UNIVERSITY OF CAMBRIDGE

Transforming construction: impact case study

Benefits to industry: improved safety; reduced costs to asset owners; less disruption to travel networks and traffic

Autonomous vision-based bridge and tunnel strike prevention system for improved safety and more efficient asset management

The challenge

Over-height vehicle strikes (OHVS) are a constant and costly problem for asset owners. An OHVS is caused by a vehicle attempting to pass under a bridge or tunnel that is lower than its height, leading to a collision with the structure. A common reason for such strikes is drivers not knowing the height of their vehicles and ignoring or missing warning signs despite a number of preventative methods installed in advance of low clearance bridges. OHVS can cause a number of problems including: impact to the wider travel networks; traffic delays; damage to bridge structures; bridge closures; and injuries. In the worst-cases, derailments, immediate collapse of bridge structures and fatalities may occur.

The costs of the problem to asset owners

According to Network Rail there are typically five bridge strikes every day nationally costing the organisation £12.7m per annum in compensation (2016/17). Each strike costs the asset owner around £13,000 and the financial burden to the UK taxpayer is calculated at £23m a year (www.networkrail.co.uk/communities/safety-in-the-community/safety-campaigns/check-it-dont-chance-it/).

The potential solution

Researchers at the Laing O'Rourke Centre (LOR Centre) for Construction Information Technology (CIT) Laboratory at the University of Cambridge are working on a project, partially funded by Cambridge Centre for Smart Infrastructure and Construction (CSIC) and Transport for London (TfL), to create, test and deploy an OHVS system for the prevention of bridge and tunnel strikes. This innovative system uses a vision-based approach featuring a single calibrated video camera mounted on the side of the road at the height of the low bridge. The camera is strategically positioned to capture three main features using the same data feed: over-height (OH) vehicle, number plate of vehicle, and record of vehicle at the scene. The camera position and orientation are determined using a calibration process with a reference object.

OHVS systems currently on market

Managing OHVS requires attention in three domains: prevention (discouraging strikes in the first place); detection (accurately recording strikes that do occur); and reporting (efficiently communicating OHVS details to the relevant authorities). The latter two aspects of OHVS management are effectively managed by existing systems. However, many of the OHVS technologies currently available are too expensive for asset owners to justify the upfront costs and very few systems are designed to mitigate OHVS impact.

Asset owners favour quick, affordable, and accessible passive methods such as signage, bridge markings, and flashing beacons as an initial attempt to warn drivers and prevent strikes. These passive interventions are readily available, easily installed and minimise further infrastructure installation. They prevent ~10–20 per cent of strikes (Cawley 2002: Cawley, P. M, 2002. Evaluation of Overheight Vehicle Detection/Warning Systems) but additional complementary systems are necessary for higher prevention rates.

Where strikes have persisted, asset owners have used sacrificial or active systems. Sacrificial systems (also known as rigid passive systems) are attractive for asset owners because post installation maintenance is minimal. These systems typically comprise crash beams, metal hanging chains and road-narrowing techniques that are protective rather than preventative. Active strike prevention systems – also known as early warning detection systems (EWDS) – detect and notify vehicle operators ahead of the presence of low structures. Current systems of this type consist of a transmitter receiver placed directly across the lane(s) of traffic (laser or infrared light warning systems have also been deployed) with an inductive loop to detect the presence of a vehicle in advance of the warning sign. There has not been widespread adoption of EWDS due to the high cost associated with the physical infrastructure requirements.

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Framework for a relatively low-cost solution for OHVS

The autonomous vision-based bridge and tunnel strike prevention system potentially provides a viable solution for OH vehicle detection that specifically addresses prevention. The objective is to develop a lower cost EWDS system by replacing the transmitter, receiver, and loop detectors with a single camera mounted upstream of the low bridge. The proposed method is based on the following geometric principle: when a camera is properly mounted at the height of the bridge clearance relative to the road surface, the OH plane will appear as a line in the camera image. The method is suitable for various shapes and sizes of vehicles, numbers of laneways, and illumination conditions (day and night time). Camera stabilisation is crucial to minimise any potential captures of noisy motion that may contribute to triggering false positive alarms.

How the system works

Video footage is converted into image frames, which are then used as inputs for the OH detection process. When an OH vehicle is detected, cameras and accelerometers are activated; a message is issued on the display unit, warning the driver of the low bridge. The driver warning process may take one of two paths: (1) if the driver exits or stops, and no impact is detected, then video data are discarded and accelerometers are deactivated; and (2) if the driver continues and an impact is detected, then the vehicle license plate number is extracted from the recorded video and impact data from the accelerometer are stored. The collision report (video segment, licence plate, and accelerometer data) is sent to the relevant authorities.

Testing the system

Testing of a small scale prototype has been carried out with London Underground and Redbridge Council to evaluate the height and detection accuracy of the system. The tests were conducted on two collector roadways with two and four lanes of traffic in sunny, cloudy, and rainy weather conditions.

Results and benefits to asset owners

Evaluation of the small-scale prototype system, which is jointly funded by Transport for London and CSIC, resulted in a height accuracy of ±2.875 mm; outperforming the target accuracy of ±5 cm. The algorithm performed with 100 per cent recall, 83.3 per cent precision, false positive rate of 0.2 per cent and warning accuracy of 96.6 per cent. Although its accuracy is comparable to existing EWDS laser beam systems, it outperforms them on cost which is an order of magnitude less because of eliminating the need for new permanent infrastructure. The proposed system is also applicable to low-deck parking garages and shipping barges with height restrictions. Additionally, components of the system are intended to minimise inspection, maintenance, and repair costs that fall to the asset owner.

Looking ahead

Researchers plan to develop and test a larger scale prototype and are seeking potential investment from system providers that may be interested in the technology, either to diversify or to complement their existing product line. Commercialisation options with system providers to roll out the product as a service offering are at an early stage. Other asset owners have expressed interest in deploying the system.

The Laing O'Rourke Centre for Construction Engineering and Technology, in the University of Cambridge Department of Engineering, was launched in 2011 with industry partner Laing O'Rourke to fulfil a shared vision of transforming the construction industry through innovation, education and technology.

Case study

This case study is based upon a Laing O'Rourke Centre for Construction Engineering and Technology PhD titled: Vision-based over-height vehicle detection for warning drivers (2017). The research is by Bella Nguyen, Senior Consultant, Arup – **with additional funding from CSIC and London Underground.**

Further details

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