries all have a role in data collection, sharing, distribution, and updating in relation to bridge and tunnel strikes; the EU also plays a role at a multinational level. Some countries are leveraging technology to improve the quantity and quality of data, and then are discovering new use cases for the information.

Measuring Heights and Clearance

Policies and Approach

In the UK, installation and maintenance of signs belongs to highway authorities, which are very fragmented outside of NH. Further, UK agencies cite poor availability of information as a leading cause of bridge strikes outside the control of the driver.

UK's NH conducts principal inspections every 6 years (including heights at each lane, upstream and downstream of a structure), and more general inspections every 2 years. NH's formula for clearance measurements considers a structure's sag curve, especially for longer vehicles. However, in practice inspectors might not capture that nuance; if they do, there is still variation in the approach and due to the movement of the measurement vehicle. As a result, NH incorporates a factor of safety beyond the measured clearance of a structure. Measurements are more carefully taken if clearance of a structure is under the 5.03m (16.5-foot) limit (see Law and Regulation).

Structures are signed only when below the required 5.03m (16.5 feet); signs reflect measured clearance with a factor of safety. When sharing data with outside parties or for over-height permits, NH uses the data with a factor of safety: there is concern about sharing raw data due to some of the nuances in measurement identified above. This information is stored in NH's database.

NR has compiled data from every bridge in its network that has been involved in a bridge strike since the year 2000. This data can be added to navigation and route planning tools to enable road users to be alerted of a bridge that has been involved in incidents previously. These data also are analyzed by agency staff, local governments, and others to better understand bridge strikes, associated risks, and how to better mitigate them. Data include time of day, month, year, over or under bridge strike, and other variables.[35] NR is currently working to connect separate datasets on bridge strikes and bridge examinations. Similarly, IR owns its bridges, to better manage them; IR also maintains its own database. TII also maintains its own database on heights and clearances.

After paving or construction

If there are pavement overlays or new construction on the NH system, then policy indicates that heights should be remeasured and updated after completion. There is a risk that systems are not updated in real-time and such checks may get overlooked. NH also may choose to reevaluate clearance after a bridge strike. RWS always mills off pavement before repaving and remeasures clearances each time. At TII, if there is a pavement overlay – regardless of who owns the bridge over TII's network – TII will check the new heights.

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35 https://www.networkrail.co.uk/running-the-railway/looking-after-the-railway/bridges-tunnels-and-viaducts/the-risk-of-bridge-strikes/prevention-of-bridge-strikes/

Inspection of Structures

UK's NH targets bridge inspection every 2 years. Inspectors for NH and NR look for damage from bridge strikes that may have not been reported.

Use of Advanced Technologies for Data Collection

NH is currently using a device that uses radar to scan conditions under the pavement of a structure: the agency is currently working to retrofit this to be pulled behind a vehicle and collect data. NH also is conducting a digital image correlation project: an inspector would scan a structure with a tablet or smart phone, and AI would create the report. Similarly, a vehicle outfitted with a camera could pass a structure and determine if something is different on the structure than a prior image.

Improving Vehicle Navigation Systems

Connected Vehicles and Virtual Signs

UK's DfT is developing an approach to leverage connected vehicles and the digitization of traffic regulation orders to reduce bridge and tunnel strikes (Figure 24). Traffic regulation orders, such as low-clearance bridges, are decentralized and managed by the relevant authority, such as a local government. While they will continue to store their own information, as part of the digitization project all authorities will be required to provide the data feed in a common format to a common location in an open GeoJSON format. Coordination for this project is done through the Transport Technology Forum, which brings many entities and agencies together from across the UK.

Figure 24: Connecting Vehicles to Road Signs and Restrictions

Source: Department for Transport (UK)

DfT is working to develop use cases for connected vehicles in relation to these data and other opportunities. One such opportunity is in-vehicle signing: transferring roadside sign information (both static and CMS) into mobile phones and in-vehicle GPS systems. While the applications are much broader than just bridge and tunnel strikes, this would include information on low clearances. An agency could also have a virtual sign: adding a sign in the database that appears through mobile and in-vehicle technology before being able to add it in the field (e.g., for emergencies). Integrating real and virtual signs into a GPS navigation system allows for routing to consider low clearances or other issues that could lead to bridge and tunnel strikes. In the future, this technology could be linked to various automated vehicle control technology such as automatic braking as a means of preventing a bridge or tunnel strike.

As in-vehicle sensors get more advanced, agencies like DfT and entities in the EU are working with auto manufacturers to leverage the real-time collection of data from those sensors on the condition of the roadway network. DfT sees its role as building the core infrastructure for such a system: developing databases, setting data and interface standards, and helping to develop use cases. Private industry then will develop the systems and technology that leverage this.

Standardized Traffic Restrictions in GPS Navigation Across EU Member States

Truck drivers may use online navigation tools to plan and execute their route. However, unlike some of the trucking-specific GPS navigation systems described in the In-Vehicle Technology section, these navigation applications do not include height restrictions or allow the driver to prepare routes that consider their vehicle heights against such restrictions.

EU Delegated Regulation (EU) 2022/670 requires GPS navigation platforms to incorporate an agreed-to set of standards and requirements across the EU that incorporate traffic regulations and restrictions. This allows local governments, through their national governments and then the EU, to incorporate provisions to ensure heavy vehicles follow appropriate routes, avoid low-clearance bridges, avoid small central city streets, and avoid big events or heavy traffic areas.[36] Road authorities, road operators and tolling operators must provide these data to the EU's DATEX II or TN-ITS mobility data portals. The law is due to go into force in a staged way – impacting different types of roads at different times – between 2025 and 2027. On January 1, 2028, Delegated Regulation (EU) 2022/670 will apply to all roads.[37]

Currently, service providers and road authorities are working together through an EU-funded project called National Access Point Coordination Organisation for Europe (NAPCORE) to discuss how to best implement the standards and requirements. NAPCORE's role is to coordinate and harmonize more than 30 mobility data platforms across Europe, beyond requirements related to the GPS navigation systems. EU ITS Directive 2010/40/EU and its Delegated Regulations require that each European Member State must establish a National Access Point (NAP) for mobility data, as data are not collected at the EU level. By now, there are more than 30 operational NAPs in most EU Member States (and beyond), where mobility related data is published and made available for use in travel information services. The existing NAPs are quite different in their setup and data access interfaces. Also, the data formats and standards used differ throughout Europe. NAPCORE defines and implements common procedures and strategy, strengthening the position and the role of NAPs, supporting steps towards the creation of European-wide solutions to better facilitate the use of EU-wide data.[38]

The participants in NAPCORE are working to produce common definitions and to decide in what format to gather and share data to implement EU Delegated Regulation 2022/670. This effort is chaired for the EU by the German Bundesanstalt für Straßenwesen (BASt), or Federal Highway

[36] https://dublininquirer.com/2023/06/28/eu-law-could-help-dublin-city-council-reroute-drivers-around-city-centre-rather-than-through-it/
[37] https://eur-lex.europa.eu/eli/reg_del/2022/670/oj
[38] https://napcore.eu/

Research Institute, with support from member states through a task force and from private service providers, who also collectively have a single seat at the table for this effort.[39] Private service providers have found that being directly involved in the effort is beneficial: better, interoperable data being provided to them will save effort and money.[40] Ultimately, the intent is to use data that already exist, with a focus on de-siloing, processing, API development, and making data more accessible.

The European Commission invested some money to help this effort. While the road authorities from each country are the collectors of the data and are primarily responsible for being compliant, if there are gaps, NAPCORE can request funding from the Commission. However, due to the time and administrative burden of such a process, some countries may just fund these gaps internally.

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[39] https://eur-lex.europa.eu/eli/reg_del/2022/670/oj
[40] Virtual meeting with BASt

6. Findings and Noteworthy Practices

Other countries identify many of the same bridge and tunnel strike challenges as those in the US. Just as the causes of the problem are multifaceted, so too are the most effective examples of overseas countermeasures: these countries report that there is no silver bullet, and a system of countermeasures, from physical measures to advanced roadside and in-vehicle technology, to effective training and education, to targeted enforcement are necessary. Some are inexpensive and quickly implemented, while others require substantial investment, planning, and an ongoing effort to operate and maintain. A combination of countermeasures can also provide redundancy and help to address the multitude of critical events that can lead to a crash. Some countries have attempted to address all these facets through structured, formal, and informal collaboration across many agencies and industry organizations.

A summary of the key findings and noteworthy practices includes:

- **There is no silver bullet.** Every countermeasure identified was documented as having advantages and disadvantages. As a result, agencies with the most robust approaches to preventing bridge and tunnel strikes combine systems of countermeasures and practices. This is clearly articulated through the UK's Network Rail 4Es: Education, engineering, enablement, and enforcement.
- **Understand risk and appropriate countermeasures for the situation.** Similarly, the exact application of a suite of countermeasures may differ across the network. An agency selects the right countermeasure or countermeasures for the right structure, location, likelihood of a strike, potential impact of a strike, and set of specific causes. The agencies in the three visited countries used a combination of risk assessments, evaluation sheets, and standards to help determine this.
- **Focus on prevention.** The agencies across the three countries indicated qualitatively or quantitatively a positive return on investment for the countermeasures they implemented. Due to the direct costs to the agency of a damaged structure, along with myriad societal costs associated with a strike and its aftermath, the upfront costs are minor: as one participant indicated, "a little money saves a lot of money."

  In particular, the agencies gravitated towards preventative countermeasures compared to protective or sacrificial countermeasures, though both were used for redundancy.
- **Involve the private sector.** Successes in reducing bridge and tunnel strikes often resulted from strong involvement from, and coordination with the private sector. The inclusion of trucking companies and firms with large fleets, was seen as essential. Ports and insurance companies were also involved.

  In the case of the UK, the involvement was driven through a regular working group on bridge and tunnel strikes. The collaboration led to significantly improved understanding of the risks, costs, and causes of bridge and tunnel strikes to all parties. This in turn catalyzed better training, communication, and in-vehicle technology.
- **Driver behavior is key.** Driver behavior was the most cited challenge across the three countries for preventing bridge and tunnel strikes. It is difficult to control for and predict. Even a high-clearance structure can be struck by a careless or distracted driver with fully extended construction equipment on a trailer or an accidentally raised dump bed. Drivers

also find ways to get around roadside sensors and warning devices. Agencies had the greatest ability to affect change through education and training. Some of this is required for licensing and certifications. Sometimes companies implement training voluntarily, though with incentives and disincentives in the law. Recent in-vehicle technology attempts to remove driver error from the equation: one UK software solution has RFIDs on all cabs and trailers that automatically warns the driver of approaching low-clearance structures. Enforcement is the final line of defense for controlling driver behavior.

- **Control for blind use of GPS navigation.** It is easy and familiar for most people in 2025 to use freely available mobile applications for route planning and navigation; truck drivers are no different. However, such publicly available, free applications, as well as standard in-vehicle GPS navigation systems, usually do not contain truck restriction or low clearance data. Even if they do, they are not in any way linked to vehicle height, and so the systems cannot create a route and navigate an over-height vehicle safely.

  Several solutions were observed across the three countries:

  - The first solution is to ensure drivers are aware of this, and through repeated education, messaging, and habitual measuring and documenting of their vehicle height, ensure that despite the GPS navigation, they are aware of their height and watch for low-clearance structures.
  - The second solution is a requirement of specialized in-vehicle navigation systems for trucks which include data on clearances linked to vehicle height. Several companies in the UK require this for their fleets, with strict procedures around their use and any unplanned deviations. Some companies created their own custom software.
  - The third solution is through legislation and resulting standards, such as the EU's regulation requiring member countries to develop a common data standard for items such as truck restrictions. These data will then be required to be used by GPS navigation applications.

- **Provide a harmonized database on bridge and tunnel heights and other traffic regulations.** According to the European experience in the NAPCORE project, roadway databases can be harmonized across jurisdictions and providers. Information on traffic regulations can be digitized by the relevant road authorities and then made findable and accessible via common data standards and access mechanisms, such as through the EU's National Access Points. These include common data standards and quality assurance practices, requiring cooperation between data stakeholders and governance structures. This also encourages standard mapping and guidance platforms to use the databases.

- **Enforcement and financial liability drive more interest in compliance and technology development.** Regulations in the UK include a strict process around financial liability related to bridge strikes; costs go beyond asset repair to include delay and other costs to operators and the public. Drivers, managers, and their companies can lose licenses, certifications, and the ability to operate their fleet. These provisions encourage companies and drivers to pay greater attention to avoiding bridge and tunnel strikes. This includes a robust ecosystem of UK-developed in-vehicle systems for routing or warning drivers, and robust procedures and training for drivers at large companies.

- **Use progressive stages of sensors, warnings, and enforcement prior to major tunnels and bridges.** Each country used a series over-height sensors and warning signs on approaches to major tunnels (and in one case, a bridge). The intent was to provide a sensor and warning early enough on an approach to both allow the driver to exit on the last regular exit and alert the traffic control center of a potential over-height vehicle. In the cases of the tunnels, when the last sensor is triggered, a gate is lowered, and the tunnel is closed. At this stage, RWS inspectors remove the vehicle via a service road and, if over-height, they fine the driver. In London, drivers have an escape ramp at the tunnel that they are forced down, but no fine is given. In Ireland, drivers are escorted off the facility, without a fine. Each country used different sign and sensor types, placed at differing margins of safety relative to tunnel clearance. Some tunnels use a hybrid of different sensors and induction loops. This technology is applied for high-risk, high-impact structures, such as major, heavily traveled tunnels on strategic roadways.
- **Remind drivers to measure vehicle height.** All three countries strongly focused a considerable amount of messaging, marketing, communication, education, and training on reminding drivers to measure their vehicle height before each run. Additionally, several companies in the UK and the Netherlands incorporated this messaging into their own training and communications; companies in the UK created strict processes of height measurement and documentation as part of standard, required procedure.
- **Educate elected officials, law enforcement, and other key partners about the problem.** Outside of those who manage bridges and tunnels, most people may not be aware of the risks and associated impacts of strikes from over-height vehicles. They may not know the potential return on investment of various countermeasures. The countries visited have elevated the seriousness of the problem within their agencies and amongst decision-makers. Educated law makers and decision-makers can craft legislation and provide support for these efforts, as was noted in the UK and Netherlands; they can also help encourage other organizations and private industry to be engaged. Often this is a precursor to being able to apply many of the countermeasures in this report. Engaged law enforcement was also identified in the three countries as very necessary in the reduction of bridge and tunnel strikes.
- **Provide focused law enforcement for over-height vehicles.** Law enforcement is overburdened, with many competing priorities. The Netherlands granted special, limited authority to RWS – their national DOT – to be able to pull over and fine over-height vehicles. The resulting RWS inspectors have similar training and oaths as standard police, and they have a strict process to follow before issuing a fine. The inspectors are linked to RWS traffic control centers and tunnel detection and warning systems: when a potential over-height vehicle is identified and stopped before a tunnel, RWS inspectors are called out to intercept them.

  Special staff at TII-tolled tunnels in Ireland, have the authority to escort over-height vehicles off the road. Alternatively, the Metropolitan Police in London has a special commercial vehicle division, which includes enforcing vehicle height violations.
- **Centralize monitoring by linking data and information to a traffic center.** All the roadside technology examples are linked to and monitored and controlled through a centralized traffic control center. These centers also tie in law enforcement and emergency services.

Appendices

A. Study Focus Questions

The following questions summarize the study team's primary areas of interest. Written responses are not requested; rather, the questions are provided to inform you of the topics, issues, and subject areas the study team is most interested in and serve as a framework for discussion.

Data and Analysis

- Do you collect data on bridge and tunnel strikes? If so, what data do you collect and is it in real-time?
- To assess bridge and tunnel strikes, do you merge data from diverse sources, such as transportation agency bridge inventory data and police crash reports? What methods do you use to merge these different data sources?
- After a bridge or tunnel strike, do you have set data points that you ask your engineers/technicians to report on for each incident?
- How do you physically identify locations of bridge and tunnel strikes, such as bridge number, roadway mile marker, GPS coordinates, or other identifiers?
- How do roadway agencies and railroads share information on bridges and tunnels and strikes of those structures? Do roadway agencies collect and keep data on railroad structures and strikes, and vice versa?
- How do you collect data on vertical clearances? Do you use mobile lidar, stationary lidar, physical measurements in the field, or other techniques?
- Have you used machine learning for data processing to determine vertical clearances?
- How often are vertical clearance measurements performed or validated? Are they routinely scheduled, or are they only after trigger events like construction?
- Do you have contract language requiring construction contractors to collect, record, and report clearances before traffic goes under bridges or through tunnels that were impacted or affected by construction?
- Roadway paving can also affect vertical clearance. Do you add pavement layers or "mill and fill" (i.e., remove the surface layer with a milling machine and apply a new asphalt layer)? If you add layers, how do you record and communicate the changes in clearance?
- Have you partnered with vehicle manufacturers with built-in sensors (e.g., lidar or radar) to anonymously collect and share vertical clearance data on a continuous, real-time basis?

Structure and Countermeasure Selection and Prioritization

- What factors do you use to identify structures with a higher probability of strikes and that should be prioritized for site-specific countermeasures? These could include truck volumes, total volumes, location, vertical clearance thresholds, roadway function, and past strike history, for example?

- How do you determine the appropriate countermeasure to use at each location? Do you have a method or process to rate or rank mitigation strategies from a risk perspective to identify those strategies that are more successful than others?
- Are you looking at global countermeasures, site-specific countermeasures, or a combination?
- Has your organization, or any other organization in your country, conducted any economic or cost-benefit analyses on no-action choices versus implementing countermeasures?

Effectiveness and Ex-Ante Evaluation

- Do you test various countermeasures and technology at any "proving ground" or testing facility prior to implementation?
- How have you conducted analysis of the effectiveness of the systems you have deployed? Within each type of technology and countermeasure, which do you find are most effective?
- How does weather affect the technologies?
- Are there power requirements for each technology? Can they be deployed in rural areas without electricity?

Liability and Cost Recovery

- When a bridge or tunnel strike occurs, what is the process for assigning responsibility and recovering costs for damages to the structure? What are the relevant laws and regulations that govern this?
- Is it difficult to recover or collect fines to cover the costs of related damages from over-height strikes? What are the biggest challenges in this process, and how do you attempt to overcome them?
- Has your organization, or anyone else, faced resistance by the trucking or related industries when identified at fault for striking bridges or tunnels because of an over-height clearance violation? If so, how did you approach the trucking company or involved owners or their respective organizations most responsible for over-height collisions to discuss how to reduce or eliminate these events?
- By providing databases on bridge clearances to the public or software manufacturers, does liability shift back to the structure's owner if there are errors in the data?

Procurement and Funding

- How do you procure these technologies? Are you allowed to use a single (sole) source method, or do you develop specifications for what you need?
- How do you fund these technologies? What level of government do these funds come from? Do you use safety funds, grants, or other sources?
- For the countermeasures you employ, how do you consider the total lifecycle costs, including the product or technology cost, installation, and operations and maintenance?

Countermeasures: Education, Marketing, and Communications

- Is specific training or information on preventing bridge and tunnel strikes provided to truck drivers and the trucking industry? How well-used are these? What mediums are most effective?
- What type of places/platforms are you using to raise awareness of bridge and tunnel strikes, such as specific social media platforms? Which are most effective?
- Do you provide maps with bridge and tunnel clearances to drivers and the public? Are these physical maps or virtual maps/platforms?
- Do you conduct any data sharing, marketing, or education with insurance carriers?

Countermeasures: Permitting Processes

- How does your permitting process for oversized loads determine the route a truck must follow based on bridge or tunnel clearance? Do you use a manual or automated system for routing trucks? Is there a graduated system of permits based on vehicle height where larger loads require more detailed routing review? How is the process enforced?
- For Network Rail's color-coded bridge rating system, does the color of a bridge affect the issuance of a permit and the prescribed route? Is the bridge color incorporated in the database given to truck routing software companies?

Countermeasures: In-Vehicle Warning Systems

- Is there any equipment or technology installed on trucks that provides warnings to the driver if approaching low bridges and tunnels? Are there systems that provide warnings about the load on a truck shifting or raising?
- For companies that manufacture and sell in-cab notification systems, do they rely solely on vertical clearance data provided by bridge and tunnel owners, or do they collect their own data and use that in their technologies? How do they update these data?
- Do you require or incentivize trucks to have certain communication or warning technologies in the vehicles? Are there incentives for companies to install or penalties if they do not? What laws and regulations govern this?
- Do you require dump trucks to have raised bed warning systems?

Countermeasures: Vehicle Height Measurement/Awareness

- One of the leading factors from the desktop review regarded drivers' not knowing the height of their vehicles. Do you know of any private company (e.g., shipper) that has voluntarily implemented measuring their vehicles as a standard practice or purchased a technology to measure their trucks as they leave their facilities?

Countermeasures: Sacrificial Beams

- Is there a national (or EU) standard warning color pattern or signage for sacrificial beams to avert a strike before it occurs?

B. Meeting Hosts and Participants

List all hosts and participants, including all organizations.

Netherlands

Hosts:

- Rijkswaterstaat (RWS)

Other participants:

- National Vehicle Authority (RDW)
- National Police

United Kingdom

Hosts:

- Network Rail
- National Highways
- Transport for London (TfL)

Other participants:

- Metropolitan Police
- Department for Transport (DfT)
- Logistics UK
- Veolia
- Pip Bains Consulting
- VUE
- TESCO
- BES Group

Republic of Ireland

Hosts:

- Irish Rail
- Transport Infrastructure Ireland (TII)

Other participants:

- Mineo
- Roughan & O'Donovan Innovative Solutions
- Jacobs
- Research Driven Solutions

C. Team Member Bios

Jeffrey Purdy, AICP, PTP, is the Freight Programs Team Leader in the Federal Highway Administration (FHWA) Office of Freight Management and Operations in Washington, DC. His team is responsible for the National Highway Freight Program, state freight planning, commercial vehicle size and weight, freight data and modeling tools, freight performance management, supply chain research, truck parking, and freight system resiliency. Prior to moving to FHWA Headquarters, Jeff served as the Technical Services Team Leader and Transportation Planner for the FHWA Wyoming Division, overseeing statewide and metropolitan transportation planning, air quality, vehicle size and weight enforcement, right-of-way, and research.

Before joining FHWA, Jeff worked for a community and transportation planning consulting firm in Michigan preparing community comprehensive plans, multi-modal transportation plans, environmental impact statements, and development codes. Jeff began his career as a community planner for the Air Force, working on base comprehensive planning and site plans for the military construction program.

Jeff has a Bachelor of Science and a Master of Urban Planning from Michigan State University. He is a member of the American Institute of Certified Planners (AICP) and an ITE Professional Transportation Planner (PTP).

Vincent P. Chiarito, PE, M.ASCE, F.SEI, is a Senior Bridge Engineer with the Federal Highway Administration, Office of Infrastructure. He focuses on Safety and Security for bridges and tunnels and protecting these structures from collisions and fire. He leads the current Transportation Pooled Fund Study "Development of Countermeasure Strategies for Protecting Bridge Girders against Over-height Vehicles' Impact." Prior to joining FHWA, serving as a Research Structural Engineer for over 37 years with the US Army Engineer Research and Development Center in the Geotechnical and Structures Laboratory, he led and conducted structural engineering research regarding vibration, dynamics, earthquake effects, blast effects, and experimental efforts to validate performance to support various civil and military projects, other government agencies, and private sector customers. Vince obtained Bachelor and Master of Civil Engineering degrees from the University of Delaware.

Bernie Carrasco, PE, is the Bridge Management Section Director for the Texas Department of Transportation (TxDOT). His section serves as a focal point for bridge planning, the prioritization of bridge projects including determining critical bridge replacement and rehabilitation needs, preliminary planning of structures, negotiating and drafting various agreements, plan review, and administration of Texas' bridge funds. Bernie also oversees TxDOT's efforts on the management and quality control of Texas' bridge data. He leads the efforts on the analysis and visualization of Texas bridge data to communicate the conditions of TxDOT's 57,000 bridges to assist TxDOT's 25 District offices with the management of bridges. Bernie also serves as the team lead for reviewing and analyzing proposed legislation that may affect the network of bridges in Texas. Bernie graduated with a Bachelor of Civil Engineering degree from Texas A&M University.

Jen Harper, PE, PMP, is the Research Director of the Missouri Department of Transportation (MoDOT). At MoDOT she has worked in the Bridge Design Division, Organizational Results Division, and currently works in the Construction and Materials Division. As the Research Director, she works with MoDOT's Senior Management Team to identify research opportunities that can help the Department provide services more efficiently and effectively. Ms. Harper serves on the Innovation Community of Practice as a MoDOT representative as well as being the current chair of the Region 3 AASHTO Research Advisory Committee. Prior to MoDOT, Ms. Harper worked for an engineering consulting firm in Kansas City, Missouri designing office buildings, schools, and parking garages. She holds bachelor's degrees in civil engineering from the University of Missouri-Columbia and Mathematics from Central Methodist University. She is a licensed Professional Engineer and a certified Project Manager.

Erik Cempel, PE, PMP is president of Cempel International Transportation Consulting, a firm he established in 2019. He also is a transportation advisor at the DePaul Chaddick Institute for Metropolitan Development and a past advisor for Korea's Metropolitan Transport Commission. Previously, he served as program manager for the implementation of the $1.5 billion master plan for Chicago Union Station. Prior to that, Erik was a principal and regional manager for Cambridge Systematics. In that role he helped agencies around the globe plan and implement transportation infrastructure and policy. He also worked at the Korea Transport Institute for two years. Erik graduated with a Master of Engineering Degree in Transportation Systems and a Bachelor of Science degree in Civil Engineering from Cornell University.

D. Network Rail Bridge Assessment Template

Reference	NR/GN/CIV/202
Issue	3
Publication date	4th September 2010
Compliance date	Not Applicable

Appendix C: Assessment of robustness of Underline Bridges

This Appendix contains guidance for items to be considered in the assessment of robustness and strength of Underline Bridges. Criteria necessary to achieve Dispensated Bridge status before an amendment to the SBSI Bridge Strike Appendix Schedule can be issued are identified. The checklist may be adapted to form a Bridge specific record.

No longer mandatory - July 2012

Assessment of Robustness of Underline Bridges for amendment to the SBSI Bridge Strike Appendix Schedule				
ELR/Bridge No………………………………				Unique Bridge Identification ……………………
General Items				
	Track level Bridge identification signs			(Yes/No)
	Road level Bridge identification signs			(Yes/No)
	Highway speed limit			
	Clearance at Up side			
	Clearance at Down side			
	Nearby Junctions / tight alignment?			
	Responses column: Y=Yes N=No U=Unknown. Leave blank if not applicable.	**Responses**	**Requirement for Dispensated status**	**Guidance** *(Details should be substituted in place of guidance below, to provide a Bridge specific record. All assumptions and judgements should be recorded clearly.)*
1 Arch Bridges				
1.1 Construction				
1.1.1	Brick: - do records confirm that the barrel has a minimum thickness of 4 rings or 3 rings if sacrificial protection plates are present?		1.1.1 or 1.1.2 must be Y	Details of construction obtained and recorded for assessment purposes may be considered as record of construction. Where stone voússoirs obscure arch thickness and no reliable construction records are available, coring or other investigation is recommended. Where brick arches are terminated with brick face rings the visible thickness may be assumed to be uniform unless bonding or stone inserts/ roll courses, etc. give cause for doubt. Consider whether concrete may be a strengthening addition rather than the full arch thickness. Stone voússoirs with stone arch rings behind may not be consistent in thickness and further assurance may be required.
1.1.2	Masonry or concrete: - do records confirm that barrel thickness is 450mm minimum or otherwise compliant with **12.2.2**?			

Source: Network Rail

Reference	NR/GN/CIV/202
Issue	3
Publication date	4th September 2010
Compliance date	Not Applicable

1.2 Condition				
1.2.1	Is the condition of structural elements of bridge 'poor'		1.2.1 must be N	Consider arch barrel and spandrel walls carrying tracks. Longitudinal cracks in the arch in the vicinity of the spandrel walls should be considered to be in poor condition. Consider direction of road traffic.
1.2.2	Structural repairs outstanding?		1.2.2 must be N	A judgement is required on the structural nature of low priority repairs to brickwork. Consider the extent and location of repairs relative to likely damage; judgement required on where damage is likely to affect the carrying capacity of the structure.
1.3 Likely damage				
1.3.1	Is there a significant difference in headroom between entrance and exit faces?		If 1.3.1 is Y then 1.3.2 or 1.3.3 must be Y	Justification is required where this requirement is not met if an amendment the SBSI Bridge Strike Appendix Schedule is to be made. Other factors may minimise the risk of damage to the arch and spandrel wall; for example, where there is extensive cover to the arch, tracks are remote from structure, or construction is substantial.
1.3.2	Do previous known strikes indicate likely damage level will not affect safety?			Consider (a) the ability of the structure to carry trains safely, (b) site evidence of damage compared to Bridge Strike history, (c) nature and frequency of road vehicle use, (d) signs of change in use, and (e) occasional high risks.
1.3.3	Is damage likely to be sustained to arch soffit and spandrels unlikely to affect safety?			Consider (a) position of tracks relative to likely damage, (b) damage arising from vehicles exiting the bridge, and (c) likelihood of vehicles becoming wedged. Take account of arch width and profile of the arch. Consider the depth from underside of sleepers to arch and any concrete backing. Are steel scuff plates or other mitigation measures fitted?
2 Beam and Girder Bridges				
2.1 Construction				
2.1.1	Is protection provided by specially designed impact protection beams, independent spans or adjacent bridges?		If 2.1.1 is Y, go straight to section 3	Protection should be in both directions (unless over a single direction carriageway) with no evidence of protection being compromised. Independent spans may merit differing status. A regime should be put in place to maintain the effectiveness of the protection.
2.1.2	Are there records to confirm that construction is sufficient for safety to not be affected?		2.1.2 must be Y	Details of construction obtained and recorded for assessment purposes may be considered to be a record of construction. Judgement required on strength issues for most vulnerable parts: see also 2.1.5 to 2.1.9.

No longer mandatory - July 2012

Source: Network Rail

Reference	NR/GN/CIV/202
Issue	3
Publication date	4th September 2010
Compliance date	Not Applicable

2.1.3	Has a quantitative assessment shown the Bridge will not be displaced or significantly damaged?		2.1.3 must be Y	Record calculations and comparisons with similar structures reviewed in detail. Loadings should be to **11.6**. Consider (a) the risk of vertical and horizontal displacement, (b) speed of approaching vehicles relative to speed limits and road layout, (c) history of strikes and (d) deck or track displacement.
2.1.4	Is track directly fastened or on longitudinal timbers?		2.1.4 must be N	Consider also fixity of any slab track associated with structure and if ballast bonding (gluing) has been applied to improve ballast retention for mitigating the effects of bridge resonance or other problems.
2.1.5	Are pedestal bearings present without vehicle collision restraint devices?		2.1.5 must be N	If provided vehicle collision restraint devices should be designed to BD60/04 or **7.1**.
2.1.6	Are timber live load carrying members present?		2.1.6 must be N	Consider role of timber decking in supporting ballast and/or transmitting live loading. Exclude timber planks carrying ballasted track supported on cross girders, when there is no significant gradient to the road.
2.1.7	Are underslung girders or girders supported on bolts/rivets in tension present?		2.1.7 must be N	
2.1.8	Is plate bonded strengthening present?		2.1.8 must be N	
2.2 Condition				
2.2.1	Are any structural elements of bridge in 'poor' condition?		2.2.1 must be N	These include all deck elements where live loading is carried. An assessment should be considered in conjunction with the visual examination of condition, particularly where there is evidence of loss of section by corrosion, tears or buckles. Poor condition of protective coatings may be ignored. Bridges with identified fatigue defects are to be considered to be in a poor condition.
2.2.2	Structural repairs outstanding?		2.2.2 must be N	A judgement is required on the relevance of low priority repairs such as painting or waterproofing. Consider extent and location of repairs relative to likely damage particularly where the defect is corrosion. Most important are restoration of bolts and rivets, re-plating, strengthening of areas vulnerable to Bridge Strikes, and those required as a direct result of a Bridge Strike.

No longer mandatory – July 2012

Source: Network Rail (UK)

Reference	NR/GN/CIV/202
Issue	3
Publication date	4th September 2010
Compliance date	Not Applicable

3 All bridges - exclusions				Where not covered in 1 and 2 or requiring specific confirmation
3.1	Known records of construction?		3.1 must be Y	These might be obtained from examination or assessment, or where sufficient details have been obtained from site from a variety of sources. It is likely to be possible to carry out an initial desk study for items which would preclude a dispensation, but site data and photographs will be necessary to confirm whether the Bridge should be dispensated. These may be available from earlier exercises, and recent examination reports may be sufficient to confirm or update data especially if good quality photographs and actual height data are available. Key features are arch construction details, and materials and quantities for determining the mass of beam/girder structures.
3.2	Headroom signs provided?		3.2 must be Y	To indicate safe height to road users; not mandatory if headroom is over 16'-6" [5.03 m].
3.3	Robust substructure present (columns, piers and abutments)?		3.3 must be Y	Solid abutments of brick, masonry or concrete will be provided at most Bridges. Where hollow or cellular abutments, columns or piers are present, consideration should be given to their robustness, vulnerability due to positioning and road layout, and any designed impact protection provided to them.
3.4	Cast Iron Bridge?		3.4 must be N	There may be a risk to road vehicles from damage to non-load bearing elements such as parapet screens or handrails, but the presence of these should not prevent dispensation. Structural cast iron elements such as girders, arches or ribs or those which retain ballast, cast iron parapet girders which support decking and ballast shoulders and possibly brick or masonry parapets are vulnerable. Consider the risk of derailment from cast iron debris reaching tracks.
3.5	Susceptible to brittle fracture?		3.5 must be N	Examples include cast iron elements encased in concrete, and slender concrete elements (particularly struts or slender decking units between more robust beams). Some steel or wrought iron may exhibit brittle fracture under high impact loading.
Comments:				
Status of assessment record – complete or incomplete?				
Signed:				Date:
Name:				Position:

No longer mandatory - July 2012

Source: Network Rail (UK)

E. Network Rail Criteria for Color-Coded Bridge Ratings

Reference	NR/GN/CIV/202
Issue	3
Publication date	4th September 2010
Compliance date	Not Applicable

Appendix E: Guidance for management actions according to assessment of robustness

Classification	Masonry	Metallic	Concrete	Other/Comments
Red	Difference in headroom between spandrel walls is significant and damage that may be sustained likely to affect load carrying ability by: • loss of single ring, • loss of spandrel, • excessive uplift.	Bridges without collision protection beams or independent spans providing equivalent protection: • which fails assessment to BD60/04 including use of reduced road speed, • with pedestal bearings without collision restraint devices, • with underslung girders or girders supported on bolts in tension.	Fails assessment to BD60/04 for horizontal loads including use of reduced road speed.	Bridges without collision protect beams or independent spans providing equivalent protection with: • slab track or track carried on longitudinal timbers • glued ballast, • metallic or composite plate bonding strengthening, • timber live load bearing members
	Arch in poor condition such as: • longitudinal crack in vicinity of spandrel, • diagonal crack in arch barrel, • loose masonry, • ring separation.	Bridges with live load carrying elements: • of cast iron, • susceptible to brittle fracture • fatigue defects, not able to accommodate local damage for Amber.	Beams without shear connection individually unable to resist uplift to BD60/04 with decreasing headroom – unless collision protection beams are provided.	Passes assessment to BD60/04 but road traffic signs not provided, and headroom less than 16' 6". Bridge in poor condition. Outstanding repair to structural load carrying member(s).
	Stone arches with barrel less than 375 mm thick and no sacrificial protection plate.			Bridges not able to be classified as Amber. Bridges with no records of construction. Bridge strike identification plates not installed.

No longer mandatory
July 2012

Source: Network Rail (UK)

Reference	NR/GN/CIV/202
Issue	3
Publication date	4th September 2010
Compliance date	Not Applicable

Classification	Masonry	Metallic	Concrete	Other/Comments
Amber	Stone arches with barrel between 375 mm and 450 mm thick in good condition on a road with no significant difference in headroom between spandrel walls, and road speed limit is 30 mph.	Compliant to BD60/04, but only able to accommodate local damage for Double Amber with reduction in permissible speed.	Compliant to BD60/04, but not able to accommodate loss of outer beam without reduction in permissible speed.	Bridges protected completely by Red spans.
	Arches with ring thickness 450 mm or more in reasonable condition such as: • minor defects, • Bridge Strike damage not exceeding Bridge Strike Nominee limit for depth, but exceeding limit for area • defects repaired but stable.	Compliant to BD60/04, and able to accommodate local damage with no reduction in permissible speed such as not exceeding: • 25% loss of flange section, • loss of outer trough, • back angle to flange in single plate flange.		Bridges which fail assessment for global stability but are to carry full RA loading for the route with maximum local damage.
	Difference in headroom between spandrel walls is significant but damage that may be sustained is unlikely to affect load carrying ability.	Collision protection beam, bearing restraints or independent spans not proven to be in accordance to BD60/94, BD60/04 or BD65/97.	Beams without shear connection compliant to BD60/04 for horizontal loads but individually unable to resist uplift to BD60/04 with constant headroom under the beams or on a one way road with a downward gradient.	Live load carrying members protected by redundant spans (not independent of structure) not proven to be compliant to BD60/94 or BD60/04.
	Centre part of arch with no significant difference in headroom between spandrel walls carrying 4 or more tracks with no risk of parapet falling on tracks when outer lines are Red.	Outer girder compliant to BD60/04 when line speed exceeds 100 mph but reduced road speed used for assessment.		Timber members carrying ballasted track supported on cross girders, and where there is constant headroom to the timber from the road.
	Arches with sacrificial protection plates with lines otherwise classified as Red.	Western Region type box girder resistant to BD60/04 horizontal loading or with headroom in excess of 5.7 metres.		

No longer mandatory
July 2012

Source: Network Rail (UK)

Reference	NR/GN/CIV/202
Issue	3
Publication date	4th September 2010
Compliance date	Not Applicable

Classification	Masonry	Metallic	Concrete	Other/Comments
Double Amber	Arches with ring thickness 450 mm or more in good condition with no significant difference in headroom between spandrel walls.	Compliant to BD60/04, and able to accommodate local damage with no reduction in permissible speed such as: • 50% loss of flange section, • back to flange angle in multi-plate flange, • loss of plate to multi-plate flange.	Compliant to BD60/04, and able to accommodate loss of outer beam without reduction in permissible speed.	Bridges protected completely by Amber spans.
	Arches with damage from Bridge Strikes not exceeding BSN limits for depth and area.			
	Difference in headroom between spandrel walls is not significant along road carrying 4 or more tracks with no risk of parapet falling on tracks when outer lines are Amber.	Collision protection beams or bearing restraints in accordance with BD60/94, BD60/04 or BD65/97.		Bridge assessed as Amber but either: • superstructure headroom greater than 16' 6" and provided with robust piers or as a single span • line speed is 25 mph or less.
	Arches with sacrificial protection plates with lines otherwise classified as Amber.	Protected by independent spans proven to be compliant to BD60/94, BD60/04 or BD65/97.		Live load carrying members protected by redundant spans (not independent of structure) proven to be compliant to BD60/94 or BD60/04 irrespective of local damage.

No longer mandatory - July 2012

Source: Network Rail (UK)

Reference	NR/GN/CIV/202
Issue	3
Publication date	4th September 2010
Compliance date	Not Applicable

Classification	Masonry	Metallic	Concrete	Other/Comments
Green	Inner tracks of Bridges carrying 4 or more tracks when outer lines are Double Amber.	Protected by independent spans proven to be compliant to BD60/94, BD60/04 or BD65/97, and able to accommodate local damage for Double Amber.		Bridges protected completely by Double Amber spans.
	Arches with sacrificial protection plates with lines otherwise classified as Double Amber.			
	Depth of cover such that arch acts as a tunnel through embankment (greater than 6 metres).	Longitudinal troughing compliant to BD60/94 on road with no gradient and wide cess or redundant span.		
	Superstructure headroom greater than 20 feet and provided with robust piers. Protected completely by an independent span or Bridges, or beams assessed as robust to BD60/04.			

No longer mandatory - July 2012

Source: Network Rail (UK)

F. Network Rail Checklist of Potential Countermeasures

Reference	NR/GN/CIV/202
Issue	3
Publication date	4th September 2010
Compliance date	Not Applicable

Appendix B: Checklist of measures considered for reducing risks

The following checklist may be used to record measures that have been considered and implemented to reduce the risks from Bridge Strikes. The implementation of several of these measures may require liaison with the Highway (Road) Authority or other Outside Party.

ELR/Bridge Number:		**Unique Bridge identification:** ....
Potential measures are listed below	Tick if considered	Indicate below if decision is to implement / action, and provide notes of significant considerations / issues, etc.
Options for All Bridges		
Install Bridge Strike identification plates		
Improve or install road traffic signs		
Apply, improve or renew road markings		
Close road to traffic		
Apply traffic restrictions to limit size of vehicle		
Apply physical traffic management measures to restrict vehicle speed		
Introduce or amend signed speed restrictions		
Install kerbs to direct road vehicles		
Introduce single carriageway operation, vehicle priorities or traffic lights		
Improve the visibility of the parapet (or abutment)		
Remove advertising hoardings		
Remove vegetation at Bridge and on its approaches		
Amend track layout to utilise least vulnerable parts of structure		
Reconstruct Bridge		

No longer mandatory - July 2012

Source: Network Rail (UK)

Reference	NR/GN/CIV/202
Issue	3
Publication date	4th September 2010
Compliance date	Not Applicable

Options for Underline Bridges		
Lower the carriageway under the Bridge		
Install or improve road traffic signs including hazard warning markings to the Bridge		
Install or improve chord markings and soffit markings		
Install lighting or improve lighting or relative lighting levels		
Install collision protection beams		
Install scuff plates or strengthening/deflecting measures		
Install warning systems to alert drivers of over-height vehicles		
Install alert systems/cameras to warn/provide details of a Bridge Strike		
Restrain or strengthen vulnerable parts		
Reconstruct Bridge with less construction depth		
Options for Overline Bridges		
Strengthen parapets*		
Reconstruct parapets		
Install safety fence on approaches and within parapets*		

These measures relate principally to mitigation of the risk of vehicle or debris incursion generated by an impact on a parapet rather than approach penetration. Options to improve approach containment are sensibly considered at the same time (in liaison with Highway Authorities).

* Where it may not be reasonably practicable to achieve H4a (formerly P6) vehicle containment capacity, it may be appropriate to enhance the containment capacity or provide a safety fence to reduce the risk of Bridge Strikes.

Summary, comments and action notes:	
Prepared by:	Date:
Signature:	Position:

No longer mandatory - July 2012

Source: Network Rail (UK)

G. Irish Rail Risk Assessment Score Sheet

Bridge No.		Location:			Line:		Mileage:
Division:		Surveyed by:	Date:		Road no.:		

VULIB
SURVEY SCORING SHEET

Iarnród Éireann
Structural Design Section

Factor	Options	Score	Factor	Options	Score
F1 (See Note A)	**Road Approach Containment** Score 1 for acceptable (safety fence and/or heavily wooded side approaches, buildings or brick wall thicker than 450) Score 12 for inadequate (imperfect fencing and/or medium/lightly wooded approaches, 225 thick brick wall) Score 24 for non-existent (No fencing, or only post & rail/wire, no significant vegetation)		F8	**Parapet Resilience** Score 1 for P6 type parapet Score 2 for P1 or P5 type parapet Score 5 for 450mm brickwork/masonry parapet Score 7 for plate girder type parapet (Half through type bridge) Score 8 for 340mm brickwork/masonry parapet Score 20 for cast iron/corrugated sheet/lattice type parapet (Half through type bridge)	
F2	**Road Alignment (Horizontal)** Score 1 for straight road with at least 7.3m carriageway Score 3 for straight less than 7.3m carriageway or curved at least 7.3m carriageway Score 8 for curved road less than 7.3m carriageway Score 12 for reverse curves less than 7.3m carriageway		F9	**Road Verges and Footpaths** Score 1 for at least 2m both sides Score 2 for at least 1m both sides Score 3 for one or both verges less than 1m	
F3	**Road Alignment (Vertical)** Score 1 for level or constant grade Score 2 for slight hump back Score 3 for hump back where vehicles are inter-visible Score 5 for hump back where vehicles are not inter-visible		F10 (See Note D)	**Road Signage/Carriageway Markings** Score 1 for signage/markings fit for purpose and clearly visible, or not needed Score 4 for unfit, non-existent or obscured signage/markings, where considered to be required	
F4	**Actual Speed of Approaching Road Traffic** Score 1 for <10mph Score 3 for <30mph Score 5 for <50mph Score 8 for <70mph Score 12 for >70mph		F11	**Type of Road** Score 1 for a green lane or farm access Score 2 for a local road Score 6 for a regional road Score 10 for a national secondary road Score 12 for a motorway/national primary road	
F5	**Site Topography** Score 1 if vehicle/debris very unlikely to foul track Score 4 if vehicle/debris unlikely to foul track Score 6 if vehicle/debris can be reasonably expected to foul track Score 8 if vehicle/debris likely to foul track Score 10 if vehicle/debris very likely to foul track		F12 (See Note E)	**Permissible Line Speed and Track Alignment** Score 1 for straight track up to 35mph Score 4 for straight track up to 60mph or curved up to 40mph Score 8 for straight track up to 80mph or curved up to 60mph Score 12 for straight track up to 90mph or curved up to 70mph Score 16 for straight track up to 100 mph or curved up to 80mph Score 20 for straight track above 100 mph or curved track above 80mph Straight ☐ Curved ☐	
F6 (See Note B)	**Site Specific Hazards Increasing Likelihood of Road Traffic Accident (RTA)** Score 1 for no obvious hazards Score 5 for single site specific hazard Score 9 for multiple minor hazards, or single major hazard (e.g. school, hospital or major factory access)		F13 (See Note F)	**Type of Rail Traffic** Score 1 for Non-Dangerous Goods Freight (Cement, shale, beet etc) Score 3 for Loco-hauled passenger train (Intercity, enterprise etc) Score 5 for DMU type stock (Arrow type service) Score 7 for EMU type stock (DART type service) Score 11 for Light Rail (LUAS, Metro services)	
F7 (See Note C)	**Site Specific Hazards Increasing Consequences of Event** Score 1 for no obvious hazards Score 3 for single site specific hazard Score 5 for multiple site specific hazards and/or Railway infrastructure likely to increase severity of an incident. Score 10 for parapet part of major structural element (Half through type bridge)		F14 (See Note G)	**Volume of Rail Traffic** Score 1 for abandoned/disused lines Score 3 for lightly used route (Branch/freight lines) Score 6 for medium used Intercity route Score 10 for heavily used intercity route Score 16 for very heavily used route (Dublin suburban DART line)	

Comments and additional notes:	Initial recommendation:			TOTAL:	
	Paint parapet ☐ Provide safety kerbing ☐ Traffic calming ☐	Provide normal containment barrier ☐ Provide high containment barrier ☐ Bridge/parapet renewal ☐ Other (Give details) ☐			

Note A Score F1 on the basis of the corner of the bridge with the least containment
Note B Site specific hazards increasing the likelihood of an RTA include the following features in proximity to the bridge: farm access, road junction, private driveway, lay-by, bus stop, school, hospital, etc.
Note C Site specific hazards increasing the consequences of the event include the following features in proximity to the bridge: exposed gas or chemical pipelines, etc.
Railway infrastructure likely to increase severity of incident to include pointwork, platforms, bridge piers and abutments and tunnel portals etc within 800m (1/2 mile) of structure. Failure of half through type support element may lead to complete collapse of bridge structure.

Note D If Score = 4, sign and/or road marking deficiencies to be brought to attention of Road Engineer
Note E If F8 scores 2 or less, score F12 on the basis of outermost tracks of a multi-track railway
Note F If F8 scores 2 or less, score F13 on the basis of outermost tracks of a multi-track railway
Note G See guidance notes for more detailed scoring within Iarnród Éireann infrastructure.

G. SDS-120-VULIB scoring sheet

SDS-120 Rev 1 Sep 03

Source: Irish Rail

H. Transport Infrastructure Ireland Detection and Warning Equipment Placement at Tunnel Approach

Source: Transport Infrastructure Ireland

Source: Transport Infrastructure Ireland

Source: Transport Infrastructure Ireland

Source: Transport Infrastructure Ireland

Source: Transport Infrastructure Ireland

Source: Transport Infrastructure Ireland

Back Cover: Source – Adobe Images. A vehicle passes under a low-clearance rail viaduct.

U.S. Department of Transportation

Federal Highway Administration

FHWA-HPL-26-012