MANAGING BRIDGE STRIKES FROM RAIL TO ROAD BRIDGES

Liam Coleman, Principal Structures Engineer, NZ Transport Agency
Mark Wheel, Senior Engineer, Network Rail (UK)
Alyson Dean, Intermediate Bridge Engineer, EXP (formally WSP-Opus Canada)

ABSTRACT

Over-dimension vehicles striking rail and road bridges internationally is a daily occurrence with each strike causing delays to customers. These strikes have financial implications, damage vital infrastructure, and in extreme cases, cause loss of life.

This paper will look at how Network Rail in the UK and the NZ Transport Agency manage the issue of bridge strikes. On the Network Rail system there are on average 5 bridge strikes daily and 2000 strikes yearly. On average each strike delays trains for 2 hours and costs the UK economy £23 million yearly. In Auckland, New Zealand, Penrose bridge has been struck over 40 times in the past 8 years with one strike alone in 2016 causing 3 hours of delays and cost the economy of Auckland over NZD$6-10 million.

Network Rail has developed a process to manage the risk of bridge strikes to try to limit the delays to customers, while keeping the infrastructure safely operational. In the case of Penrose bridge which spans over a motorway accommodating 200,000 vehicles daily, collision protection beams and advanced warning variable message signs (VMS) have been installed to protect the asset and reduce the number of bridge strikes.

1 INTRODUCTION

In the context of this paper, bridge strikes will be in relation to bridges which directly support rail traffic (underbridges) and bridges which span a motorway (underpasses) susceptible to over-height vehicle collisions. The topic of parapet bridge strikes above the primary railway or motorway will not be covered but have similar disruption and implications on the transport infrastructure.

Although train derailments and bridge collapses due to over-height vehicle strikes are very rare, there remains a possibility that each bridge strike has the potential for this to occur. The most likely injury due to bridge strikes is to the over-height vehicle driver and other highway users. On the UK Rail network there are approximately 40 bus/coach strikes nationally, particularly double decker buses which have led to serious injury and deaths of passengers. This paper will not cover the safety impacts as it implies that vehicles hitting and damaging bridge infrastructure will have safety consequences.

This paper will give a brief overview of bridge strikes Network Rail and the NZ Transport Agency must deal with and how they manage the issue – from physical barriers and warning systems, to prevention in the form of education of the wider industry from drivers, employers, asset owners, police, and insurance companies.

2 BRIDGE STRIKES – NETWORK RAIL (UK)

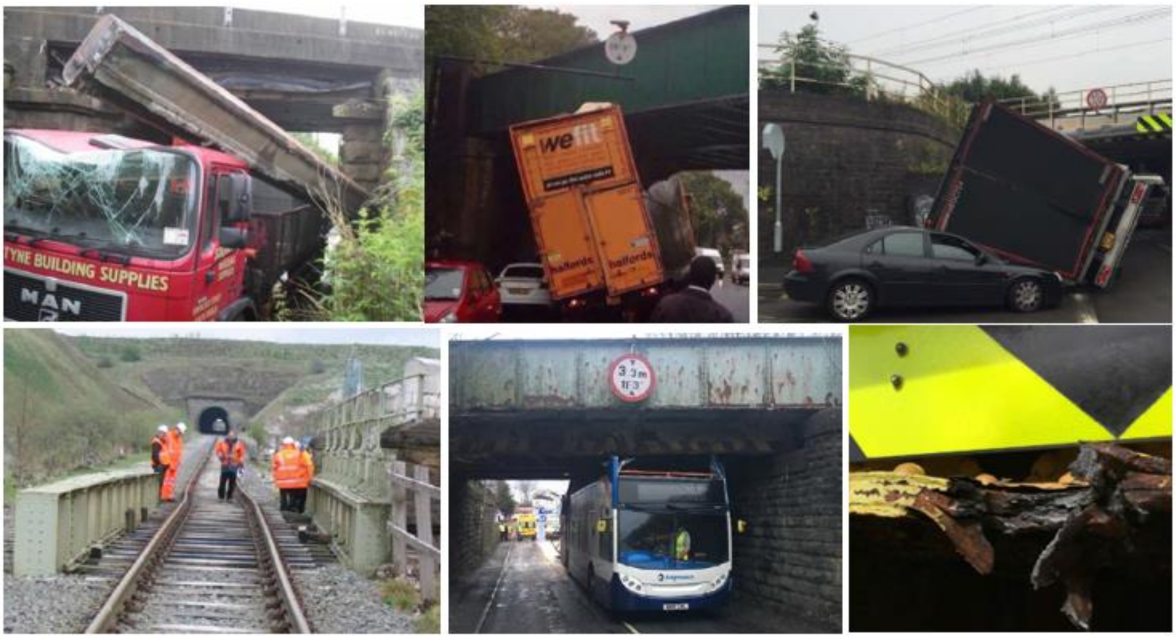

Figure 1 Examples of bridge strikes on the UK rail network. (Source - Network Rail)

2.1 Overview of Network Rail

Network Rail owns and operates the railway infrastructure in England, Wales, and Scotland and is responsible for 20,000 miles (32,000km) of track, and over 30,000 bridges and viaducts, on the oldest commercial network in the world and busiest mixed modal network in Europe. Over 1.7 billion passenger movements are carried out every year on the network. As can be appreciated on such an intensive network, any disruption due to bridge strikes can severely impact the operation, resilience, and safety of the network.

2.2 Schedule 8 payments

In short Network Rail sells access to the railway network to the Train and Freight Operating Companies (TOC's & FOC's). Schedule 8 is a mechanism for ensuring that both Network Rail 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/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 Network Rail are liable for the schedule 8 payments. Where vehicle / driver details are known Network Rail pursues the recovery of all cost including schedule 8 through the vehicle insurers.

2.3 Scale of the issue

Bridge strikes pose a significant safety risk to drivers, other road users and the traveling public. Typically, on the UK rail network there are 5 bridge strikes per day, 2000 annually. This increases up to 10 strikes a day at certain times of the year, such as the approach to Christmas. 1.5% to 2.0% of all train delays are due to bridge strikes. Taking the wider considerations into account, for example, repairs to vehicles, bridges and the cost of emergency services the total cost to the UK economy this equates to £23million (AUD$42m) yearly of which £12.7million (AUD$23m) are schedule 8 payments to the operating companies. The current trend of bridge strikes is increasing from the 2009/10 low and this trend is consistent with other UK infrastructure asset owners such as Highways England and Transport for London. Outside the obvious risk, safety, resilience and disruption aspects Network Rail are directly penalized financially because of external parties not knowing their height and hitting their infrastructure. This is an additional aspect which influences behaviors and procedures in trying to eliminate/reduced bridge strikes.

As can be appreciated routes in and around London or other major metropolitan centers will have a greater impact on delayed minutes. To give an example back in 2016 a hiab dumper truck hit a rail under bridge at Rugeley (30miles north of Birmingham). While the cost of the physical repairs and bridge examiner costs were around £13,600 (AUD$25,000) the schedule 8 payments were £690,600 (AUD$1.265million). While some of these costs can be passed onto the offending drivers insurance this is not always possible as all too often the driver fails to report the incident and leaves the site.

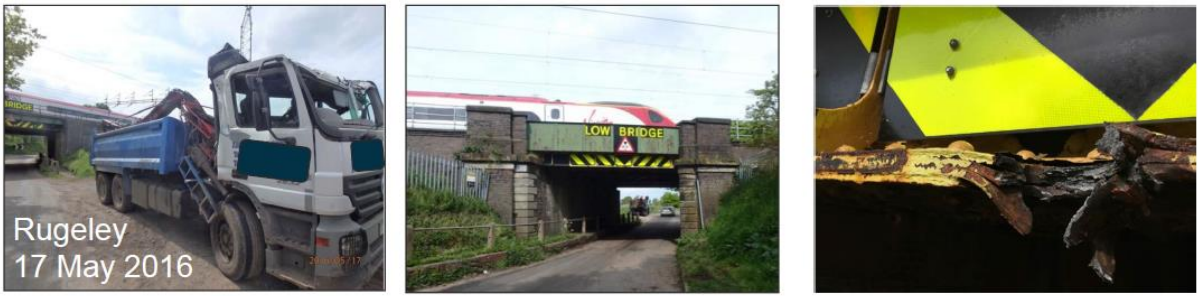

Figure 2 Photos of the Rugeley 2016 bridge strike. (Source - Network Rail)

3 BRIDGE STRIKES – AUCKLAND MOTORWAY (NZ)

3.1 Overview of Auckland Motorway Network

The city of Auckland lies on and around an isthmus which is less than two kilometres wide at its narrowest point, sandwiched between the Waitemata Harbour and the Hauraki Gulf. As a result, the motorway network is very linear and intensive as it carries over a million journeys daily.

The topographical constraints which would require significant infrastructure has resulted in Auckland having limited public transport alternatives, limited resilience and alternative motorway routes, which in turn funnels large traffic volumes over key infrastructure. Some of this bridge infrastructure carries over 200,000 vehicles daily which equates approximately to 12% of the population of Auckland relying each day on a single piece of infrastructure. With Auckland city responsible for 35% of the national gross domestic product (GDP), any disruption to the network due to bridge strikes can have an impact not only on the growth of Auckland, but on New Zealand Inc.

3.2 Scale of the issue

Pre-2008, the Auckland network would have approximately 25 recorded strikes yearly. This has now dropped to an all-time low of two recorded strikes in the financial year of 2017/18. In the past 10 years there have been three major incidents which resulted in media coverage and prosecution. One such case was in 2009 when the Onewa underpass just north of the Auckland Harbour Bridge (largest and busiest bridge in New Zealand) was struck with the hydraulic arm of an excavator being transported on a flatbed trailer. The incident caused significant damage to the bridge rendering it unsuitable to vehicle traffic and closing the motorway south into Auckland city for over 6 hours. By chance, the bridge was due to be demolished as part of the Onewa interchange project and was only weeks away from planned demolition. As a result of the incident, the demolition was brought forward.

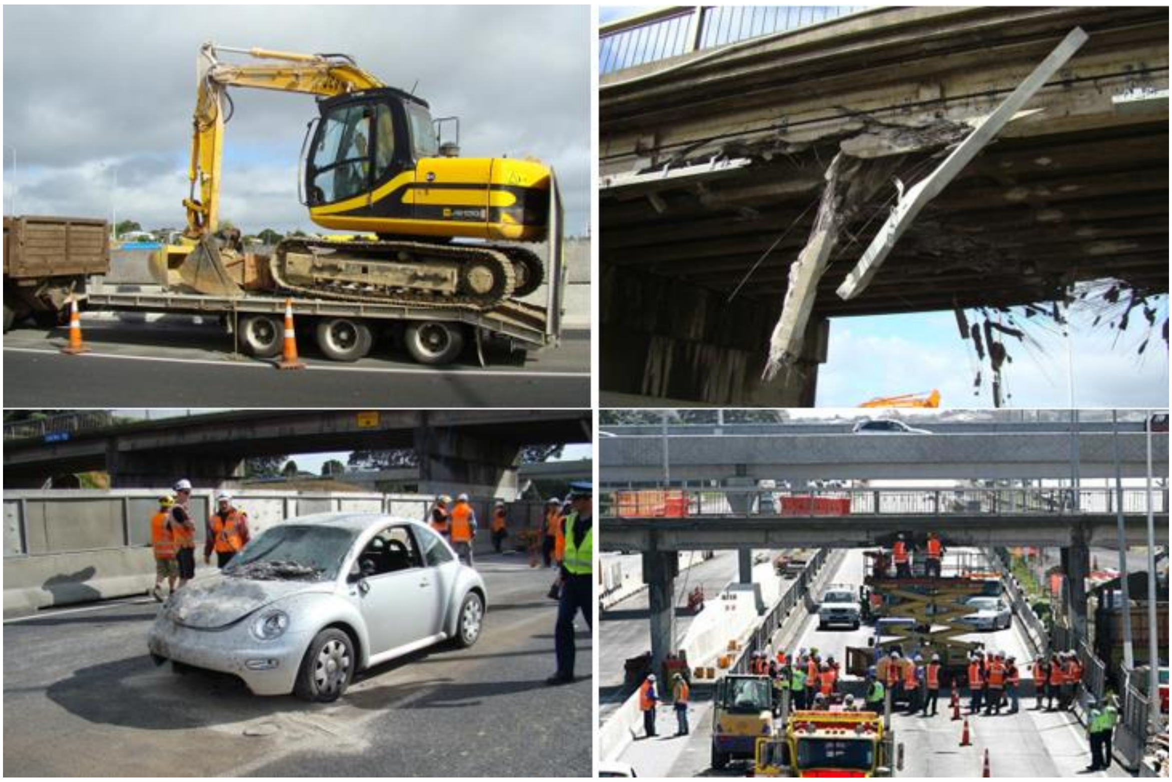

Figure 3 Onewa underpass 2009. (Source – Stuff.co.nz)

3.2.1 Penrose Underpass

Penrose underpass is located approximately 9km south of downtown Auckland and spans over State Highway 1 (SH1). The bridge owner is the NZ Transport Agency (NZTA) and the Road Controlling Authority is Auckland Transport (AT). The bridge itself accommodates over 15,000 vehicles per day, is on an AT overweight permitted route, and supports multiple utilities (power, water, gas, sewer, and fibre). Underneath Penrose is one of the most intensive motorways sections in New Zealand with over 200,000 vehicle movements daily.

At 4.41m above the State Highway, Penrose underpass is the lowest point on the Auckland network and as such, is the most struck bridge. In the past 8 years there have been over 40 recorded bridge strikes, with one strike alone in 2016 causing 3 hours of delays, 10km tailbacks, and a cost to Auckland's economy of NZD$6-10 million. The incident in 2016 at Penrose was very similar to the Onewa case (hydraulic arm of an excavator being transported on a flatbed trailer hitting the bridge). Penrose bridge is 180mm lower than Onewa and it was only luck that prevented a similar outcome happening at Penrose.

4 PREVENTION IS BETTER THAN A CURE

To take a medical analogy, "prevention" in this case is the education of the heavy haulage and over-dimension transport industries. "A cure" is measures aimed at limiting the consequences of a bridge strike such as collision protection beams, over-height warning signs, and bridge strike live load assessment calculations.

4.1 The cure

Similar to the medial industry, it is only human nature to concentrate on the cure, and the infrastructure asset management discipline is no different. Bridge strike events are very much reactive, and the typical cures won't eliminate, but rather protect the asset or limit the outcome. There are a multitude of examples of measures that can be applied/designed to limit or reduce bridge strike events. The remainder of this paper will concentrate on the National Bridge Strike Initiative (NBSI) that Network Rail has developed, and the NZ Transport Agency's collision protection beam and over-height detection signs at Penrose underpass.

4.1.1 Network Rail – National Bridge Strike Initiative (NBSI)

As mentioned previously, Network Rail is directly penalized (financially) through the schedule 8 payment process for outside parties striking their infrastructure and as such, their methods and behaviours have been shaped to manage bridge strikes. With any infrastructure asset management organization, every minute counts. Network Rail has taken this approach literally when it comes to the NBSI. Through this process, Network Rail evaluates how they can continue to keep trains moving following a bridge strike and limit the minutes delayed while ensuring the safety of the infrastructure. Reference should be made to two Network Rail documents:

- *NR/GN/CIV/202 Management of the Risk of Bridge Strikes*.
- *NR/L3/CIV/076 Management of the risk of Bridge Strike from road vehicles and waterborne vessels*

Through the NBSI process, Network Rail carries out numerical (assessment) calculations to see what effect a strike has on the bridge globally (i.e. will the bridge lift upwards or slide due to the impact) and locally (i.e. can the bridge still support loading with predetermined loss of section to the main structural members). The outcome of the NBSI is to give the railways tracks on a bridge structure a rated:

- RED – All train movements are stopped until a bridge examiner/Engineer can give approval for train movements to resume.
- AMBER – First train goes over the bridge at 5mph and reports back to the signaller whether they felt any defects on the track. If not, subsequent trains can travel over the bridge at 20mph until the bridge examiner/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 signaller 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/Engineer .
- GREEN – No action required and trains continue to run at line speed unless instructed not to by the bridge examiner.

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. Following all recorded bridge strikes an examiner attends 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 examiner including divers' name, vehicle registration etc. This record is subsequent entered into Network Rail's safety management systems and used to pursue the recovery of costs.

4.1.2 Penrose Underpass – VMS and Collision Protection Measures

After a spate of significant bridge strikes in the mid 80's, the Ministry of Works (now NZTA) constructed an over-height warning system to detect over-height vehicles and provide warnings to allow them to avoid impact.

In 2016 the NZTA upgraded the 1980 system by installing six next-generation advanced variable message signs (VMS) to inform over-height vehicle drivers that they risk hitting the upcoming Penrose underpass. The warning system is triggered by sensors at either side of the motorway that scan and check the height of passing vehicles. If a vehicle is over-height, warning messages are displayed on the signs and the event is logged. The signs give drivers the opportunity to leave the motorway system to avoid Penrose. If the vehicle does not leave the motorway at the proceeding junction to Penrose, the subsequent signs inform the driver to pull over followed by a final sign telling all traffic to stop.

The VMS cure is purely a visual prompt to inform drivers and still relies on compliance; it will not protect the bridge. The system is currently triggered approximately 12 times a day with 2% of events being deemed critical or close calls. The majority of these events are caused by repeated offenders consciously ignoring the warning as they believe they won't hit, as they do this regularly.

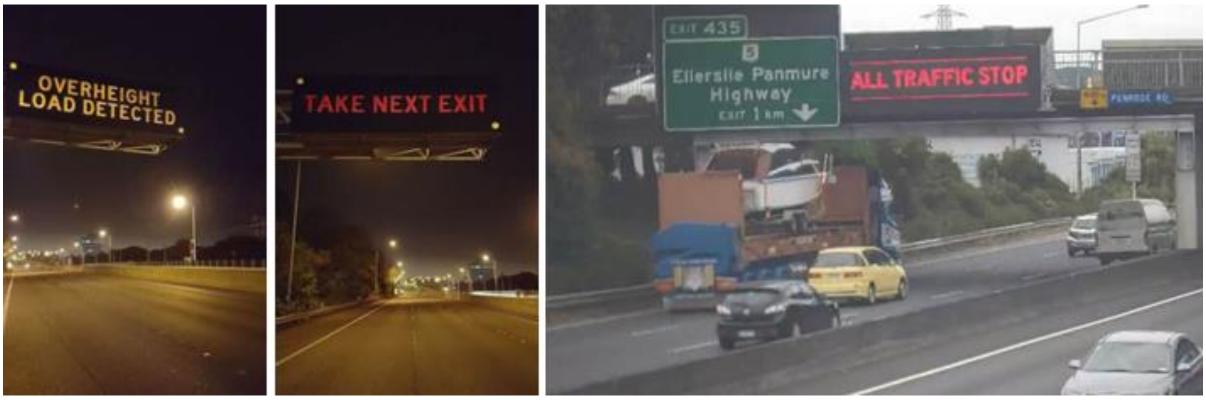

Figure 4 Penrose VMS displays (Source – NZ Transport Agency).

As mentioned, Penrose has had over 40 recorded strikes in the past 8 years, all of varying severity. The event in 2016 was a carbon copy of the Onewa incident in 2009 and due to the slight difference of the digger being lighter and not tied to the flatbed trailer, a similar outcome would have occurred. As a result of repeated strikes at Penrose, it has been noted that fatigue-like defects are starting to propagate and manifest. With subsequent and repeated strikes, this may lead to the failure of a structural member under an innocuous incident. For this reason, a physical barrier in the form of a steel collision protection beam was bolted to the bridge which was designed to take full codified impact loading and protect the bridge from future over-height strikes.

It must be noted that Network Rail also installs similar collision protection beams on their high-risk sites with multiple recorded strikes and high schedule 8 payments. Bridges with RED and AMBER ratings will typically get little resistance during the business case process, especially if a DOUBLE AMBER dispensation can be given following the installation of a collision protection beam.

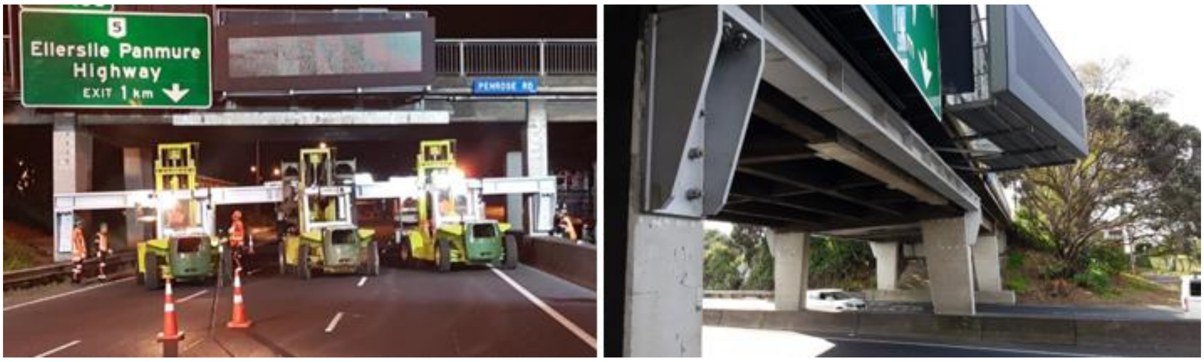

Figure 5 Penrose collision protection beam (Source – NZ Transport Agency)

4.2 Prevention

Network Rail and the NZ Transport Agency take a proactive approach at educating the industry in an effort to eliminate the threat completely. Network Rail takes the approach of the 4E's of Education, Engineering, Enable, Enforcement, while in a similar vein the NZTA takes the approach of the 4P's of Prevention, Prosecution, Pursuit for payment and Publicity.

In 2012 the UK the Rail Safety and Standards Board (RSSB) research Brief T854 found that when it came to drivers, 32% didn't know their vehicle heights, they tended to use maps with no height restrictions marked, 56% didn't consider low bridges in their route selection, and only 10% used satellite navigation. It was also discovered that 31% of drivers didn't get any guidance from their employers.

The recommendations of T854 was for the industry to design route planning, height measurement tools, in cab low bridge warning systems, better advanced warning signs, engagement and training of the industry, and effective enforcement of the regulations.

The NZTA has carried out several campaigns which targets the industry and typically involves attending/presenting at Road Transport organization's annual events, articles in trucking magazines, media releases, classroom-type presentations to drivers, and discussions with the police and insurance companies on how to better implement enforcement and prosecution. While the NZTA does not actively promote the advertisement of vehicles hitting Penrose, social media and news outlet footage of events have been found to influence and educate the behaviours of the trucking and haulage industry.

The NZTA has found that following an active campaign, there is a noticeable reduction in the number of recorded strikes in the subsequent years. This typically gives a 3-year grace period until the number of strikes start to increase again and people become normalized to the issue.

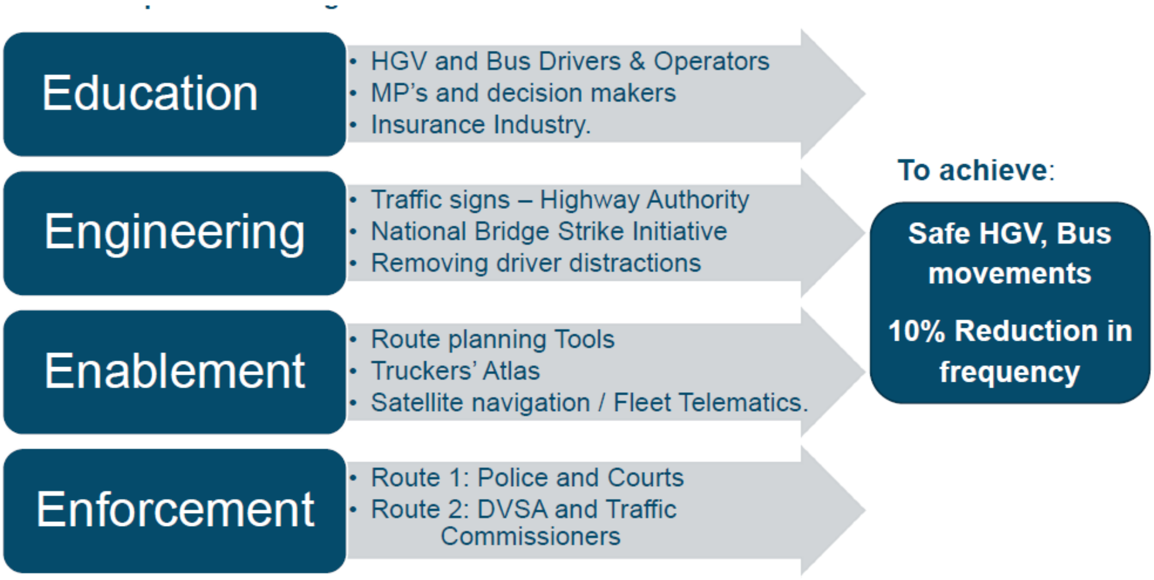

Figure 6 Network Rail 4E's (Source – Network Rail).

5 CONCLUSION

Over dimension vehicles striking rail and road bridges internationally is a daily occurrence with each strike causing delays to customers, has financial implications, damages vital infrastructure, and in extreme cases loss of life. Network Rail developed the NBSI process to limit the disruption to its customers and help keep trains moving's following a bridge strike. The key to reducing the frequency and impact of bridge strikes is to, yes improve the "engineering" of a site with signage, collision protection beams etc. but more importantly promoting a behavioral change of both vehicle drivers and operators, that ensure that before any journey is taken the vehicle height is known and journey planned accordingly. The NZ Transports Agency has installed steel collision beams to protect Penrose for future strikes and safe guard its future, this supplemented with VMS warning over height signs helps inform drivers and reduces/ eliminates strikes. These approaches help protect the asset and limit the disruption to network users but what has been found is be it in the UK or NZ is that education of the industry is the most effective and probably cost-effective mean at reducing and in an ideal world eliminating bridge strikes.

6 AUTHOR BIOGRAPHY/IES

Liam Coleman is a Chartered & Fellow Civil and Structural Engineer with 15 years' experience primarily in bridge inspection, design, assessment, and asset management. Liam has extensive experience of managing railway and highway assets from Ireland, UK, and New Zealand. Liam was previously responsible for the live load carrying capacity of the oldest and busiest mixed modal railway in the world and Europe for Network Rail. Liam currently works for the NZ Transport Agency National Structures team responsible for the development and application of operational policy, technical standards, processes, enabling transport safety, inclusive access, and the environmental performance of the network to achieve the agreed levels of service of bridges over the asset lifecycle at the least whole-of-life cost.

Mark Wheel is a Chartered Civil Engineer with 37 years' experience in the rail sector. He has spent his career managing railway bridges and structures before moving in 2017 to Network Rail's Safety, Technical and Engineering Team at Milton Keynes. Since 2009 Mark has been working to reduce the frequency and impact of road vehicles hitting railway bridges. By working with the UK Road Haulage Association (RHA), Freight Transport Association (FTA) and logistics companies he has gained a significant understanding of the issue and is currently raising awareness through a national campaign, this focuses on Education, Enablement (Route planning tools, fleet telematics systems, etc.), Engineering and Enforcement.

Alyson Dean is a Bridge Engineer specialized in highway infrastructure with a Bachelor of Science in Engineering from the University of New Brunswick in Canada. She also completed her Masters in Engineering, with thesis on the "Performance of Corrosion-Resistant Reinforcement in Concrete". She has completed a variety of engineering assignments including steel design, bridge inspections, and the assessment and load rating of numerous steel, concrete, and timber structure types. She has experience working with various technical codes and structural analysis software packages. Alyson has also been involved in various bridge asset management projects (including the design of the collision protection beams at Penrose Underpass), expanding her skills beyond the traditionally technical role.