Mitigating Overheight Vehicle Collisions for Low Clearance Bridges

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Abstract

An overheight vehicle collision is an incident in which a vehicle, typically a commercial truck or bus, tries to pass under a bridge that is lower than their vehicle's allowed clearance, therefore colliding with the low clearance bridge. According to the US Federal Highway Administration, the third most common cause of bridge failure is bridge-vehicle collision damage (FHWA, 2013). Crashes between overheight vehicles and low clearance bridges are a frequent phenomenon occurring throughout transportation networks all over the country. FHWA reports that the third most common cause of bridge failure is vehicle crash. Similarly, transportation and bridge engineers report that the leading cause of damage to both prestressed concrete bridges and steel bridges are in fact vehicle collisions. There are a number of reasons why overheight collisions occur, and why drivers of heavy commercial vehicles sometimes fail to recognise the warning traffic signs, consequently striking the bridge. In my thesis I will present the current scope of these incidents, their impact on current transportation networks, and recommendations based on current state of practice and research.

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One of the leading causes of bridge failure, vehicle collisions, is highly undocumented, in fact an inventory for this type of accident does not exist. However overheight vehicle collisions are reported in bridge maintenance and inspection reports including the National Bridge Inventory Conversion Profile and the General Condition Ratings. Several studies have been conducted in the past drawing parallels between the data that were available at the time. In these studies the adverse effects of structures, mainly bridges with insufficient vertical clearance are obvious. For example a study conducted in 1990 (Harik et al. 1990) analyzed bridge failures in the United States over an approximately 40 year period. Of all the bridges where failure occurred approximately 15% of these failures occurred because of some type of damage to the superstructure and substructure caused by a collision with a vehicle, typically a commercial vehicle or a truck. Collisions to low clearance bridges create possibly fatal risk for the driver of the vehicle and vehicles that may be near the incident. In severe situations, the collision can result in the bridge closing for a long period, incurring costs to state, federal and private agencies. Overheight vehicle collisions are preventable incidents, since these studies overheight detection systems have seen significant improvements but overheight collisons have seen a steady rise over the years. In fact a more recent study (Bedi 2000) indicates that damage sustained by girders and beams part of the bridges substructure and superstructure are more severe than previously reported. Of the damaged girders reported over half sustained minor damages , mostly small cracks. Some bridges sustained moderate damage defined as cracks to the girder showing the tendons behind the damaged concrete. The remaining bridges sustained significant damage to the substructure and the superstructure, damage to these components caused damage to the tendons and significant concrete loss. Usually, if significant damage occurs not only does the bridge in question shut down, large blocks of concrete are scattered on the streets completely hindering traffic. If the collision occurs at a steel bridge, as in the one found at the intersection of 14th Street North West and Main Street, significant damage to the vehicle causes lane closures. However if there are warning systems in place for overheight vehicles, why have the number of incidents risen and why do they continue to occur? In this paper, I present a thorough analysis of the nature problem of overheight bridge collisions also known as low clearance vehicle collisions, I will take into consideration the current state of research and mitigation methods in my analysis in order to make the most fitting recommendations, remarks and suggestions. .

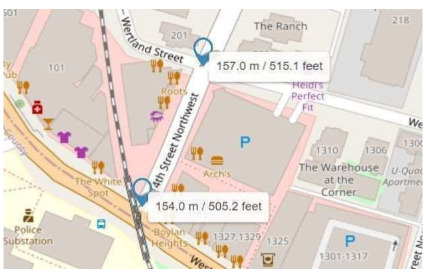
A simple definition for overheight vehicle collisions are accidents where a vehicle strikes a bridge with inadequate vertical clearance to that of the truck. The standards for a vehicle's vertical clearance is adopted by the Interstate System for national defense purposes. On Interstates Highways, height of structures shall not be less than 16 feet over the entire roadway width,(AASHTO, 1994). In urban areas, the 16-foot clearance also applies. However on other urban Interstates , the height shall not be less than 14 feet . The minimum height clearance for urban and rural roads range from 14 to 16 feet. These criteria are set to provide at least a 1-foot differential between the maximum legal vehicle height and the roadway (AASHTO 1994). A design exception is required if this standard is not met. These designs are rigid and in compliance with several agencies one of which is the Transportation Engineering Agency of the Department of Defense. If these design regulations are so rigid, why do collisions such as overheight collisions even occur. Turns out the very nature of low clearance collisions isn't at all that simple. The maximum allowable vehicle height varies with each state. The most common allowable height limit is 13 feet and 6 inches, but throughout the states, height clearance ranges from 11 feet 6 inches to 14 feet 6 inches (RVIA, 2017). Even Kentucky with the lowest allowable height limit of 11 feet 6 inches permits a 13 feet 6 inches limit on state maintained roadways. If the minimum bridge clearance is of 14 feet, in theory collisions are bound to occur for the upper range of overheight vehicles. Given this information , are OVCs occurring because of the drivers or inadequate prevention systems.

In one of the most extreme and severe cases, on June 8, 1999 a commercial vehicle traveling with an improperly loaded trailer hit the superstructure of a bridge on the Baltimore Beltway. Unfortunately, a motorist lost his life and three others were gravely injured as the concrete collapsed onto oncoming traffic. In response to this catastrophe the National Transportation Safety Board (NSBE) appointed a task force to investigate the incident and to devise appropriate conclusions on preventive measures in the future (NTSB 2000a,b). The investigation team found that the collapse of the pedestrian bridge was due to the impact of the trailer attached to the commercial truck. The investigation team also found that the driver had loaded on the trailer incorrectly and loaded the trailer backwards so the maximum height of the attachment to the vehicle actually came to about 17 feet 9 inches above the interstate highway (NTSB 2000b).

The commercial vehicle was not inspected by any authorities where the load orginited from before leaving for its destination; it was left to the driver to ensure that the trailer attached was within the allowable dimensions which a permit from the local Transportation agency in Maryland indicated to be 13 feet 6 inches. The pedestrian bridge on the Beltway had a maximum vertical clearance of 16 feet , which is well within both state and federal limitations.When the truck struck the superstructure of the bridge, the driver did not realize he had hit the continued to travel since it never occurred to him that he struck the bridge. The driver stopped when the truck hit and slightly damaged another overpass on the same interstate. The task force investigative team concluded that the accident was the result of human error from the driver, who had not received proper training regarding overheight clearance and loads (NTSB 2000b). The ask force suggested that electronic height detection devices and driver training on oversize loads be instituted to address the issue of Overheight Vehicle Collisions. The task force also recommended a nationwide review of low clearance vehicle collisions of similar nature to determine the extent of the problem thus commencing research and possible mitigation procedures.

Based on the investigation from NTSB one possible cause can be attributed to OVC, human error. However factors not considered in the study, vehicle height detection systems could also play a major role in OVCs. In the US, some states post the actual vertical clearance, while other states under-report the clearance by up to 12 inches. One whole foot of clearance can have serious effects since drivers are more likely to ignore clearance signs knowing that state's limits are under-reported anyways. Taking everything into consideration, OVCs can mainly occur due to these factors ; human error where the drivers do not know the real height of their vehicles or the bridge on their route and warning signs reporting inaccurate clearance height failing to prevent collisions.

The Bridge in Charlottesville located on the Historic Corner in 14th Street NorthWest saw as many as 13 collisions per observation from July 2017 to December 2019. On the bridge the sign warns any and all vehicles over 10 feet of a possible collision. Many of these accidents have made the local news, so why is it that it continues to happen again and again. The light duty box trucks involved in the collisions have an interior height clearance of 6 feet 6 inches in addition to a ground clearance of about 3 feet, the total clearance comes to about 9 feet 6 inches. In theory OVCs should not occur on the corner with a six inch differential clearance height. The elevation at the intersection of 14th Street Northwest and Main Street is 502 feet, there is a rise in elevation in all directions with the highest elevation being 515.1 feet at a distance of approximately 245.41 feet away which yields a slope of 5.24 percent for the road. The slope is important because if the road were to have a slope of less than 1 percent it would be considered relatively flat and the marked clearance at the bridge wouldn't pose such a big issue.



The roads near the bridge that the box trucks are on would not be considered flat so the marked sign would have to take into account a sloped truck not a flat one. A sloped truck would need enough distance to clear the bridge and that is near impossible with the steep rise of 14th Street and main Street for the typical light duty box truck. On average box trucks are 16 feet in length. Let's consider this scenario: the vehicle in question, a 16 feet light duty box truck, is traveling down 14th to make a right or a left at Main Street. The box truck in question has a height clearance of 9 feet 6 inches. The box portion of the truck is 10 feet long. When the initial

6 feet of the car where the driver is located clears the bridge the top of the box is on a road elevation of 505.2 feet, this puts the top of the box at 514.7 feet with the bottom of the bridge being at 512 feet, a collision will happen. Based on this information the clearance of the bridge should be approximately 7 feet instead of 10. If the truck is traveling on Main Street though , with the same previous principles the clearance sign should say 9 feet. For this 14th Street Bridge , the preventive warning sign is the main factor behind OVCs.

Overheight vehicle collisions impact more than just the bridges that are struck. When OVCs occur traffic congestion and delays are sure to follow. Traffic can be at a standstill for several hours while the truck and debris from the strike is removed. In the case of the Charlottesville bridge, for some of the OVCs that occured traffic was halted for hours and diverted as officials removed and and all obstructing objects. Usually for these incidents the truck only hit the bridge but no significant damage was sustained. In some instances though, the top of the vehicle may scrape the underside of the bridge, since the Bridge on 14th street is a steel bridge, the top of the box trucks completely come off sometimes. When this happens traffic and delay last much longer than when a less severe OVC occurs. Traffic and delays though aren't the only impact, the renting company sustains a maintenance cost on the truck in question, the driver may have sustained an injury and the traffic may cause other unforeseen consequences. For example the merchandise inside may have been damaged. In severe OVCs the structure itself may be damaged,some examples can include breaking the concrete which then exposes the prestressing steel. When OVCs occur in severe cases, traffic is delayed until the bridge has been inspected to determine if the superstructure and substructure have been significantly damaged and whether it is safe to resume operations and traffic. If the structural integrity is at all questioned, traffic on the bridge and under it must be halted until a definitive outcome on how to move forward is determined. Usually when the accident happens the driver of the truck in question is charged and responsible for the damages caused to the bridge, the road, vehicle and any other collateral damages. This can lead to many unfortunate consequences, the driver can incur increased insurance rates, points added to their license, and possible legal fees against the city or the employer, some amongst many. In some cases some companies may even choose to terminate the employee.

Aside from traffic delay and logistical issues , OVCS can have an impact on overall public health, this can range from minor injuries to more serious consequences, one of which being death. The 14th Street bridge runs above the bridge structure and can pose a risk to drivers themselves in the long run. OVCs have the potential to cause both horizontal and vertical displacement of the railway track. This can cause a complete failure in the bridge's structural integrity or, in the worst case scenario, result in derailment of the train where consequences could become unfathomable. OVCs pose several issues in the transportation and infrastructure industry, apart from the research conducted by the NTSB investigation team, further research efforts for prevention of OVCS has been severely lacking. At first glance, it may seem like the problem of OVCs is a fairly easy problem to solve, stopping vehicles from striking bridges using preventive signs sounds easy enough. No matter how well designed a roadway may be; driver error and human error in general is always a factor, and so are inadequate signs.

Preventive technologies currently available are categorized as physical and non physical. However, preventive measures available today are targeted towards preventing OVCs from occurring but not mitigating their impact. Bridge owners and DOT agencies are mostly interested in protecting the structural integrity of the bridges under their purview, if prevention of a crash isn't a possibility, having the option to mitigate the OVC could be beneficial in the long run. Physical preventive technologies include any and all signage, fixed signage, message signs, beacon , flashing signs and bridge markings like the sign on the 14t Street Bridge. Non-physical preventive technology are mostly related to law regarding OVCs that assign restrictions, permits, mandatory height requirements in vehicles. Preventive signage makes bridge clearance appear smaller from a distance, unless they are underreported. Although physical and non-physical preventive technologies are a quick fix and easily installed and amended, they do not provide a concrete solution. For example in the case of the 14th Street Bridge, even a box truck 8 and a half feet in height would strike the bridge, per the physical sign and Charlottesville ordinances this shouldn't occur, yet it happens fairly often. In order to mitigate OVCs though more should be used. The previous preventive systems will need to be used in conjunction with other OVC prevention systems to make the most of both prevention and mitigation. At the policy level, bridge owners, local, state and federal agencies have attempted to manage the problem of OVCs by enforcing fines to drivers of overheight vehicles and the companies that either rent or own the vehicles. In order not to sustain unnecessary fines drivers are encouraged to check the height of the vehicle and clearly display the clearance height before they embark on their trips. Although these systems may not necessarily prevent OVCs from happening, the aim is mostly to raise OVC awareness amongst anyone involved with driver training courses. Fines are a deterrent but drivers courses can have a positive upward effect and can be effective for all parties in the long run. Another type of OVC preventive technology is a subcategory of a physical system, they are known as sacrificial systems. Sacrificial systems consist of impact beams also known as collision protection beams and crash beams, hanging chains bars, portal frames and speed bumps. Impact beams are designed to dissipate the energy from vehicle impact when an OVC occurs to protect the structure in question. The truck driver and other drivers in question are still at risk for injuries and even fatalities . Impact beams may be an effective mitigative tool but they too only solve part of the problem. Impact beams provide no advance warning to drivers, and act as a last resort for drivers who fail to notice the low clearance bridge warnings. Impact beam installation requires permit approvals and plan approvals from architects, professional engineers and project managers. The whole process from permit procurement to construction can be very time-consuming and costly. Hanging metal chains are commonly seen as a modern variant of the typical overhead frames used at drive-thru restaurants and parking garage entrances. On non interstate roads with overhead bridges the hanging chains are effective at warning drivers since they are travelling at relatively low speeds, at higher speeds though the impact may not be felt which can lead to an OVC down the road. Geographical Positioning Systems (GPS) are another preventive technology used by overheight vehicle drivers to locate low clearance bridges and structures. A GPS unit is installed in the vehicle, and as vehicles approach a potentially low structure, the system will warn the driver within the cab if the vehicle’s clearance height is too high for the bridge. The issue though is that often the information could be inaccurate and fail to prevent OVCs.

As the current state of research and implementation stands, one would assume the vast availability of many effective detection and reporting systems for OVCs. However for the preventive side, effective methods are sparser. OVCs still occur very often, and OVC prevention systems available on the market are too expensive to implement nationwide. Physical and non-physical systems described earlier may be cost effective, but they are not sufficient, scrapes are often clear on the underside and the facade of bridges, especially for the 14th Street bridge. Bridge owners DOT and local agencies aim to minimise the occurrences of OVCs as part of bridge restoration and maintenance programs. The need to develop an affordable solution is crucial to prevent future OVCs posing serious risks to civil infrastructure both private and public.

The current state of research in OVCs involves computer vision methods. Computer vision methods include imaging and vision-based sensing and seek to understand and automate digital information mainly in infrastructure. A reliable OVC prevention system must be able to detect all overheight vehicles, whether that be trucks , box trucks, or trucks carrying oversized loads to provide sufficient warning to the driver. Such a system must be designed for accuracy to determine the appropriate system for installation. Computer vision methods no doubt have much room for improvement in the future , but they are low cost for how well they currently perform and their level of output. Imaging, mainly satellite and digital imaging have shown constant improvement throughout the years, which in the long run may attract bridge builders and owners. However, adequate testing has not been conducted therefore more research is needed before they can replace preventive technology currently available.

In this paper, I presented a comprehensive analysis of the nature of overheight bridge collisions, followed by the current state of research of preventive technology implementation. I mentioned that effective OVC preventive technology and methods exist in the form of physical and non-physical systems, but they do not suffice for both prevention and mitigation of these types of incidents .For example, many physical systems are given too much weight and considered to be adequate fixes for the problem. Regardless of how many preventive signs that are put in place, truck drivers both commercial and private, will continue to strike low clearance bridges, if this weren't the case most low clearance bridges would not need at least some warning in place. Collision marks and scrape wear and tear are visible on the underside and the facade of bridges; one thing that this may confirm is that many OVCs go unreported. Therefore, in such instances, preventive technology paired with detection and reporting tools are an important aspect of a possible solution, not only to prevent OVCs from happening in the first place , but also to identify any and all responsible parties.

GPS systems, sensors and deterioration classification methods are recommended in addition to classify the level of severity caused by OVCs. More often than not, OVCs go unreported, this is especially true in areas that don't see as much daily traffic.That bridge sustained some sort of damage and the proper authorities were never informed which can lead to a potentially dangerous operational bridge. A dangerous operational bridge could have dire consequences and the results can be catastrophic; a proper inspection, a bridge assessment system and a reporting method is ideal to handle these types of situations. The system would notify and provide an assessment report of each OVC to authorities and the agencies involved; categorised by the severity of damages. DOT agencies can then use this information to determine the appropriate course of action and how to properly move forward. This will have a positive effect on overheight vehicle collisions in the long run meaning the number of collisions that go unreported and prevent stricken structures deemed unsafe from continued operation. The biggest issues for bridge owners and DOT agencies are affordability and reliability of a proper OVC detection system for widespread implementation. I deduce that a multi faceted based approach to accurately detect OVCs using the combined benefits of physical, non physical and reporting systems is the most affordable solution for all agencies involved, providing a comprehensive answer to the problem of OVCs.

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