Project # C-07-10

BRIDGE VEHICLE IMPACT ASSESSMENT

FINAL REPORT
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EXECUTIVE SUMMARY

Bridges in New York State have been experiencing close to 200 bridge hits a year. These accidents are attributed to numerous factors including: improperly stored equipment on trucks; violation of vehicle posting signs; illegal commercial vehicles on parkways, etc. The objectives of research conducted in this report have been to (i) review and identify major factors contributing to bridge hits, (ii) provide recommendations to the NYSDOT about effective measures for reducing the likelihood of future bridge hits, (iii) provide long term, feasible and economical suggestions to reduce the likelihood of bridge hits, (iv) review and comment on the NYSDOT *Collision Vulnerability Assessment Procedure* and provide recommended improvements and (v) develop a computer program for analyzing the bridge hits phenomenon as new bridge hits data become available. The focus of the research has been on commercial vehicles hitting structural members of bridges. This study doesn't address water vessels colliding with highway bridges.

In order to meet the above objectives, an exhaustive literature review was carried out to identify factors that lead to bridge hits in other parts of the world and preventive measures taken to reduce such accidents. A comprehensive survey of state DOTs in the country was carried out to collect data on bridge hits in different parts of the country and types of actions taken by different agencies. Based on feedback during the survey, a second in-depth survey of selected DOTs was carried out to collect more detailed information on the performance of various automated over-height detection systems used to warn over-height vehicles from hitting bridges.

Many bridges are hit multiple times. This can be because of localized issues surrounding the bridge. Hence, further investigation was done to identify site specific issues by visiting bridges hit multiple times in 4 selected regions of the NYSDOT. Several specific issues have been identified based on these visits.

New York State Department of Transportation has been actively collecting data on bridge hits since 2010 to identify issues contributing to increased bridge hits. A computer program has been developed to analyze bridge hits data by classifying according to different criterion, e.g., DOT region, AADTT, maximum vertical under-clearance. The computer program also allows plotting of data on a GIS map for geo-spatial analysis of bridge hit patterns.

New York State Department of Transportation carries out collision vulnerability assessment of bridges using a *Collision Vulnerability Procedure.* A critical review of this guideline has been carried out based on historical bridge hits data to propose changes in the collision vulnerability assessment procedure of New York State.

Finally, based on detailed investigation carried out in this project, general recommendations have been proposed for reducing bridge hits in New York State. These recommendations have been classified into (i) Regulatory, (ii) Technological and (iii) Education Outreach categories. Implementation and costs issues related to these recommendations have been discussed.

STATEMENT ON IMPLEMENTATION

The main outcome of this project is report on specific and general recommendations for reducing bridge hits and a computer program for analyzing bridge hits data. The computer program analyzes bridge hits data to help NYSDOT engineers identify factors affecting bridge hits. NYSDOT engineers can implement specific countermeasure (such as vehicle over-height detection system at a location) or general countermeasure (such as increased enforcement over a wider area). The computer program also has a GIS module where NYSDOT engineers can carry out geo-spatial analysis of data, such as locations or corridors of bridge hits, bridge hits by NYSDOT region, etc. Collision database used by the computer program is updatable as new bridge hits data become available. The project report also provides detailed information on vehicle over-height detection systems and their performance. Hence, the outcome of the project can be implemented immediately by the NYSDOT. The computer program can be used for many years in future to analyze bridge hits occurrences in New York State.

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16. Abstract

Bridges in New York State have been experiencing close to 200 bridge hits a year. These accidents are attributed to numerous factors including: improperly stored equipment on trucks; violation of vehicle posting signs; illegal commercial vehicles on parkways, etc. This report describes the work done to achieve the following objectives: (i) review and identify major factors contributing to bridge impacts, (ii) provide recommendations to the NYSDOT about effective measures for reducing the likelihood of future bridge hits, (iii) provide long term, feasible and economical recommendations to reduce the likelihood of bridge hits, (iv) review and comment on the NYSDOT *Collision Vulnerability Assessment Procedure* and provide recommended improvements and (v) develop a computer program for analyzing the bridge hits occurrences as new bridge hits data become available. The focus of the research has been on commercial overheight vehicles hitting superstructures of bridges. This study doesn't address water vessels or trucks colliding with highway bridge piers.

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1.1. INTRODUCTION

Bridges in New York State are experiencing close to 200 bridge hits a year. From the analysis of bridge hits data provided by the NYSDOT, it has been observed that these accidents could be attributed to numerous factors, including improperly stored equipment on trucks, violation of vehicle posting signs, illegal commercial vehicles on parkways, etc. According to the Federal Highway Administration (FHWA), over 600,000 bridges are registered in the National Bridge Inventory (NBI). By a wide margin, most bridges that collapse do so during floods. Overweight vehicles, usually crossing a bridge in violation of posted weight limits, are the second biggest cause of bridge collapses. According to Federal Highway Administration, a 3rd leading cause of bridge failure or collapse is collision damage when a vehicle or a vessel hits a bridge[1].

Impact of vehicles with bridge components may result in failure of the bridge system and loss of lives. A tractor cargo-tank semitrailer loaded with 9,200 gallons of propane (a liquefied petroleum gas) drifted across the left lane onto the left shoulder, struck the guardrail and the tank hit a column of the Grant Avenue overpass over Interstate 287 on July 27, 1994 in White Plains, New York. During this accident, the driver was killed, 23 people were injured, and an area with a radius of approximately 400 feet was engulfed by fire. According to the National Transportation Safety Board (NTSB), the design of the highway geometries and appurtenances, which did not accommodate an errant vehicle, were contributing factors, in addition to the driver fatigue [HAR9502 (1994)]. The Alexandria Avenue Bridge on George Washington Memorial Parkway in Alexandria, Virginia was hit by a 58-passenger motorcoach on November 14, 2004, even though there were low vertical clearance warning signs indicating that the bridge had a 10-foot, 2-inch clearance in the right lane. Of the 27 student passengers, 10 received minor injuries and 1 sustained serious injuries. The National Transportation Safety Board determined that the probable cause of this accident was the bus driver's failure to notice and respond to posted low clearance warning signs due to cognitive distraction resulting from conversing on a hands-free cellular telephone while driving [HAR0604 (2004)]. A bridge on I-80 route in Big Springs, Nebraska failed when a bridge pier was struck by an errant truck on May 23, 2003 [ENR (2003)]. One person was killed and the Memorial Day traffic was severely disrupted because of the accident. In 1996, an unknown overheight vehicle struck the center span of a 3-span prestressed concrete (P/C) bridge carrying I-680 over County Road L34 near Beebeetown, Iowa [Russo et al (2003)]. Due to concerns about the remaining strength of the two most severely damaged beams, unknown effect of the damage on the load distribution patterns in the remaining structure, and concerns regarding the durability and effectiveness of any proposed repair, the beams were replaced. Above examples highlight the significant risk to highway bridges and motorists using them from vehicular collisions.

1.2. LITERATURE REVIEW

Although bridge collisions have been a common occurrence, few studies have focused on systematic investigation on causes of occurrence and mitigation approaches. The most

[1] http://www.fhwa.dot.gov/infrastructure/intrstat.cfm

prominent research study on collision of overheight vehicles with bridges has been by Fu (2001) and Fu et al. (2003). This study quantifies the problem of over-height vehicle collision using bridge collision data for bridges in Maryland. Fu (2001) and Fu et al. (2003) found that 1,496 bridges were susceptible to over-height vehicle collision out of the total Maryland Bridge Inventory of 5,056 structures. It has been observed that the frequency of overheight accidents reported in Maryland increased by 81% between 1995 and 2000, as shown in Figure 1-1. Figure 1-2 compares the number of bridge hits recorded in Maryland as they relate to vertical clearance. It is observed that the bridge hits frequency has peaks at 14.5 and 16.5 feet. Above 16.5 feet, the number of bridges struck drops off sharply. The two distinct peaks in Figure 1-2 indicate the existence of two different populations of bridges: those designed for a standard vertical clearance around 14.5 feet, and those designed for a clearance around 16.5 feet. In order to study this trend, Fu (2001) studied bridges hit by separating them into two groups: those crossing Interstate, U.S., and Maryland routes; and those crossing County, Municipal, or other routes. They found that typically the bridges with 16.5 foot of vertical clearance were constructed over the Interstates and State routes, while the bridges with 14.5 foot of vertical clearance were more commonly constructed over local roads. Of the 1496 bridges susceptible to impact by overheight vehicles statewide, 309 (20%) have been struck. Scrapes were sustained by 144 of these damaged bridges, minor damage was sustained by 107 bridges, and 58 required considerable repair. Figure 1-3 shows frequency of bridges hits for different vertical clearances and damages. It is observed that the maximum number of bridges requiring repairs also had vertical clearances of 14.5 feet and 16.5 feet.

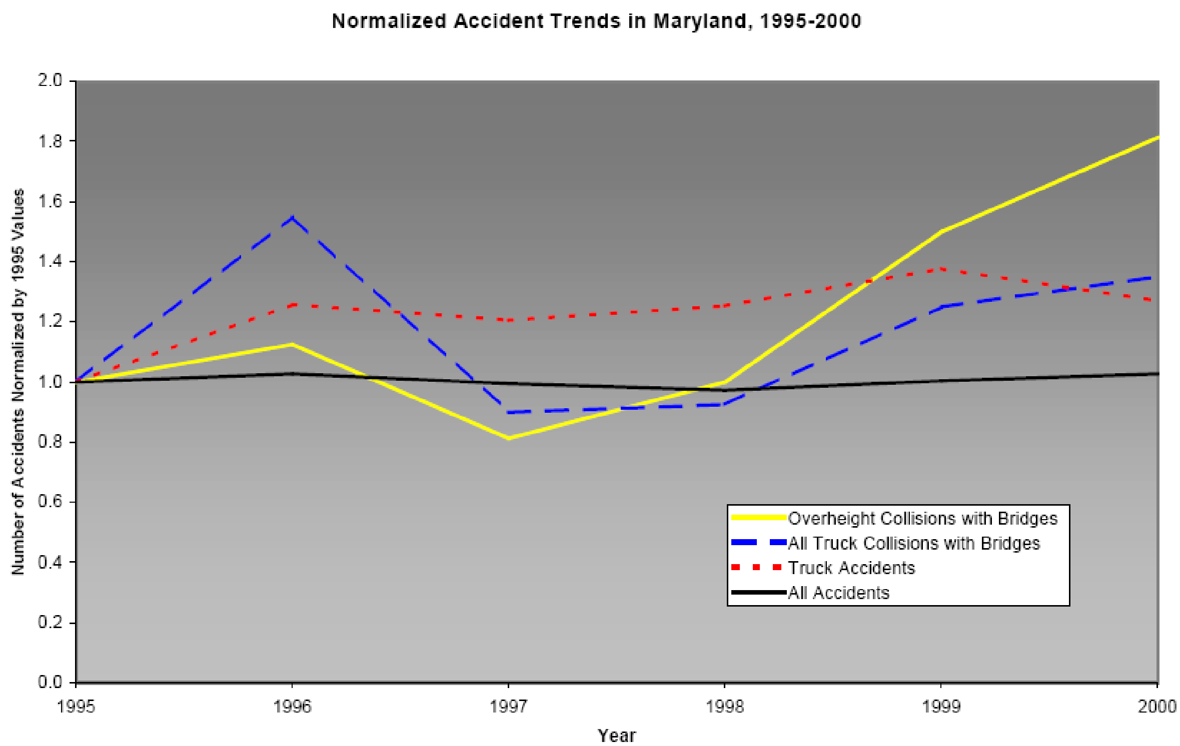


Figure 1-1: Frequency of Recorded Bridge Hits in Maryland From 1995 to 2000.

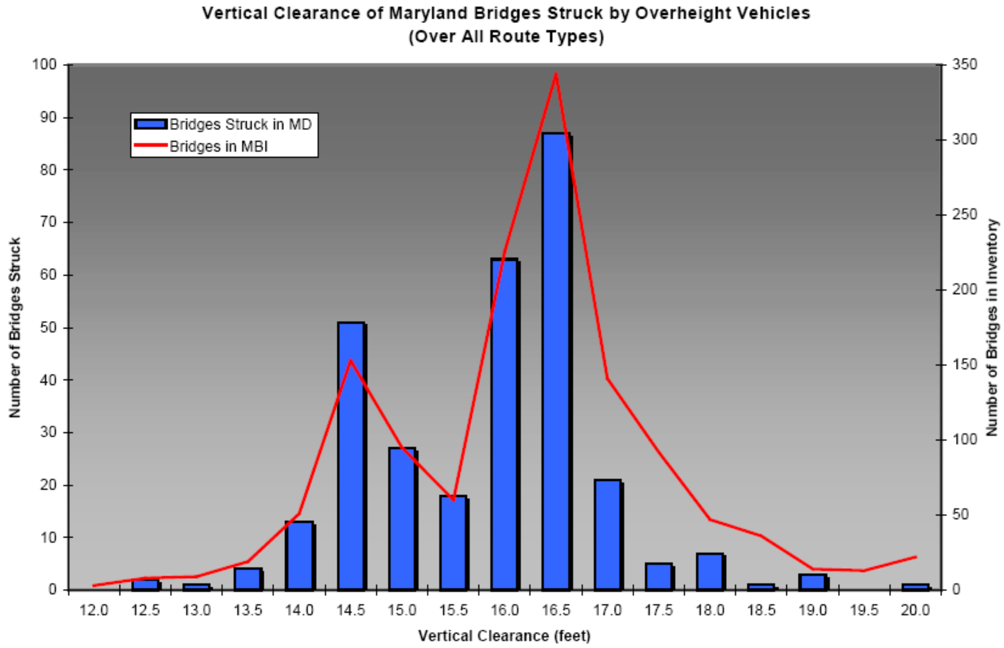


Figure 1-2: Frequency of Recorded Bridges Hit as Related to Vertical Clearance.

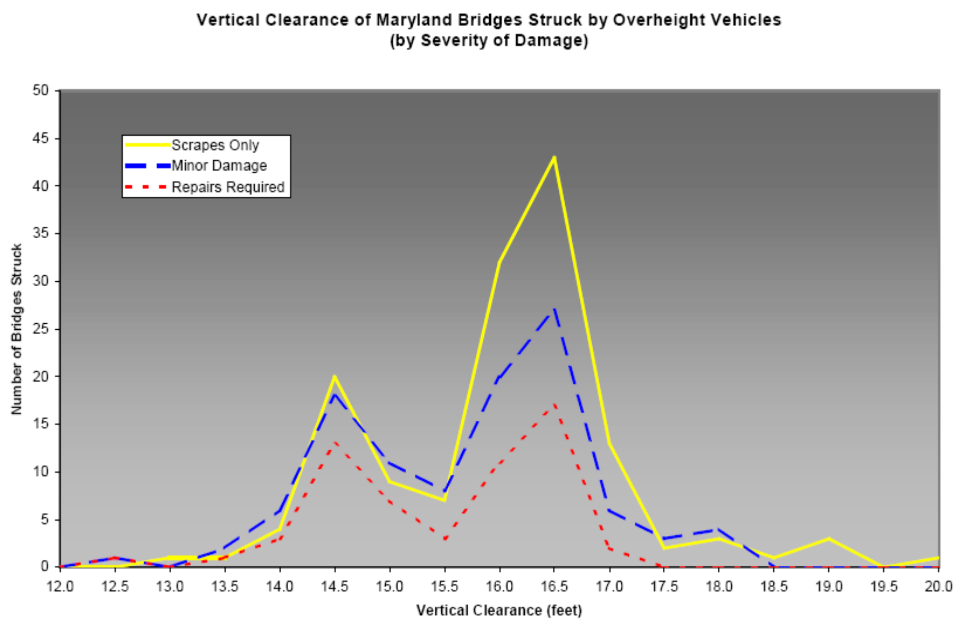


Figure 1-3: Frequency of Recorded Bridge Hits as Related to Vertical Clearance and Damage Extent

Fu (2001) also carried out a detailed survey of 29 states on the severity of the bridge hit problem. The state survey shows that 19 states (out of 29 responding) consider overheight collisions to be a significant problem. However, very few states collect data on the bridge hits. Figure 1-4 shows the map of USA with states considering overheight collision a serious problem shown by red (dark shading), and states not considering overheight collision a problem by green (light shading). It is observed that the states considering overheight collision a problem are: California, New Mexico, Texas, Louisiana, Mississippi, Florida, Georgia, Ohio, Kentucky, Indiana, New York, New Jersey, Maryland, Delaware, Illinois, Iowa, Alaska, Hawaii and Maine.

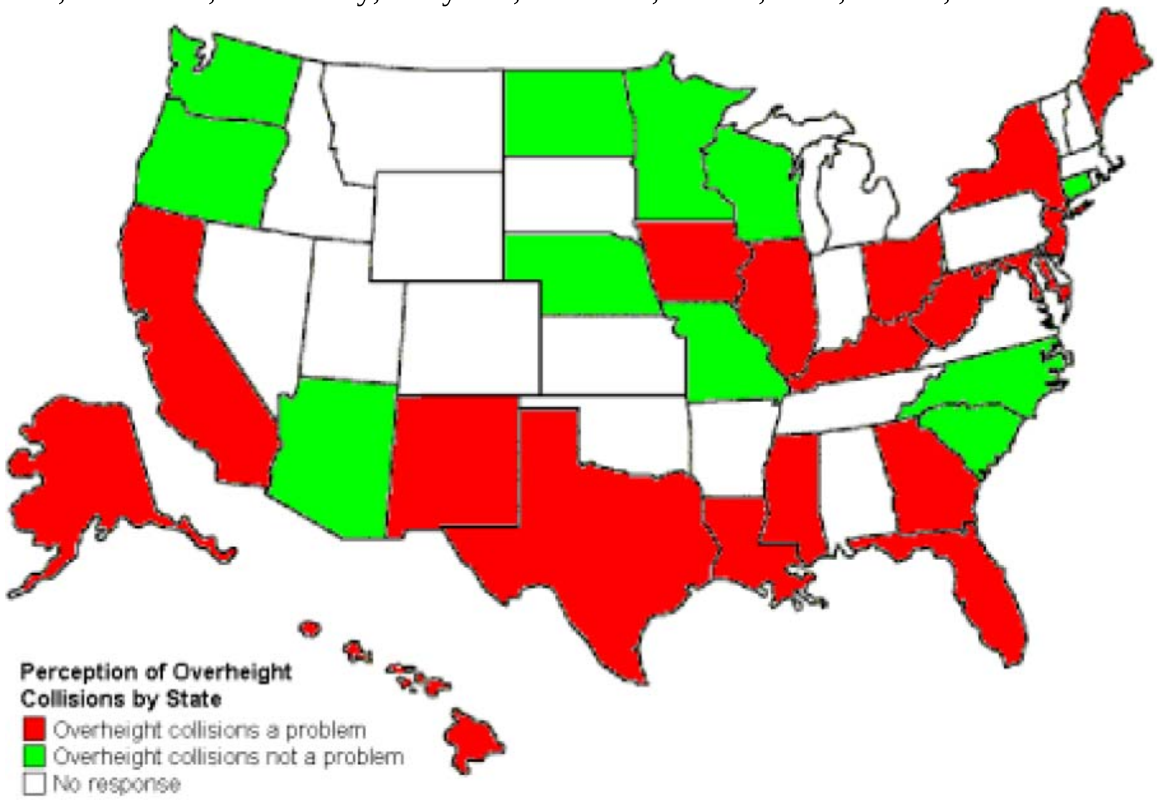


Figure 1-4: Map of USA Showing Perception of Severity of Bridge Hits in Different States.

The nationwide survey by Fu (2001) has documented many observations that are important for the bridge hits problem in New York. These observations are:

- Standard bridge clearances on the National Network[1] range from 16 to 17 feet. Standard clearances range from 14 to 17 feet on bridges off the National Network.
- Some states post the actual vertical clearance on warning signs, while other states under report the clearance by up to twelve inches. For example, New York State posts at 1 feet under when the bridge has a vertical clearance less than 14 feet. This can have negative effects as truckers are likely to ignore clearance signs knowing that clearance are under-reported, depending on the state.
- Most states allow vehicle heights up to 13.5 feet without a permit; a few states allow up to 14.5 feet.
- There is a wide disparity in penalties for overheight violations, with fines ranging from $20 to $1000 between different states.

[1] The National Network includes Interstate Highways and sections of the Federal-Aid Primary System on which large dimension trucks designated under the Surface Transportation Assistance Act (STAA) are authorized to travel.

- Although 17 states maintain records on overheight collisions, only 6 states maintain computerized records. States with a maximum number of overheight collisions (California, Connecticut and Illinois) are among those that maintain computerized records.
- 18 states out of 29 responding to the survey (62%) feel that overheight collisions are a significant problem, 11 out of 29 states (38%) do not.
- On specific actions taken by each state to reduce the frequency of overheight collisions, nine states (31%) reported installing more signs posting clearances on or in advance of bridges. Most felt that these were effective in reducing accidents. Seven states (24%) responded that they had increased vertical clearances by grinding pavement or raising overpasses, and that this was very effective in reducing overheight collisions. In fact, Georgia has a program in place to raise all existing Interstate bridges to clearances over 16' 6". Only three states use overheight detection systems.

Hilton (1973) investigated general accidents involving highway bridges in Virginia to characterize bridges that had been the scene of frequent accidents. "Inadequate vertical clearance" was listed as a key contributing factor. Shanafelt and Horn (1980) reported on damage evaluation and repair methods for prestressed concrete bridge members through a countrywide survey. In response to the survey, state bridge engineers listed overheight loads as the leading cause of damages (81%) to prestressed concrete bridges. Other causes were overweight loads, fire, salt, and water freezing. Shanafelt and Horn (1984) released a similar report on damaged steel bridge members over a 5 year period. They found that 95% of damaged steel bridges were caused by overheight vehicles.

A study by the University of Kentucky in 1990 [Harik et al (1990)] analyzed U. S. bridge failures over a 38 year period (1951-1988). Each collapse was classified by its cause. Of the 79 bridge failures considered in the study, 11 were precipitated by truck collisions (14%).

Some states have recorded a significant rise in the frequency of bridges being hit by overheight vehicles. In 1988, the Michigan Department of Transportation reported a 36% increase in overheight collisions over a one year period [MRC (1988)]. The Mississippi State Highway Department installed overheight warning systems on some rural bridges after an increase in bridge damage by overheight logging trucks [Hanchey and Exley (1990)]. A 1992 study by the Texas Department of Transportation [Feldman et al (1998)] revealed a rise in the occurrence of overheight impact damage to prestressed concrete bridges. They have developed guidelines for assessing the degree of impact damage to prestressed concrete bridge girders and developing repair procedures. These guidelines are drawn from case studies of prestressed concrete bridges damaged by overheight vehicles in Texas. Of the damaged girders inspected, 61% were assessed as having minor damage, defined as isolated cracks, nicks, shallow spalls, or scrapes. Moderate damage, defined as cracks or spalls large enough to expose undamaged prestressing tendons, was found in 25% of the girders. Severe damage, consisting of damaged tendons, significant concrete section loss, or lateral misalignment, made up the remaining 14% of bridges.

Bedi (2000) has examined the reduction in load-carrying capacity of a wide-flange steel girder distorted by a vehicle impact. The girder was modeled with a finite element analysis program. Typical impact damage was simulated by imparting a lateral deformation to the lower half of the cross section. The deflection under vertical loading was compared to that of the undistorted cross section. Under loading, the deformed section underwent further distortion and tended to twist. It was found that the reduction in strength was more than double of that predicted by the section properties alone. These results suggest that the damage to steel girders struck by overheight vehicles may be more severe than previously thought.

El-Tawil et al (2004) performed inelastic transient finite element simulations to investigate the demands generated during collisions between vehicles and bridge piers. Two different bridge/pier systems were used in the simulations. The approach speeds for the trucks range from 55 to 135 kph. Their simulation results show that current collision design provisions could be unconservative and there may be a population of bridge piers that are vulnerable to collapse because of accidental or malicious impact by heavy trucks.

Damages to railway bridges by vehicles passing under such bridges have been investigated extensively in the United Kingdom. Martin and Mitchell (2004) have carried out extensive investigation of various factors leading to vehicular collisions at bridges owned by "National Rail" and developed measures to reduce such damages. Their detailed investigation has identified three main causes of bridge hits in the U.K.:

- Drivers not knowing the height of their vehicles/cargo
- Lack of provisions of alternative routes around low bridges, and lack of planning of routes by haulers
- Inadequate signing at and on the approach to low bridges

In addition to the causes cited above, they have also identified several other factors contributing to bridge strike (hits) in the United Kingdom, including lack of signs, distraction, positioning of signs, driver cognizance and bumpy road conditions. They have observed that almost 75% of the hits occur at plate girder bridges. They have investigated and proposed several approaches to reduce bridge strikes, such as:

- Driver education
- Accurate vehicle height measurements
- Alternative route symbols
- Infra-red detection systems
- Database of low bridges
- Enforcement cameras
- Driver training and behavior observation by simulation
- In-cab alerting systems (GPS)
- Improvement in signing

Horberry et al. (2002) have experimentally evaluated a new design of markings for low bridges to prevent bridge hits. In order to carry out the study, they constructed a full size bridge capable of having its overhead clearance adjusted. Subjects (test divers) sat in a truck cab as it drove towards the bridge and were asked to judge whether the vehicle could pass safely under the bridge. The objective of their study was to investigate the effectiveness of new markings versus old markings[2] (See Fig. 1-5) in preventing a truck impacting a bridge. In their experiment, they measured the effectiveness by asking the subject drivers at 100 m, 30 m and 8 m from the bridges with two markings whether they would safely cross under the bridge or not. Figure 1-6 shows the outcome of the study. In Figure 1-6, A, B and C represent decision making by the drivers at distances 100 m, 30 m and 8 m. The mean score of 1 represents that the drivers thought they will definitely hit the bridges. It is observed from Fig. 1-6 that the new markings

[2] These markings aren't in the Federal MUTCD and are commonly used in the United Kingdom.

helped drivers achieve scores closer to 1 than those by the old markings. Hence, the type of bridge marking influenced the level of caution associated with decisions regarding bridge navigation, with the new marking design producing the most cautious decisions at all distances away from the bridge structure. Additionally, the distance before the bridge at which decisions were given had an effect on the level of caution associated with decisions regarding bridge navigation (the closer to the bridge, the more cautious the decisions became, irrespective of the marking design).

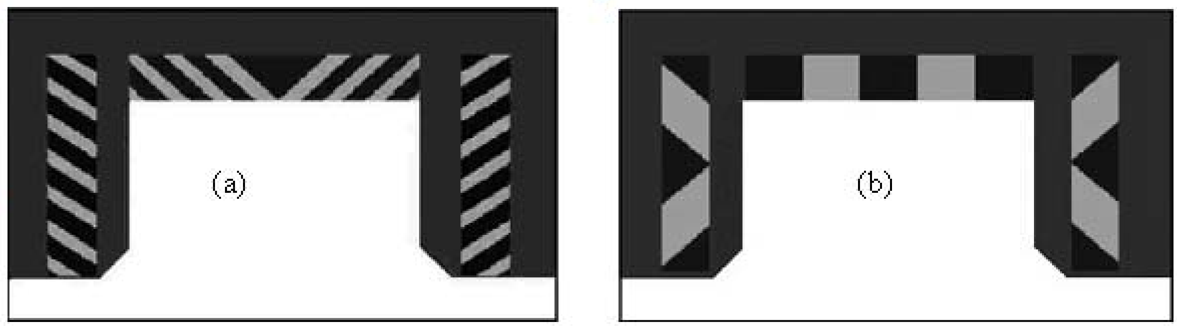


Figure 1-5: Design of Markings Used in Experimental Study by Horberry et al. (2002); (a) Old Marking, (b) New Marking.

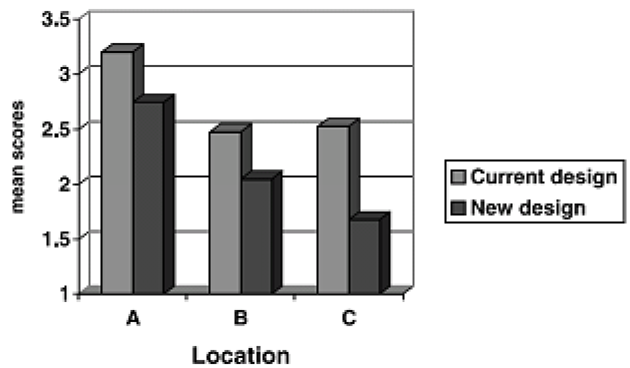


Figure 1-6: Effects of Two Markings in Decision about Bridge Heights from 100 m (Case A), 30 m (Case B) and 8 m (Case C)

Mattingly (2003) has investigated the use of overheight warning systems to mitigate overheight vehicle crashes into bridges through a nationwide survey of State DOTs. The prime focus of the survey has been on early warning detection warning systems (EWDS), e.g., laser systems, infrared systems, etc. Out of forty-nine State DOTs surveyed, 29 State DOTs responded to the survey. Thirty-eight percent of the responding states (i.e., 11 states) indicated the use of EWDs. Table 1-1 below shows types of EWDs used by these 11 states, their manufacturers and initial costs. Although there is a lack of definitive effectiveness of EWDS based on this survey, the use of these devices certainly results in reduction of bridge hits. Figure 1-7 shows the perception on overall effectiveness of EWDs based on survey results in Table 1-1. It is observed from Figure 1-7 that eight out of eleven states using EWDs believe their systems reduce overheight vehicles striking bridge components. Among three states reporting “slight reduction” in 4th column of Table 1-1, two states actually used passive systems (chains or headache bar). Based on this survey, laser and infrared systems appear to successfully reduce bridge impacts. However, these systems still suffer from operational issues. For example, DOTs experience false detections from antennas, debris, birds, and snow deposits on the top of trucks. Additionally, some DOTs experience hunters sighting their weapons on receivers (aiming and/or shooting the receivers), and occasionally the laser moves and comes out of alignment with the detector. The one state that used battery power for its system encountered significant problems. However, states that use laser and infrared detection systems appear to value the reduction in impacts regardless of the small operational difficulties that they experience. Table 1-2 shows options available to Alaska DOT on various types of EWDS. Chapter 2 of this report focuses on the use of EWDS and their reliability through more focused vendor surveys, DOT survey and several site visits of states using them.

Table 1-1: Survey of States by Mattingley (2003) on Early Warning Detection System.

State	Manufacturer	WEDS Used	System Affect on Impacts	Initial Cost
Kansas	Elwood	Laser system	Reduction	$500 + labor
Iowa	In House	Chains	Slight reduction	N/A
New York	In House	Headache bar	Slight reduction	N/A
Oregon	IRD	Laser system	Reduction	$32,000
Idaho	IRD	Laser system	Reduction	$65,000
Pennsylvania	IRD	Laser system	Reduction	Unavailable
Florida	In House	Light beam	Reduction	Unavailable
Louisiana	IRD	Laser system	Reduction	Unavailable
Mississippi	Unavailable	2 EWDS	Slight reduction	Unavailable
Maryland	Unavailable	Light beam	Reduction	50,000
California	IRD, Trigg	Laser system	Reduction	10,000-20,000 + Labor

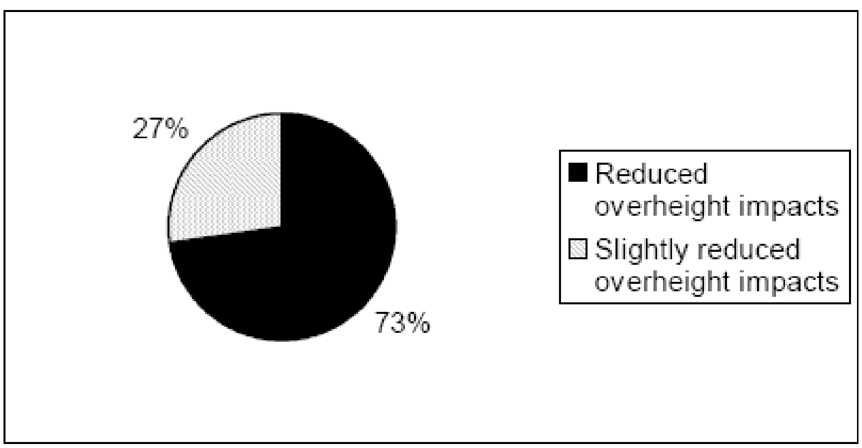


Figure 1-7: Effectiveness of EWDS through State’s Survey by Mattingly et al. (2003).

Table 1-2: Comparisons of Options Presented to Alaska DOT to Reduce Bridge Strikes [Mattingly et al. 2003]

Solution	*Power Req'd*	*Initial Cost*	**Assessed Effectiveness**	**Problems**
Warning signs and lights	Yes	Low	Unknown	Unknown
Passive-rigid	No	Low-Mod.	Slight reduction	Possible damage to truck and other nearby vehicles
Passive-nonrigid	No	$ 2-35K	Slight reduction	Inaudible over road noise for drivers
Laser/Infrared w/signs	Yes	$7-70K	Reduction	False positives
Enforcement/Penalties	No	Unknown	Unknown	Unknown
Police Escort	No	Unknown	Unknown	Still prone to human error

1.3. REVIEW OF NYSDOT BRIDGE HITS DATABASE

NYSDOT provided a bridge hits database containing information on 1345 reported bridge hits for hits till August 2011. The database contains the following fields: BIN (Bridge Identification Number), Span, Region, County, Carried Over, Crossed, Date of Collision, Damage, Comments, Collision Class, and Collision Rating. Several of the records only had feature carried over and feature crossed, without any BIN information. The New York State DOT bridge inventory database was used to augment other relevant tables, such as AADT, vertical clearance under, necking[3], feature carried under, etc. into the bridge hit database so that a detailed study on the effects of different factors on bridge hits could be carried out. Bridge hit data from the New York City region was provided by Dr. Yanev of NYCDOT. This data was integrated with the NYSDOT database to provide a detailed statistical analysis. The database doesn't include hits on bridges owned by the New York State Thruway Authority. The combined database has a total of 2031 records. Fatality Analysis Reporting System (FARS) and the Federal Motor Carrier Safety Administration (FMCSA) databases were also searched to identify additional information on bridge hits. However, the search of these two databases didn't yield any new bridge hit data.

A detailed analysis of bridge hits in New York State using this database is presented below.

1.3.1. BRIDGE HITS BY YEAR

Figure 1-8 shows a histogram that details the number of reported bridge hits in New York between 1993 and 2011. It is observed from Figure 1-8 that the number of reported annual bridge hits increased from 69 to 219 during 2001 to 2005, and was steady during 2005 to 2008. The number has declined significantly after 2009 (data shown for 2011 is only partial). However, the number of total annual hits has been varying. The increase in bridge hits during 2001 to 2007 may be linked to the increased construction activity because of the real estate boom during this period. Increase in bridge hits data may also be attributed to better record keeping practice that NYSDOT started implementing after 2001.

[3] Necking is defined as the difference between curb-to-curb width and the approach width.

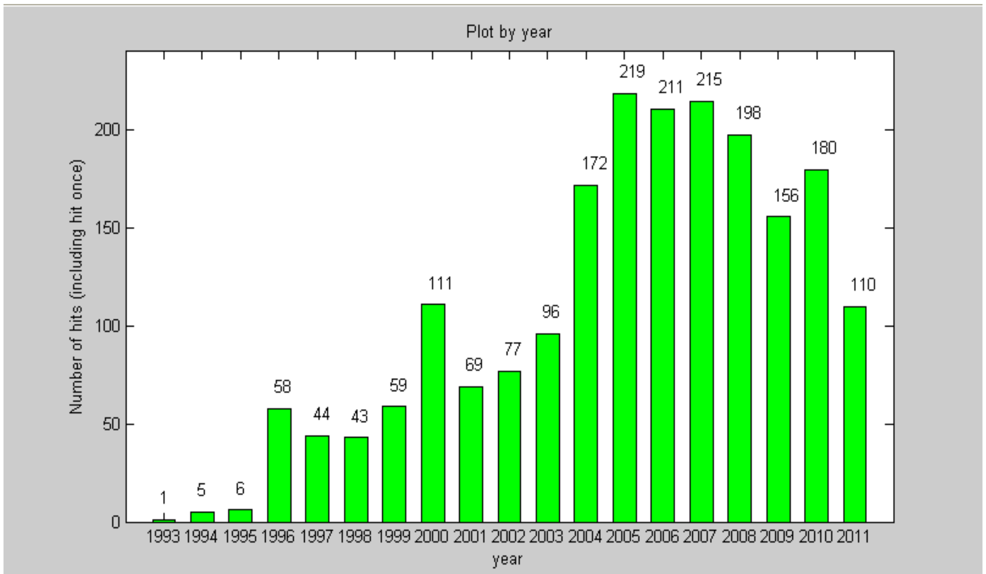


Figure 1-8: Number of Recorded Bridge Hits by Year (New York State).

1.3.2. BRIDGE HITS BY NYSDOT REGIONS

Figure 1-9 shows a GIS map of New York State with the 11 NYSDOT Regions. Bridge hits in each of the Regions are shown as blue dots as well as number written below the region name. Figure 1-10 shows the histogram of number of bridge hits by NYSDOT Regions. It is observed from Figure 1-9 and 1-10 that Regions 8, 10, 5 and 11 have 856, 415, 213 and 256 bridge hits and these four Regions account for approximately 85.7% of the total bridge hits in the state between 1993 and 2011 periods. In fact, bridge hits in Region 8 (Poughkeepsie) are significantly higher than other Regions because of significant agricultural and commercial activity in the area as well as Region 8's proximity to New York City. For Regions 8 and 10, there are more bridge hits in areas close to New York City. Similarly, there are more bridge hits near the Canadian border in Region 5.

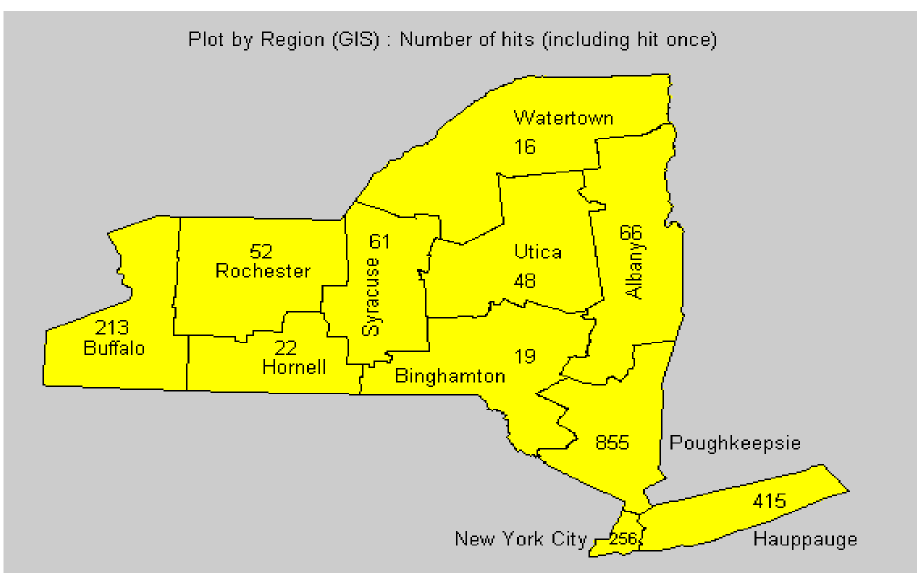


Figure 1-9: Number of Reported Bridge Hits in each NYSDOT Region.

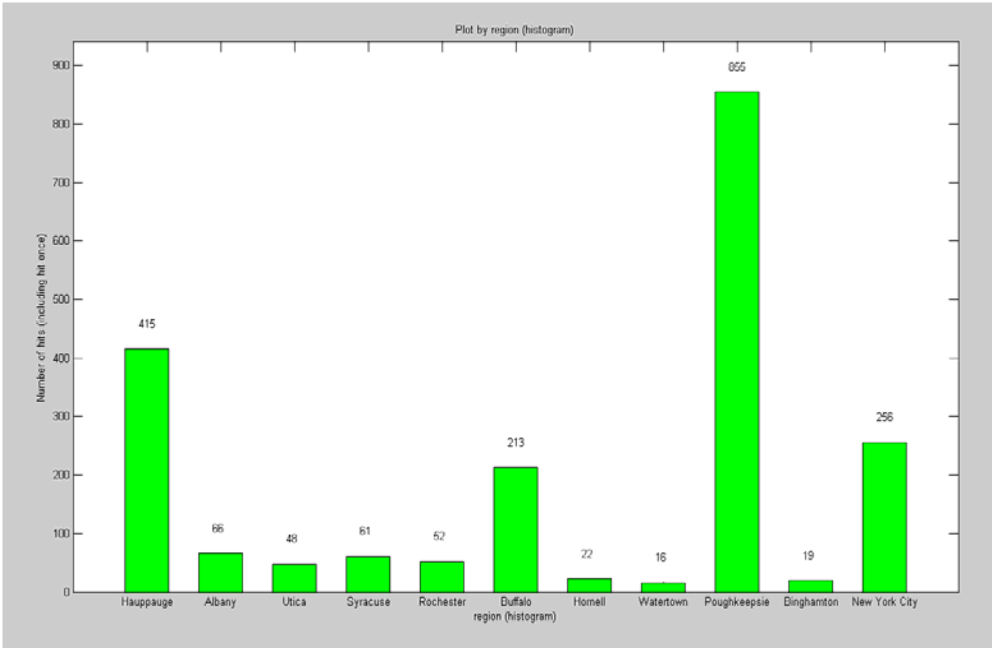
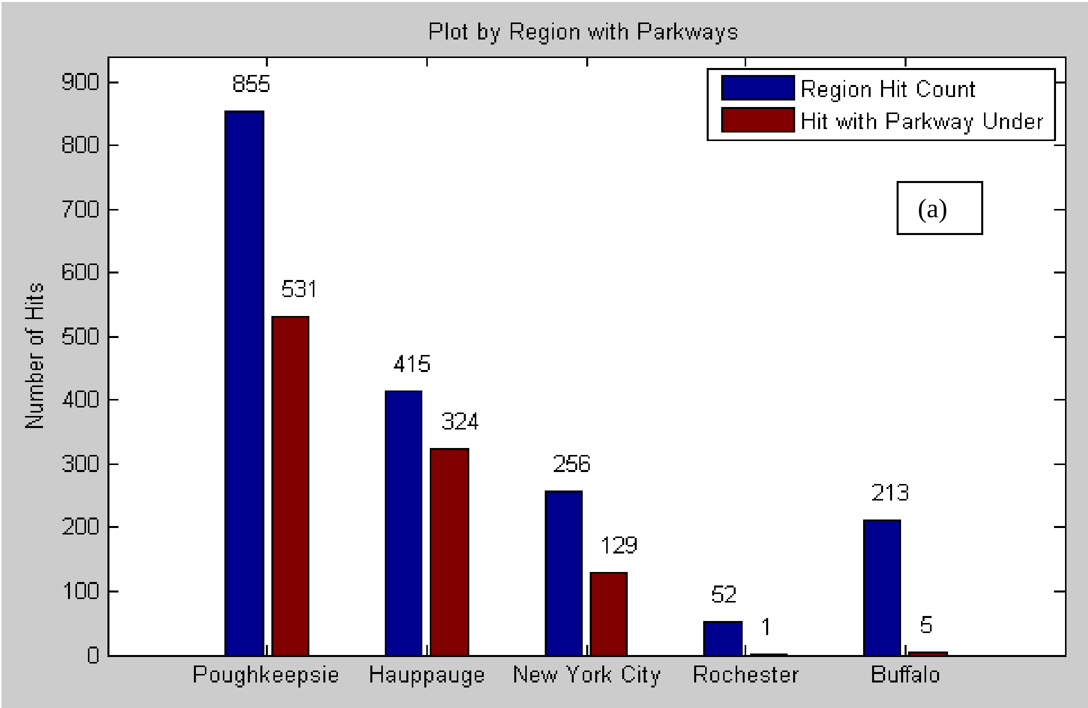


Figure 1-10: Number of Recorded Bridge Hits in Each of the NYSDOT Region.

Figures 1-11(a) and 1-11(b) show histograms of bridge hits by NYSDOT Regions with and without parkways. Figure 1-11(a) show histograms of Regional bridge hits and hits on bridges with parkways under for Regions 4 (Rochester), 5 (Buffalo), 8 (Poughkeepsie), 10 (Hauppauge) and 11 (New York City). It is observed from Figure 1-11(a) that the presence of parkways contribute significantly to bridge hits. In fact, 324 out of 415 hits in Region 10 are on bridge over parkways. On the other hand, number of hits on bridges in Regions without parkways is significantly lesser with Region 1 (Albany) having 66 hits, as shown in Figure 1-11(b).

Figures 1-12(a) and 1-12(b) show the number of bridges hit multiple times and the total number of multiple hits (i.e., number of bridges hit multiple times multiplied by the number of hits on each bridge) by NYSDOT regions. It is observed that Regions 8, 10 and 5 have 77, 53, & 17 bridges, respectively, that have been hit multiple times. In Region 8, 77 bridges have been impacted a total of 742 times, i.e., the multiple hit per bridge frequency is approximately 9.64. This frequency is 6.4 and 10 for Regions 10 and 5, respectively. High multiple hit per bridge in Region 8 is attributed to higher number of parkways passing through Region 8. A much higher multiple hits per bridge in Buffalo area can be attributed to the presence of significant trucking activity around the bridges hit multiple times.



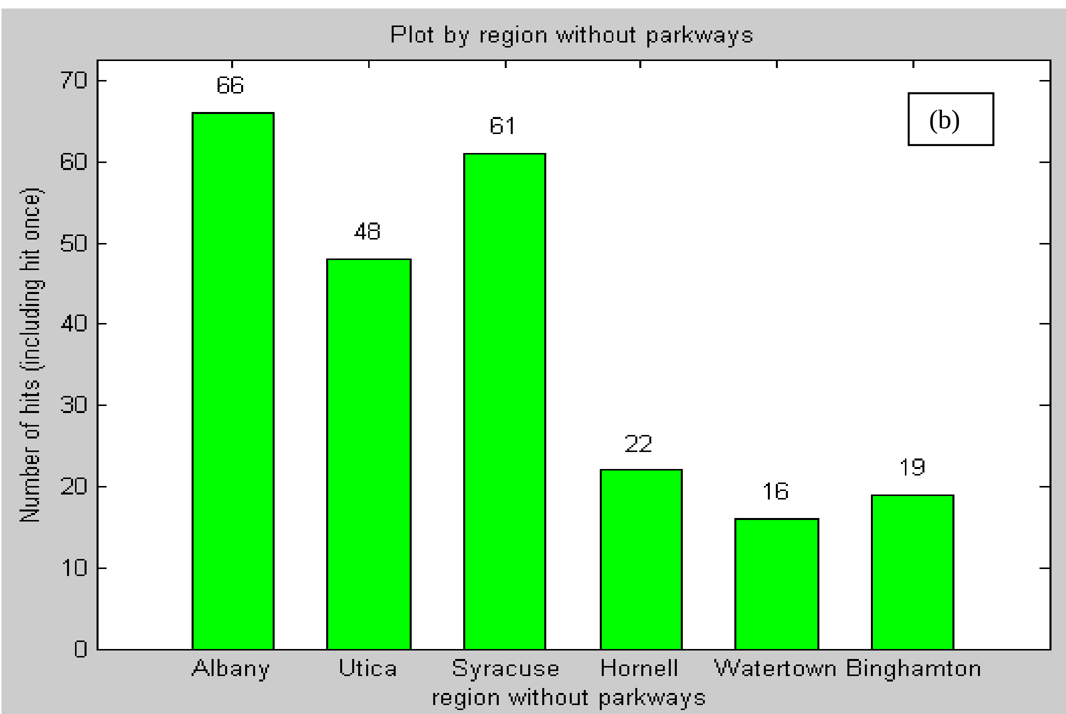
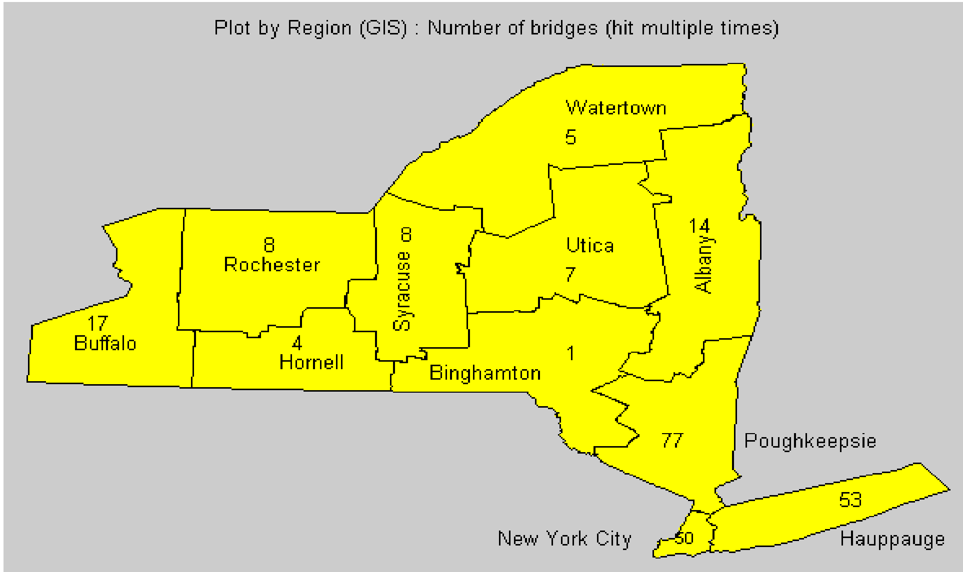
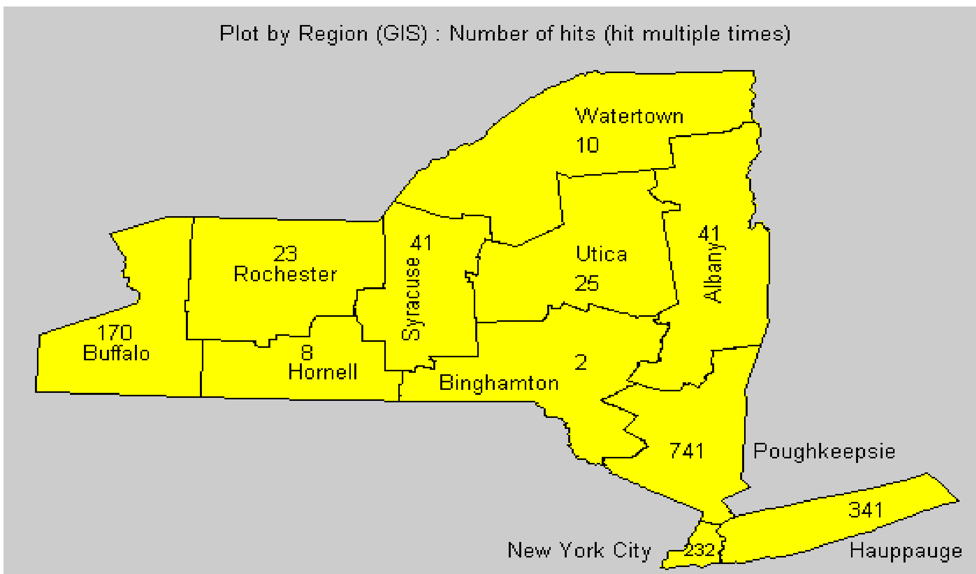


Figure 1-11: Number of Recorded Bridge Hits during 1995-2011 in NYSDOT Regions; (a) Regions with Parkways, (b) Regions Without Parkways.



(a) Number of Bridges Hit Multiple Times



(b) Hit Counts on Bridges Hit Multiple Times

Figure 1-12: NYSDOT Multiple Bridge Hit Demographics.

1.3.3. BRIDGE HIT BY COUNTY

Figure 1-13 shows histograms for the number of reported bridge hits by county. Figure 1-13(a) shows the histogram for all reported bridges hits. It is observed from Figure 1-13(a) that Westchester County has the maximum number of reported bridge hits and is followed by Nassau, Erie, Suffolk and Rockland counties. Figure 1-13(b) shows the number of multiple bridge hits by county. Note that a majority of bridge hits recorded in the five counties noted above are a result of bridges being impacted multiple times. In fact, in Westchester, Erie and Nassau counties, 33 bridges have been impacted 837 times (41.2% of all recorded hits in the New York State) out of a total of 1088 bridge hits recorded in these counties (See Figure 1-13(c)).

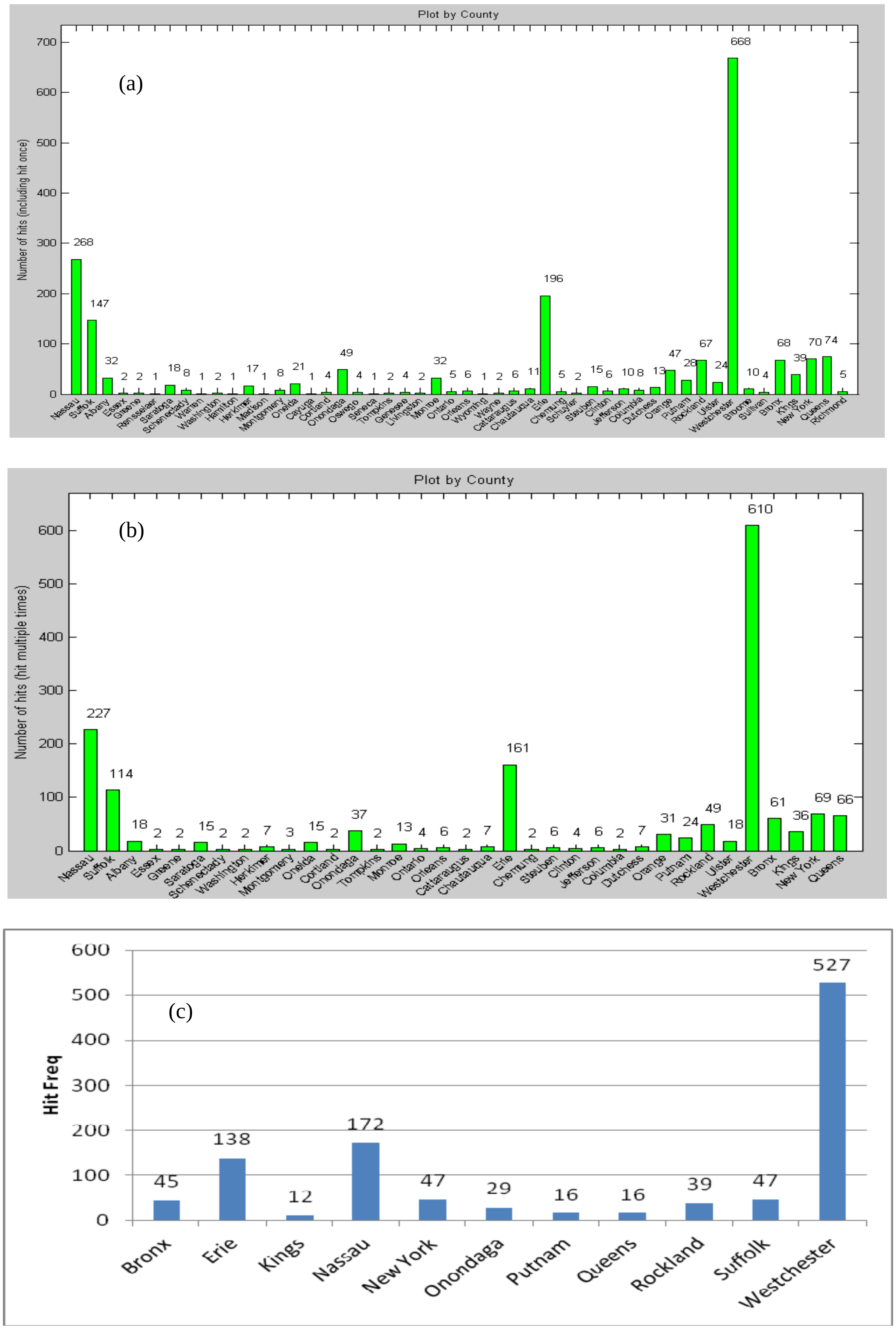


Figure 1-13: Number of Recorded Bridge Hits by County; (a) Considering All Bridges Hits; (b) Considering Multiple Bridge Hits Only; (c) Considering Multiple Bridge Hits by 55 Most Hit Bridges.

1.3.4. FEATURE CARRIED ON THE BRIDGE

Figure 1-14 shows a histogram of the number of reported bridge impacts plotted as related to the type of roadway the bridge is over. Note that bridges carrying local roads (County, Town, City, and Village) have been subjected to a total of 826 impacts. Bridges carrying state highways had 401 recorded impacts and bridges carrying railroads had 284 recorded impacts.

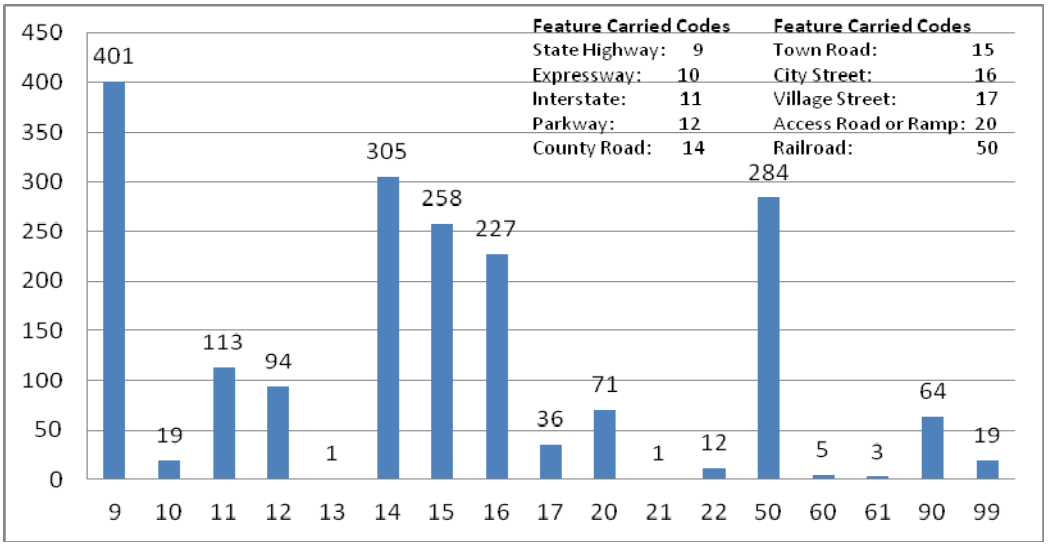


Figure 1-14: Number of Recorded Bridge Hits as Related to the Feature Carried.

1.3.5. FEATURE CARRIED UNDER THE BRIDGE

Figure 1-15 plots the number of recorded bridge hits as related to the type of roadway the bridge is over. It is observed that, of 2031 recorded bridge hits, 990 hits occurred on bridges over parkways, 401 on bridges over state highways, 200 on bridges over city streets, and 204 on bridges over interstates. Since trucks are not allowed on parkways, the large number of hits on parkways clearly indicates the presence of unauthorized trucks on parkways. A high number of hits on bridges over state highways and city streets may be a result of many impacts to railroad and other low clearance bridges.

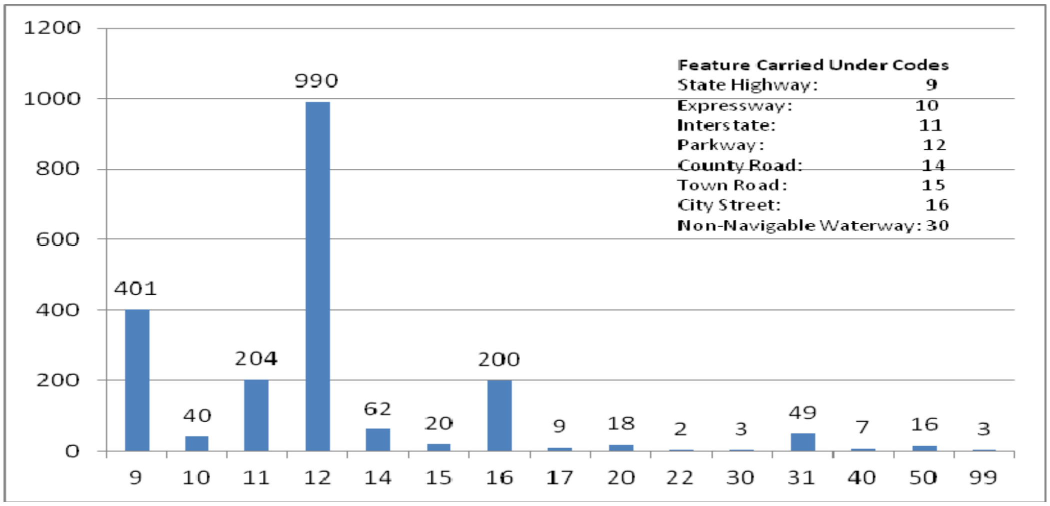


Figure 1-15: Number of Bridge Hits by Feature Carried Under the Bridge.

1.3.6. BRIDGE HITS BY SUPERSTRUCTURE DESIGN TYPE

Figure 1-16 shows the number of reported bridge hits by the superstructure design type. Note that bridges with frame type superstructure have been experiencing the highest number of recorded impacts. A large number of these bridges are over parkways or carry railroad traffic. Other design types that are impacted frequently are rolled beam with multi-girder, plate girder with multi-girder, deck arch with closed spandrel and plate girder-thru with floor beam.

1.3.7. BRIDGE HITS BY BRIDGE COMPONENT HIT

Figure 1-17 shows components of bridges that are impacted most frequently during recorded bridge hit events. The histogram in Figure 1-17 is based on limited observed data in the NYSDOT bridge hits database. It is observed that frame and girders are the most frequently hit components, which are similar to those in Figure 1-16. Deck arch and piers are the next most hit components.

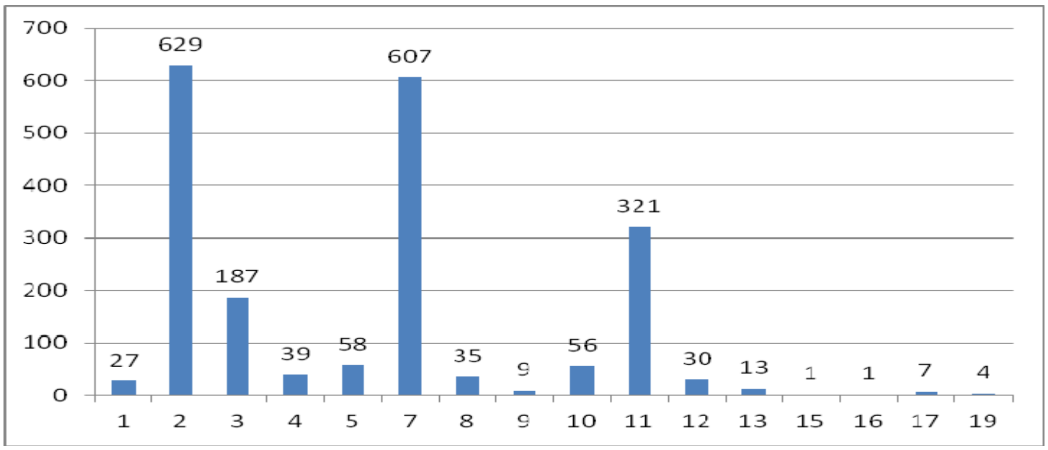


Figure 1-16: Number of Recorded Bridge Hits as Related to the Superstructure Design Type.

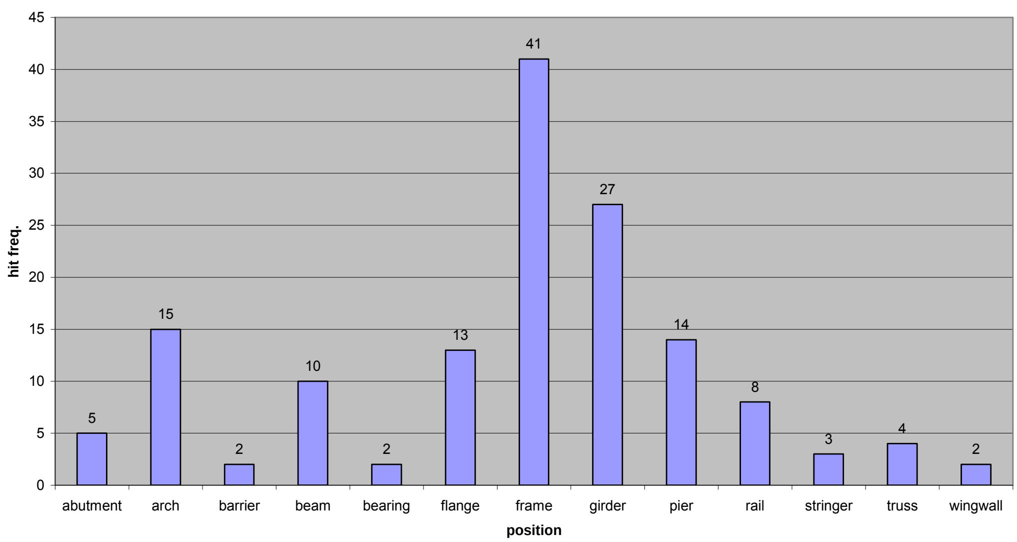


Figure 1-17: Number of Recorded Bridge Hits as Related to Bridge Element Type (Based On Limited Observations).

1.3.8. BRIDGE HITS BY MAXIMUM VERTICAL CLEARANCE UNDER

Figure 1-18 plots the number of recorded bridge hits as they relate to the maximum vertical clearance under the bridge. Note that a majority of bridge impacts occurred on bridges with a maximum vertical under-clearance in the range of 12 to 15 feet with peaks at 13 and 13.5 feet. Several bridges with vertical clearance greater than 15 feet have also been hit. Figure 1-19 plots the number of bridge hits as they relate to the maximum vertical clearance for bridges hit multiple times. It is observed that the peaks in Figures 1-18 and 1-19 are at identical vertical clearances and the frequencies of hits in Figure 1-19 are more than 85% of those in Figure 1-18. This clearly shows that the vertical clearance is one of the most dominant factors responsible for bridges being hit multiple numbers of times. This fact must be accounted for when considering any modifications to the collision vulnerability assessment procedure for bridges in New York.

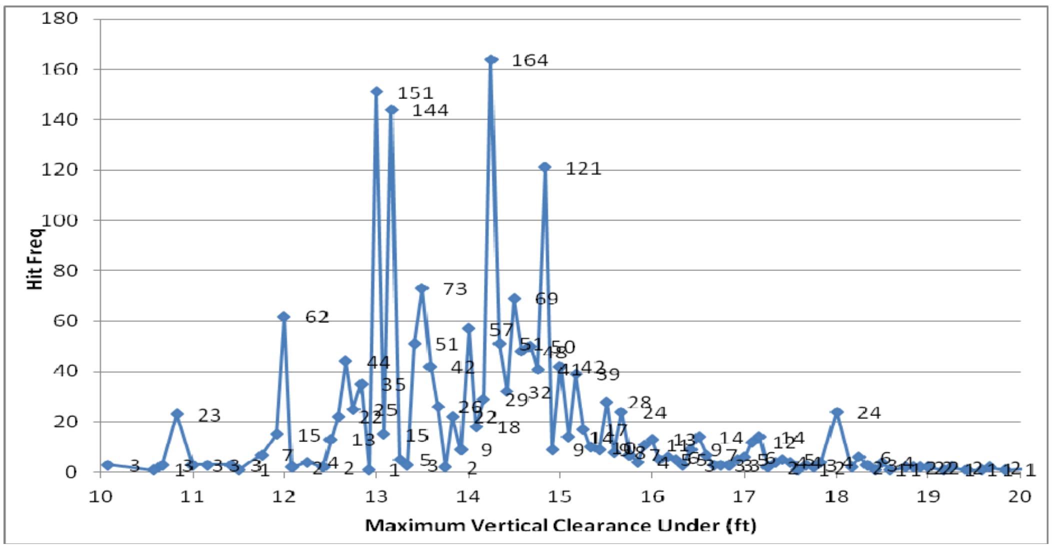


Figure 1-18: Maximum Number of Recorded Bridge Hits for the Maximum Vertical Under-Clearance.

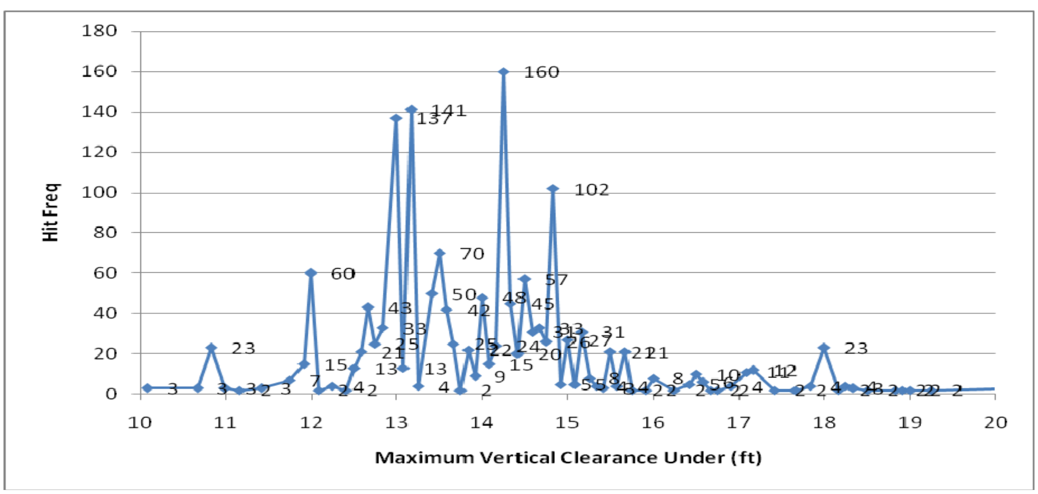
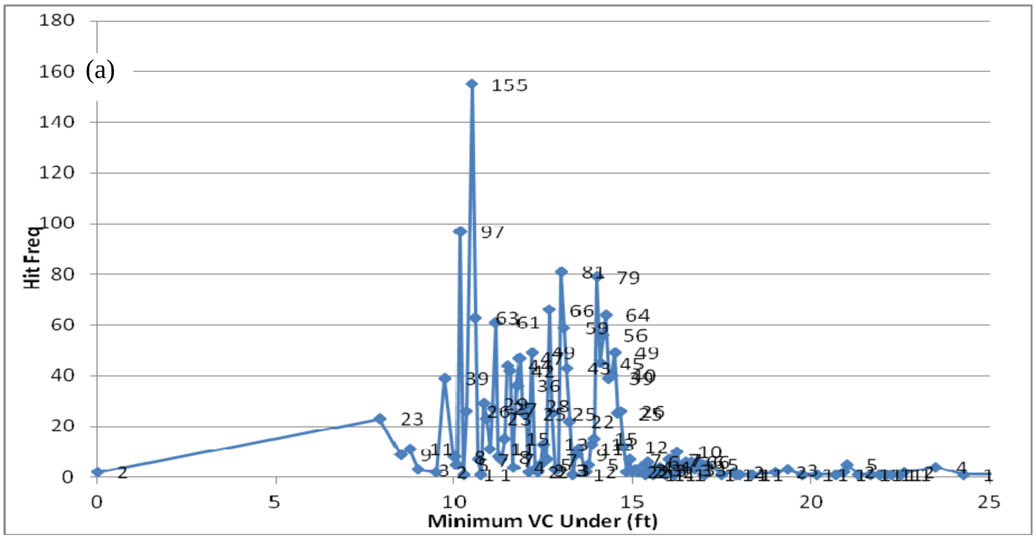


Figure 1-19: Maximum Number of Recorded Bridge Hits for the Maximum Vertical Under-Clearance (Bridges with Multiple Hits).

1.3.9. BRIDGE HITS BY MINIMUM VERTICAL CLEARANCE UNDER

For a highway bridge, minimum vertical clearance is defined as the minimum clearance between the lowest permanent overhead obstruction and a point on the pavement which is directly below it. Figure 1-20(a) plots the number of reported bridge hits as they relate to the minimum vertical clearance. Note that the frequency of bridge hits is the most prominent for minimum vertical under-clearance less than 15 feet. The largest incident of bridge impacts has been noted at about a minimum vertical clearance of 10.5 feet. Figure 1-20(b) plots the number of reported bridge hits as they relate to the minimum vertical clearance for bridges that have been hit multiple times. Note that the trend and distribution of hit frequencies in Figure 1-20(b) are almost the same as those in Figure 1-20(a). This observation implies that the minimum vertical clearance contributes to the increased risk bridges being hit multiple times.



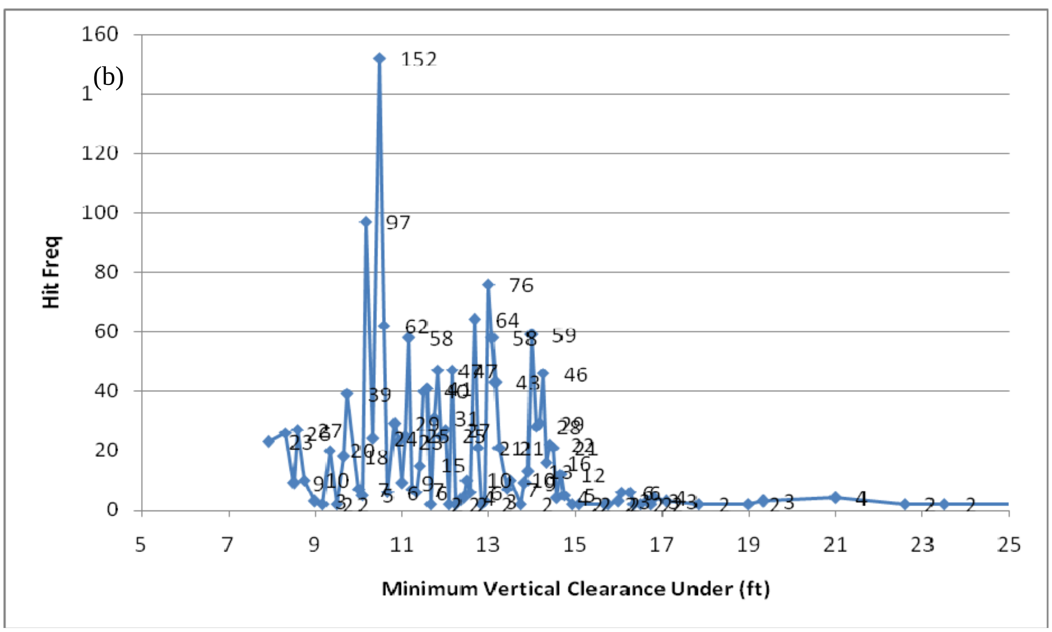


Figure 1-20: Number of Recorded Bridge Hits as Related to the Minimum Vertical Clearance: (a) For All Bridge Hits, (b) For Bridges with Multiple Hits.

1.3.10. BRIDGE HITS BY POSTED VERTICAL CLEARANCE UNDER

Table RC06 of the NYSDOT bridge inventory database provides information on vertical clearance posting for the roadway passing under the bridge. If the roadway is not posted, this item is left blank. Figure 1-21 plots the number of reported bridge hits for the reported “Posted Vertical Clearance Under”. It is observed that the incidence of bridge hits has been observed to mostly occur mostly for vertical clearances in the range of 9 to 12.5 feet with a peak number amount of impacts between 9 to 10 feet. Based on a recent site visit to bridges in the Buffalo area by the PI, bridges in these clearance ranges seem to be hit multiple times because of their proximity to areas of extensive trucking activity. Most of these bridges are also railroad bridges or bridges over parkways with low vertical clearances.

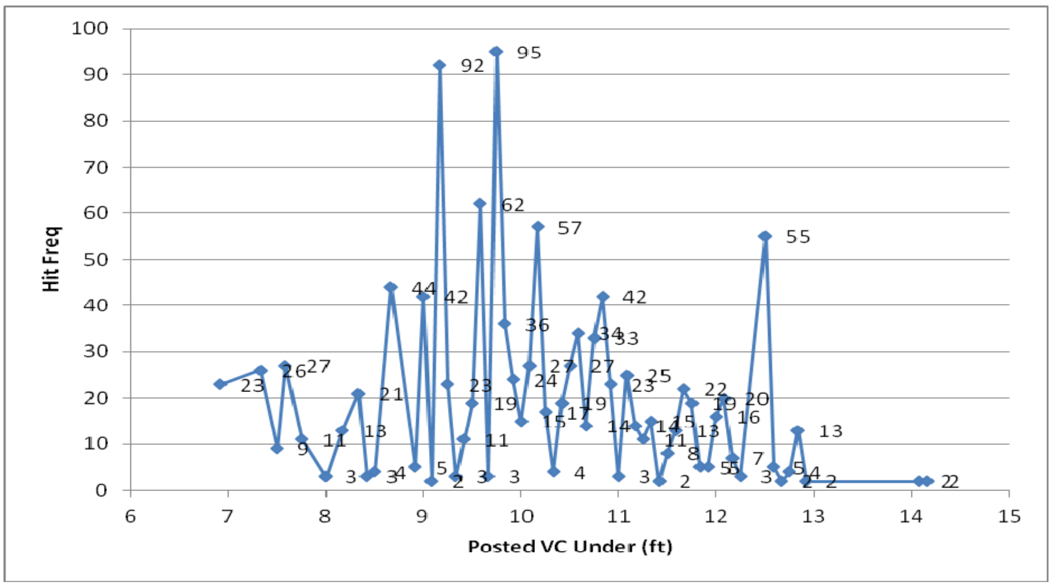


Figure 1-21: Number of Reported Bridge Hits as Related to Minimum Vertical Clearance for Bridges with Multiple Recorded Hits.

1.3.11. BRIDGE HITS BY VEHICLE AND CARGO TYPES

Figure 1-22 plots the number of reported bridge hits as related to the vehicle type. Note that the maximum numbers of hits are caused by trailer and trucks with some accidents caused by construction vehicles. Figure 1-23 plots the number of reported bridge hits as related to the vehicle cargo type. Vehicles carrying construction equipment, fence posts, garbage and modular homes have been found to be hitting bridges frequently. It should be noted that the histograms are based on a limited number of recorded comments in the NYSDOT bridge hits database.

1.3.12. BRIDGE HITS AND ASSOCIATED BRIDGE SAFETY ASSURANCE (BSA) RATINGS

The New York State Department of Transportation (NYSDOT) BSA ratings are used to identify bridges according to their vulnerability to collisions. The procedure for determining BSA classifications and ratings can be found in the NYSDOT Collision Vulnerability Manual located at https://www.nysdot.gov/divisions/engineering/structures/manuals/collision.

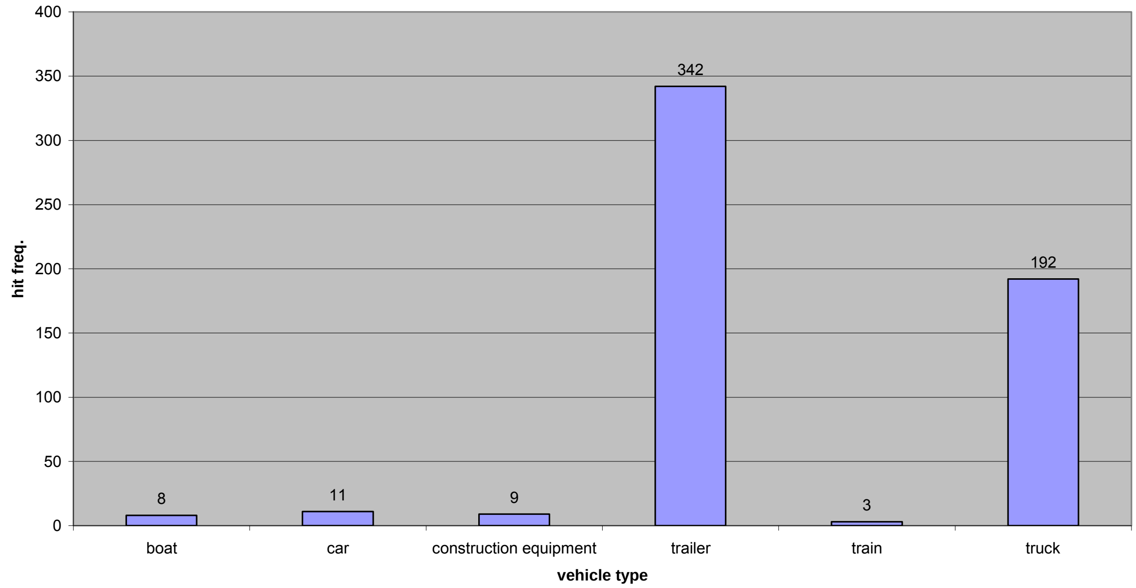


Figure 1-22: Maximum Number of Reported Bridge Hits for the Vehicle Type.

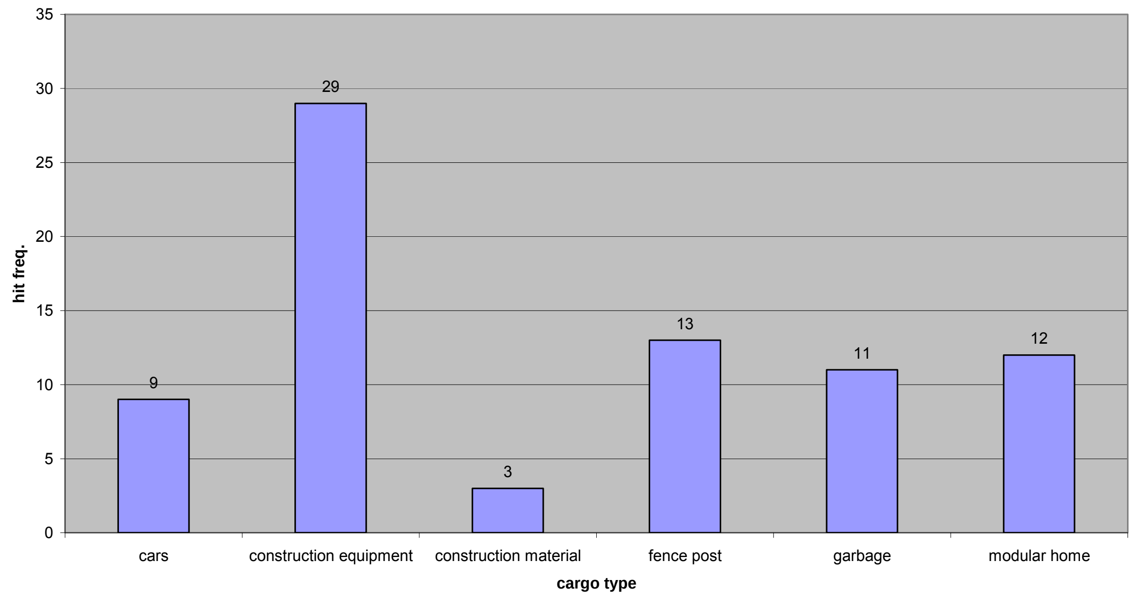


Figure 1-23: Maximum Number of Reported Recorded Bridge Hits for the Cargo Type.

Based on the collision vulnerability analysis, bridges are classified into High (H), Medium (M), Low (L) and not vulnerable (N) vulnerability classes. Figure 1-24 shows a histogram of the number of reported bridge hits as related to the vulnerability classes. Note that a large number of bridges in class N (not vulnerable) have been hit by vehicles. These bridges are most likely on parkways. Likewise, 396 bridge hits have been on bridges classified as L (Low).

NYSDOT assigns Collision Vulnerability Ratings of 1 to 6 based on their detailed collision vulnerability assurance assessment procedure. These ratings are assigned with a goal to prioritize safety/capital retrofit/inspection programs and are assigned as follows: Safety Program Watch:1, Safety Program Alert:2, Capital Program Action:3, Inspection Program Action: 4, No Action: 5 and Not Applicable: 6. Figure 1-25 shows a histogram of the number of reported bridge hits as related to the Collision BSA Rating.

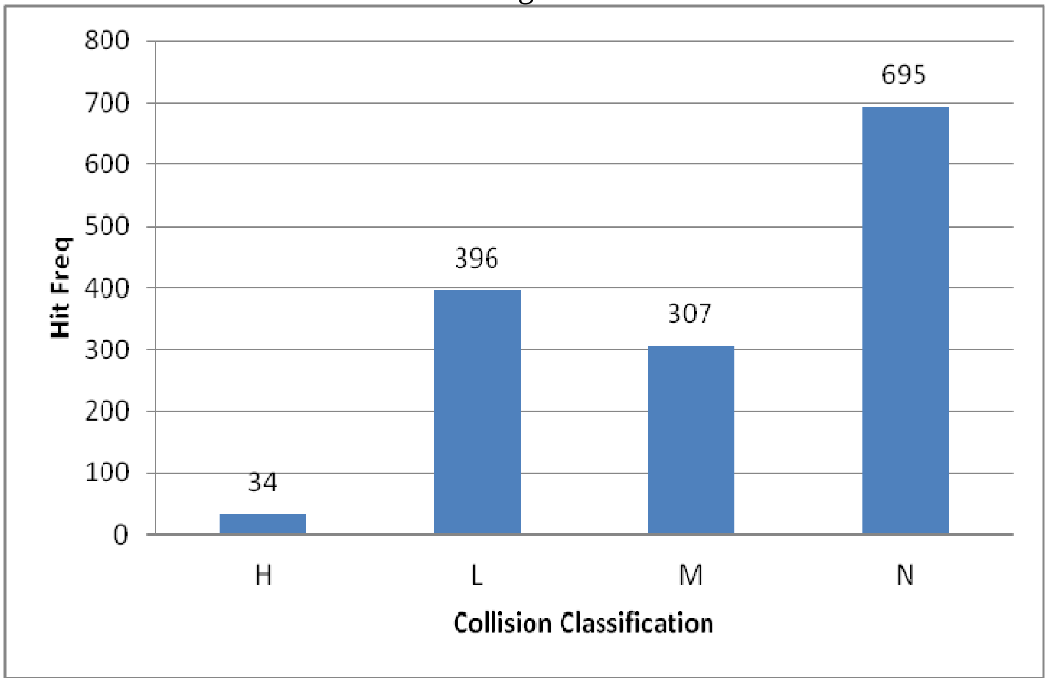


Figure 1-24: Number of Reported Bridge Hits as Related to the NYSDOT BSA Collision Vulnerability Class.

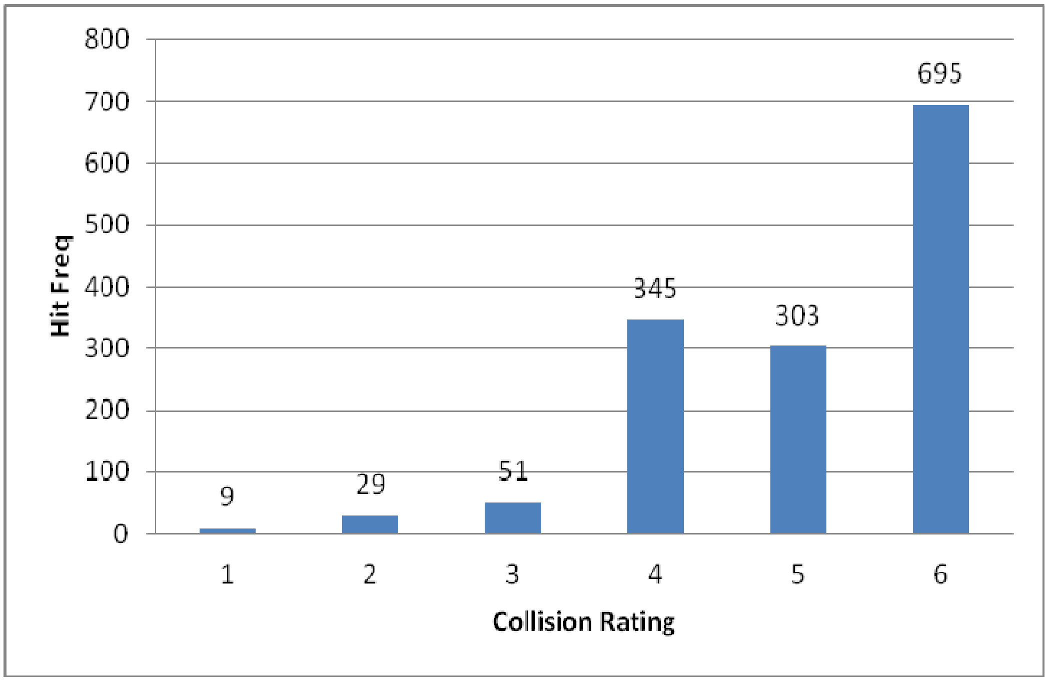


Figure 1-25: Number of Reported Bridge Hits as Related to the NYSDOT BSA Collision Rating.

Note that a majority of the bridges that have been hit have been assigned a collision rating of 6 (not applicable). This may be because parkways are not allowed to have truck traffic, although a large number of bridges on parkways have been hit. Also note that a significant number of bridges with collision ratings of 4 and 5 have been hit. A large number of bridges with these ratings may be railroad bridges. Hence, the current CVA procedures have to be reviewed and revised so that bridges susceptible to collision are assigned appropriate ratings.

1.3.13. BRIDGE HITS BY NECKING

Necking is defined as the difference between curb-to-curb width and the approach width beneath a bridge. Hence, a negative value of necking will indicate a smaller curb-to-curb width at the structure as compared to the approach width. Figure 1-26 (a) shows the number of reported bridge hits as related to necking. Figure 1-26 (b) shows the number of reported bridge hits as related to necking for bridges that have been hit multiple times.

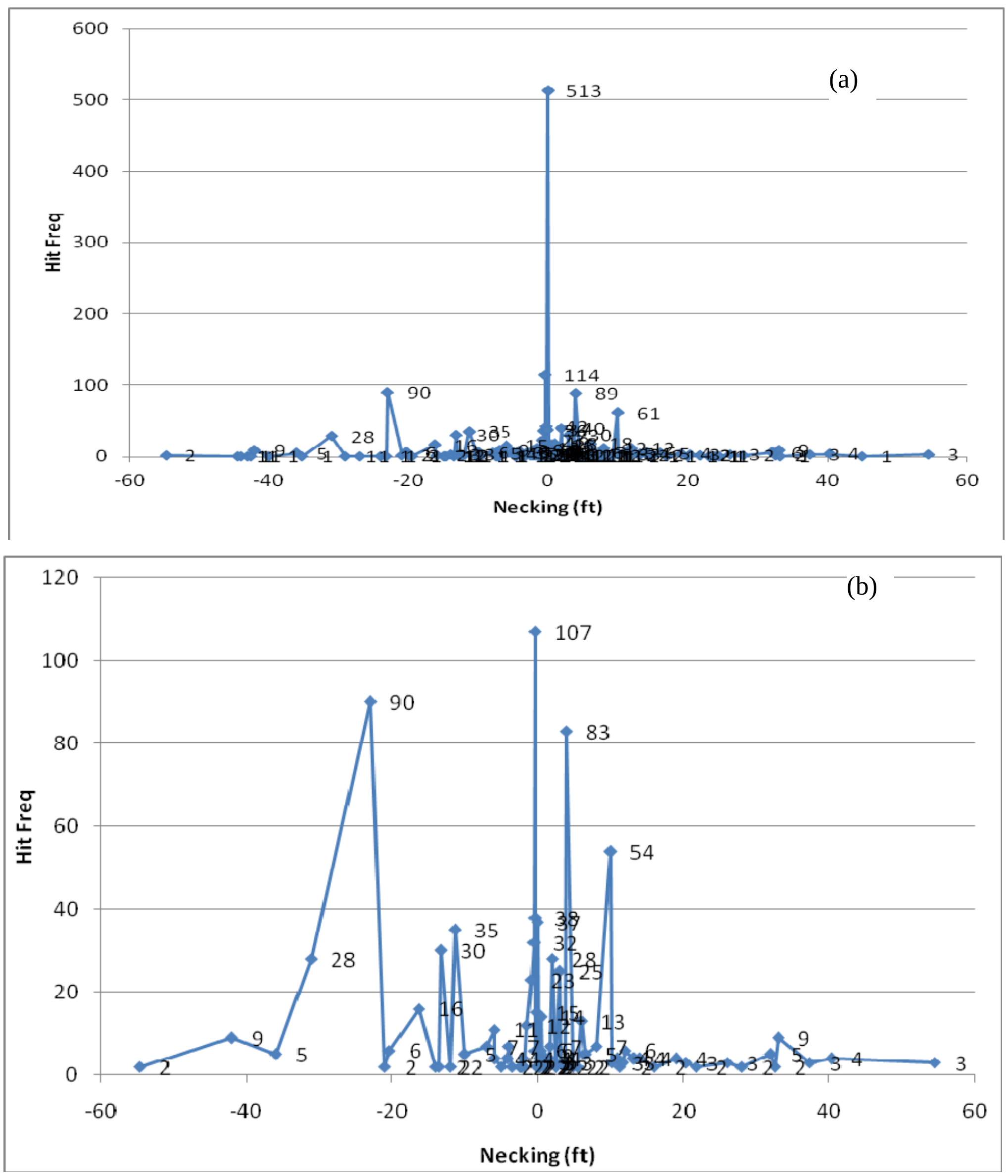


Figure 1-26: Number of Reported Bridge Hits as Related to Necking: (a) Histogram Using All Reported Bridge Hits, (b) Histogram Using Multiple Bridge Hits Only.

It is observed from Figures 1-26(a) and 1-26(b) that bridge hits are mostly concentrated near zero necking, since necking is usually zero. Although hits occur in the case of both negative and positive values of necking, more hits seem to occur in negative necking region. The trend for multiple hits in Figure 1-25(b) is almost the same as that in Figure 1-26(a). Figure 1-26(b) also shows that there are more hits on bridges with negative necking.

1.3.14. BRIDGE HITS AS RELATED TO AADT

Average Annual Daily Truck Traffic (AADTT), calculated by multiplying AADT by the percentage of trucks, under a bridge can directly be linked to the number of bridge hits. For this purpose, AADT data for feature under the bridge from the RC13 table has been used since the percentage of truck traffic is not available from this table. Figure 1-27(a) shows a histogram of AADT for all bridges in New York. Figure 1-27(b) shows the histogram of number of recorded bridge hits by AADT.

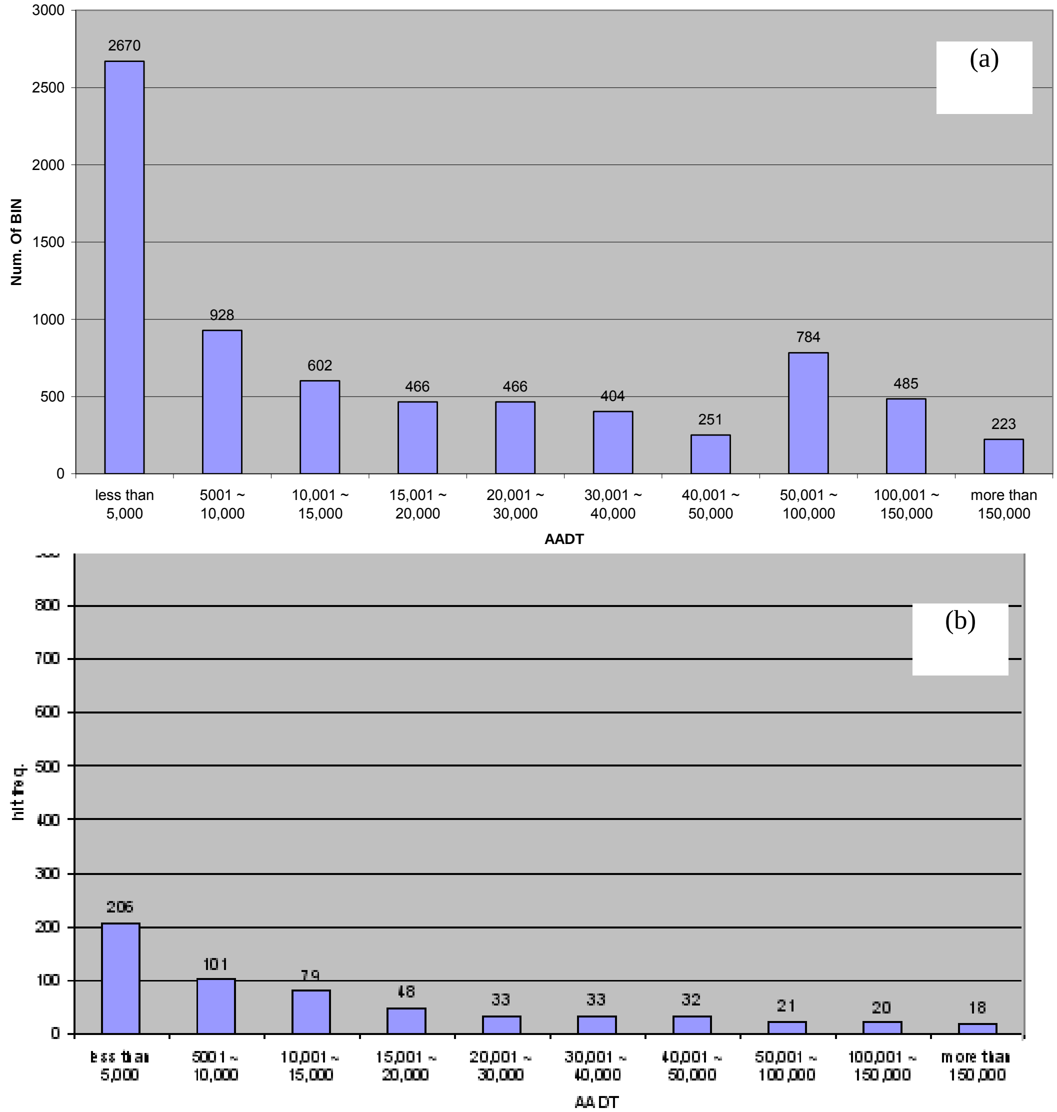


Figure 1-27: Number of Recorded Bridge Hits as Related to AADT: (a) Histogram Using All State Bridges Over Roadways, (B) Histogram Using Bridge Hits Only.

It is observed from Figures 1-27 (a) and 1-27(b) that AADT data for all bridges and hit bridges follow the same pattern, except for a slightly different pattern for AADT > 50,000 in case of bridge hits in Figure 1-27(b). Bridges with high AADT for feature carried under seems to have much smaller instances of hits.

1.3.15. BRIDGE HITS AS RELATED TO TOTAL HORIZONTAL CLEARANCE, LEFT CLEARANCE AND RIGHT CLEARANCE

Total horizontal clearance is the clearance between under-bridge components (e.g., curbs, non-mountable medians, railings and any other items which restrict horizontal clearance) which provide the least restrictive horizontal clearance. Figures 1-28(a) and 1-28(b) show the total number of recorded bridge hits and the number of multiple bridge hits, respectively, as a function of total horizontal clearance.

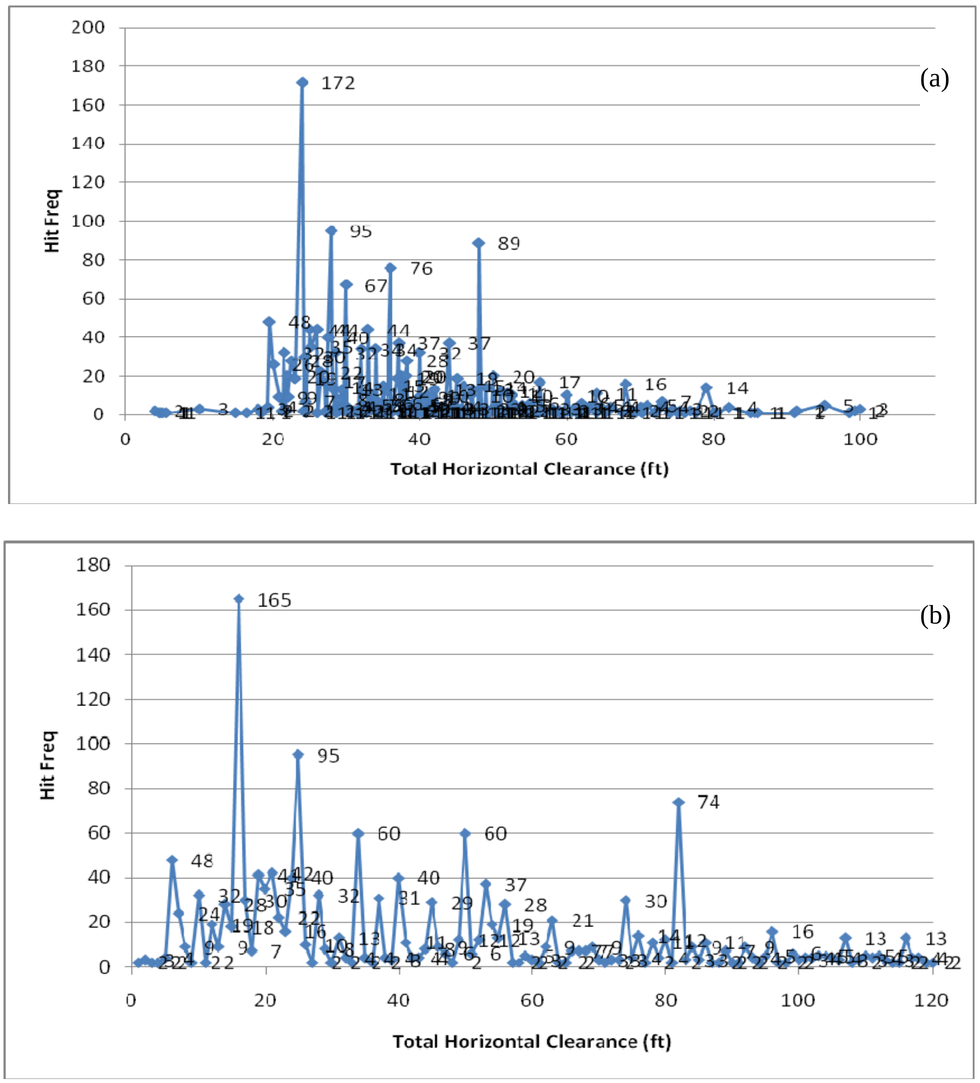


Figure 1-28: Number of Recorded Bridge Hits as Related to Total Horizontal Clearance: (a) Histogram Using All Recorded Bridge Hits, (b) Histogram Using Bridge Hits Multiple Times Only.

It is observed from Figure 1-28 that although bridges with total horizontal clearance between 20 to 75 feet have been hit, bridges with total horizontal clearance between 25 to 45 feet have been hit the most.

Figure 1-29 (a) shows the number of recorded bridge hits as related to the minimum horizontal clearance left. It is observed that the number of hits increases significantly if the minimum horizontal clearance left is less than 4 ft. Figure 1-29(b) shows the number of recorded bridge hits as related to the minimum horizontal clearance right. It is observed that a majority of hits occur when the minimum horizontal clearance right is less than 10 ft. It is also observed that the number of hits becomes suddenly high for minimum right clearance in the range of 25 to 30 feet. This may be related to a particular bridge being hit multiple times.

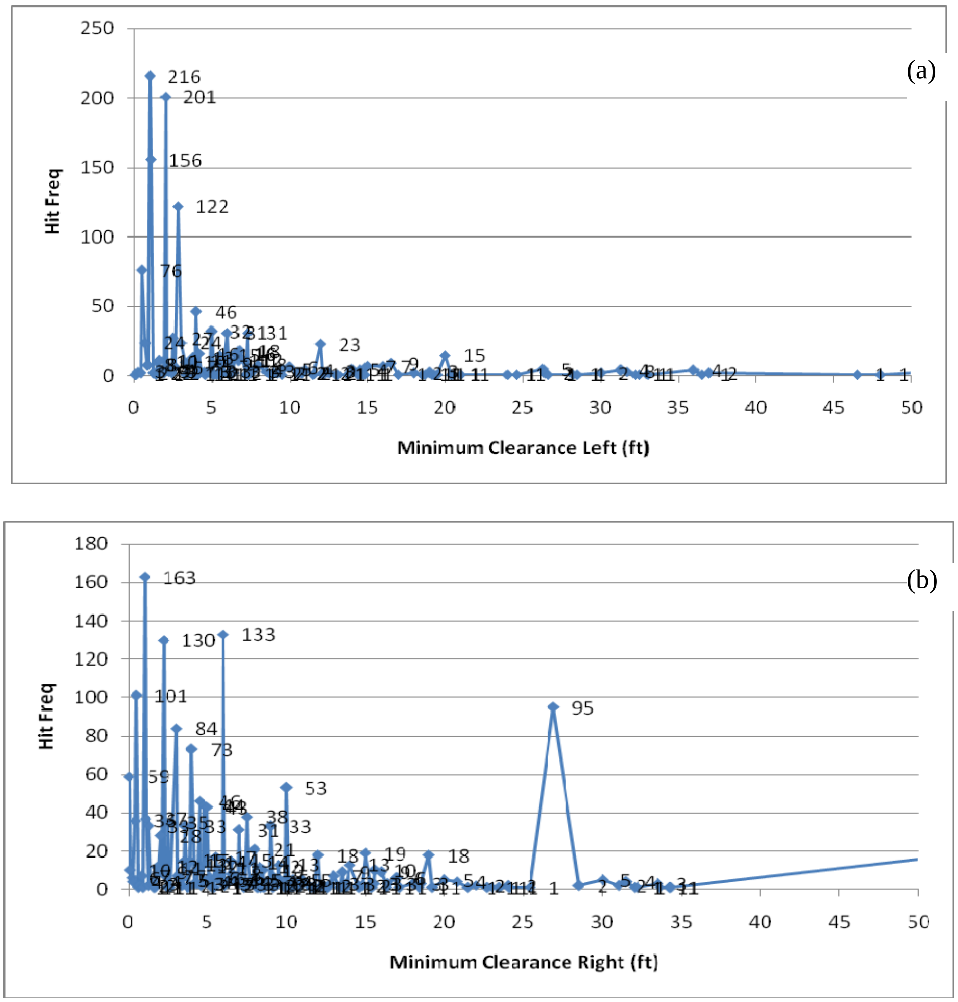


Figure 1-29: Number of Recorded Bridge Hits as Related to Left and Right Horizontal Clearance: (a) For Left Horizontal Clearance, (b) For Right Horizontal Clearance.

Overall, although horizontal clearance seems to be correlated to the frequency of bridge hits, this correlation may simply be because of the fact that the minimum right clearance is typically less than 10 feet for most low height highway and railroad bridges. This correlation will be investigated in detail using more detailed statistical models.

CHAPTER 2 : CURRENT STATE OF PROBLEM AND MITIGATIONS

2.1. INTRODUCTION

It has been observed from literature review that bridge hits are a serious problem in several states across the country. These states have taken numerous measures to address this problem, including maintaining a separate bridge hits computerized database to identify and implement measures to reduce such incidents, using vehicle over-height detection systems, regulations, police enforcements, etc. However, limited information is available on problems faced by other states and measures taken to reduce the likelihood of bridge hits. In order to fill this knowledge gap, a two stage survey has been carried out to collect information on different aspects of bridge hits problem across the country.

To address bridge hit concerns in New York, NYSDOT's *Collision Vulnerability Assessment Procedure* has been developed to identify relative vulnerability of the state's bridges to failures due to collision impact damages. An extensive review of this procedure has also been carried out to verify the effectiveness of the vulnerability procedure.

This chapter describes the outcome of the surveys of states and a review of NYSDOT's *Collision Vulnerability Assessment Procedure.*

2.2. SURVEY OF STATES ON BRIDGE HITS PROBLEM

A two-stage survey was developed and carried out to collect information from states across the country on different aspects of the bridge hits problem. The first stage survey consisted of 23 questions prepared by the PI, and critically reviewed and modified by the TWG of the project. The stage 1 questionnaire is included in Appendix A. The second stage survey consisted of 12 questions primarily focused on automated vehicle over-height detection systems. The second stage survey can be found in Appendix C. Both surveys were carried out through a web-based survey service.

2.3. OUTCOME OF THE FIRST STAGE SURVEY

The first stage survey focused on basic aspects of the bridge hits problem, such as the number of bridge hits, collection and management of bridge hits data and regulatory aspects. The survey was circulated among all 50 state and district DOTs, as well as the District of Columbia, and two local agencies (New York State Thruway Authority and New Jersey Turnpike Authority), out of which 44 state DOTs and 2 local authorities responded. Appendix B shows the responses to the survey by the participating states. A detailed analysis of responses to the first stage survey has been carried out and is presented in the following.

Q1. Seriousness of the Bridge Hits Problem: The response of states to the question "Do you consider bridge hits to be a major problem in your state?" is presented through the map of the states in Figure 2-1. In this figure, states which consider bridge hits a major problem are indicated by a red (dark) color, states which consider it a minor problem by a green (light) color and states not responding to the survey by a yellow color. It is observed that a majority of the states across the country consider bridge hits to be a major problem. In the

North-East, all responding states, except Massachusetts and Virginia, consider bridge hits to be a major problem.

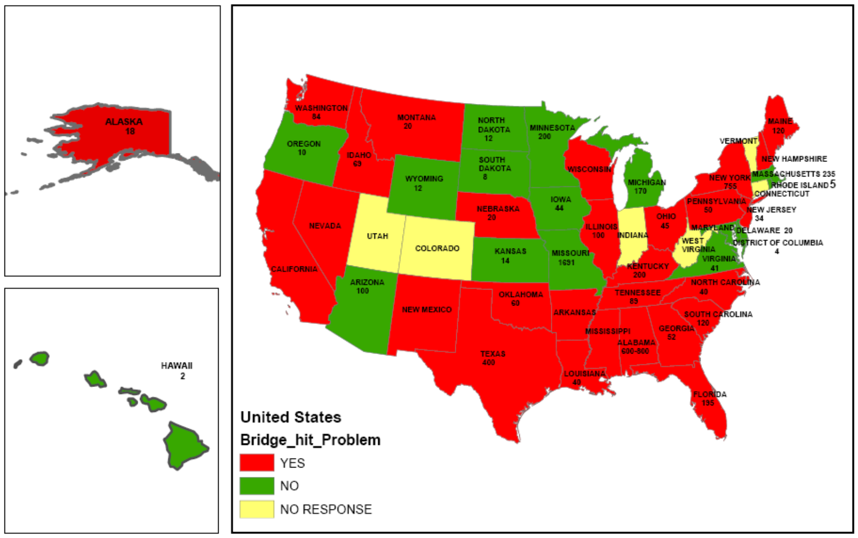


Figure 2-1: Seriousness of the Bridge Hits Problem across the Country.

Q2. Number of Bridge Hits during Last 4 Years: Figure 2-2 shows the total number of bridge hits from 2005 to 2008 in different states. For comparison, this figure also shows the seriousness of the bridge hit problem as perceived by different states. It is observed that states considering bridge hits a serious problem have a significant number of hits to their bridges. In Figure 2-2, some states, such as Louisiana, have only reported hits that resulted in serious damages to their bridges. On the other hand, states such as Missouri, have reported all impacts. Engineers in Missouri don't perceive bridge hits a serious problem even though there have been 1691 impacts to bridges in Missouri from 2005 to 2008. On the other hand, it is perceived to be a major problem in Louisiana even though there have only been 40 instances of hits causing serious damages to bridges.

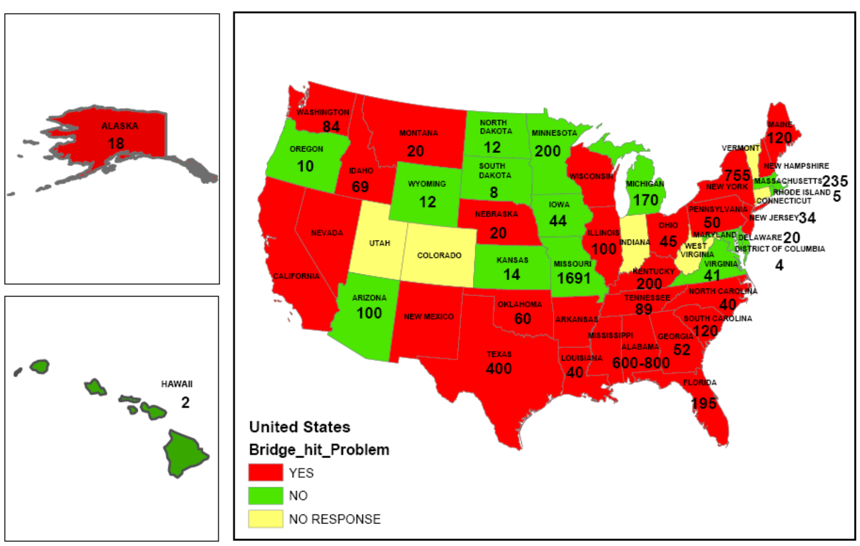


Figure 2-2: Number of Bridge Hits during Last 4 Years across the Country.

Q3. Types of Bridges Hit Most Often: Figure 2-3 shows a histogram of types of bridges hit most often. It is observed that steel multi-girder bridges are hit most often, followed by concrete (including pre-stressed) multi-girder bridges. Truss bridges are the third most hit bridges. A few states have reported Concrete Slab/Frame, Concrete Box Beam and Concrete Simple Span bridges as being hit.

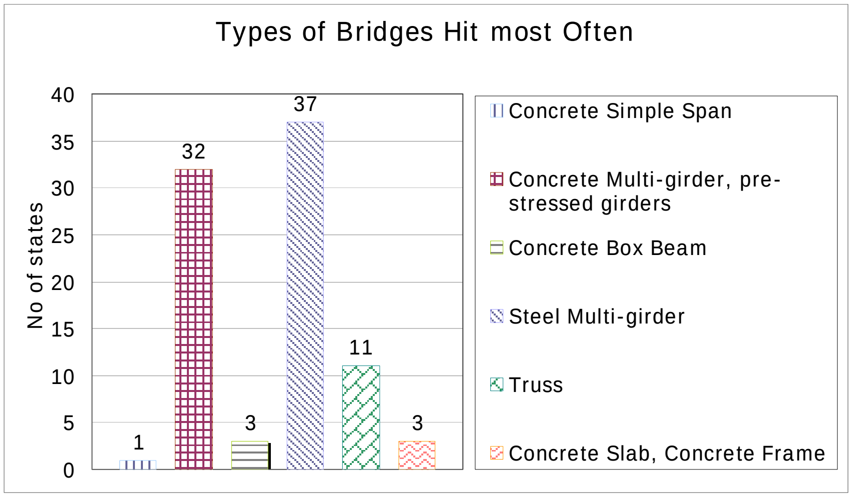


Figure 2-3: Types of Bridges Impacted Most Often.

Q4. Perceived Prime Causes of Bridge Hits: Participants were asked to rate on a scale of 0 to 10 the following three causes of bridge hits identified on the basis of analysis of the NYSDOT bridge hits database: Over-height Trucks, Reckless drivers and Accidental Equipment Storage. Figure 2-4 shows the histogram of rating of these causes by participating states. It is observed that “over-height trucks” was rated 10 as the prime cause of bridge hits by 16 states whereas only three states gave a rating of 10 to “Accidental Equipment Storage”. A majority of states gave a rating of 2 to 6 (with a median of 2.5) to “Reckless Driver”. A significant difference between the median values for overheight trucks, reckless driver and accidental equipment storage is observed from the statistical results presented in Figure 2-4. This difference is because of the survey response statistics. It is observed from Figure 2-4 that 22 out of 44 States gave a rating of 80% (i.e., 8 out of 10) or more to “Over-height Trucks”, resulting in a median value of around 75% or (7.5 out of 10). On the other hand, 14 states gave a rating of 20% (2 out of 10), 6 states a rating of 40% (4 out of 10), 2 states a rating of 60% (6 out of 10) and 2 states a rating of 80% (8 out of 10) to “Reckless Driver”, resulting in a median of 2.5.

Ratings in Figure 2-4 assigned to the three causes of bridge hits have been analyzed further by taking the weighted mean of these ratings for the three causes. Figure 2-5 shows a histogram of the weighted mean for the three causes of bridge hits. It is observed that over-height trucks have been considered to be the prime cause of hits to bridges, followed by “Accidental Equipment Storage” and “Reckless Drivers”.

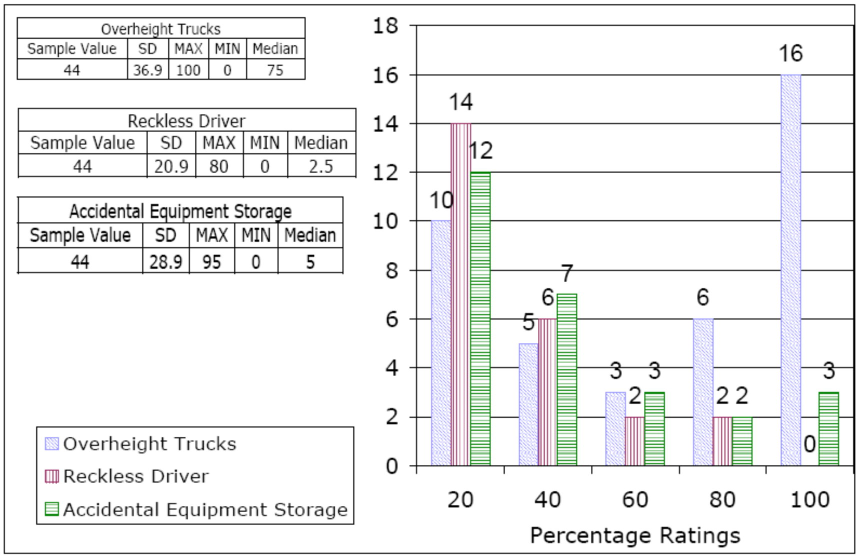


Figure 2-4: Ratings of Perceived Prime Causes of Bridge Hits.

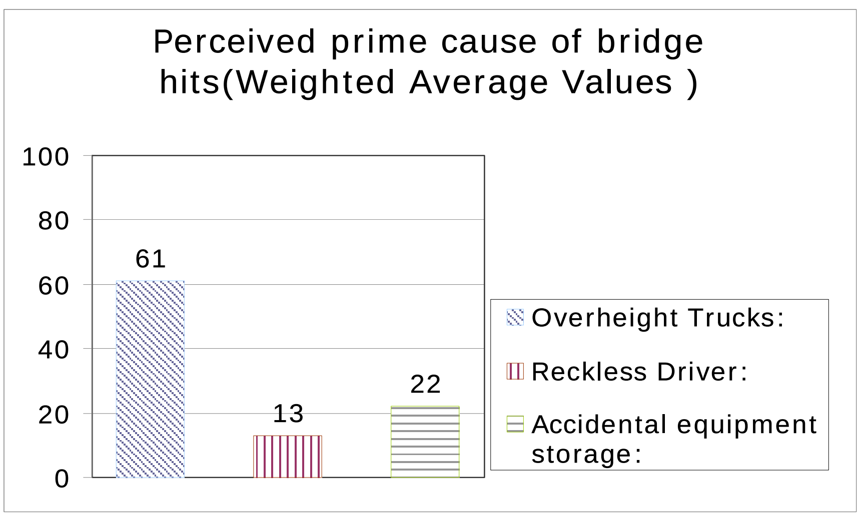


Figure 2-5: Perceived Prime Cause of Bridge Hits.

Q5. Types of Damages Caused to Bridges: States were asked to provide feedback on the types of damages observed to bridges because of impacts by trucks: (a) Serious damages, (b) Minor Damages and (c) Mostly scrapes, however, they cause serious traffic congestion problems. Participants were allowed to select multiple types of damages. Figure 2-6 shows histogram of types of damages to bridges. It is observed that all three types of damages are caused across the country, although serious damages have been caused the most.

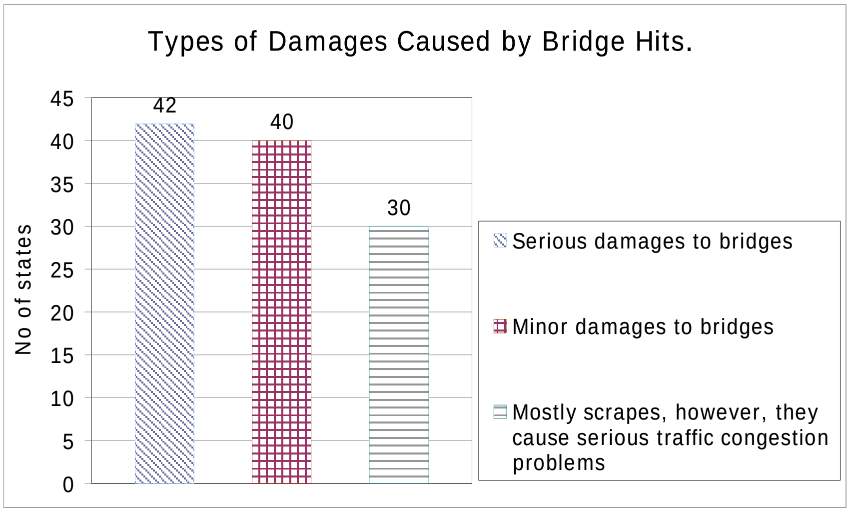


Figure 2-6: Types of Damages Caused by Bridge Hits.

Q6. Presence of Parkways: Since most of the hits in New York have been caused on bridges over parkways, participants were asked if they have parkways similar to those in New York State. States responding affirmatively to this question are: Massachusetts, Maryland, North Carolina, New Jersey, Kansas, California and Rhode Island. These states were further asked about the percentage of hits on bridges over parkways in their states. Three states reported having no hits on bridges over parkways whereas four states reported having less than 4% hits to bridges over parkways, as shown in Figure 2-7.

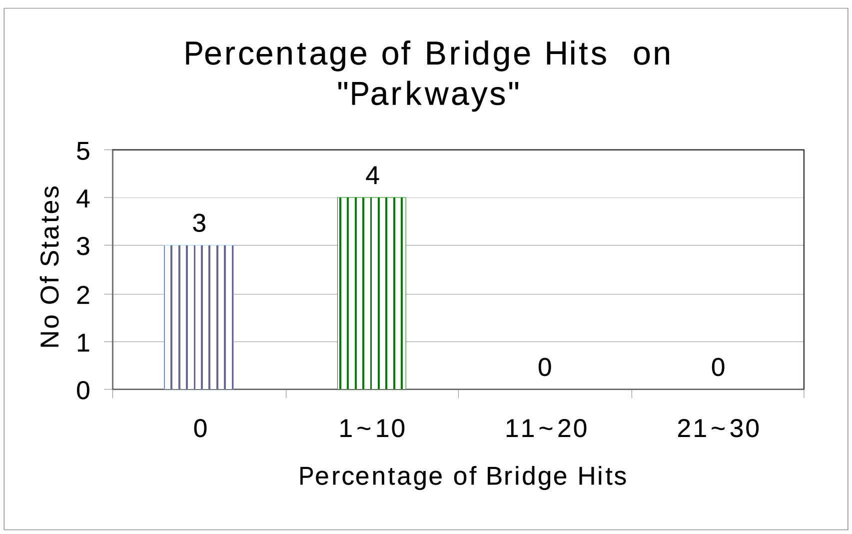


Figure 2-7: Percentage of Bridge Hits on Parkways.

Q7. Bridge Hits Information Collection and Management: Participants were asked how they collect and manage bridge hits data in their state: (a) through a separate bridge hits database, (b) as a part of bridge inspection database or (c) through police reports. As shown in Figure 2-8, seven states (Oklahoma, Maine, Ohio, South Dakota, Michigan, Nebraska and Iowa) indicate collecting and managing bridge hits data through a database, while 22 states collect the information as a part of the bridge inspection program and 14 states collect bridge hits data through police reports.

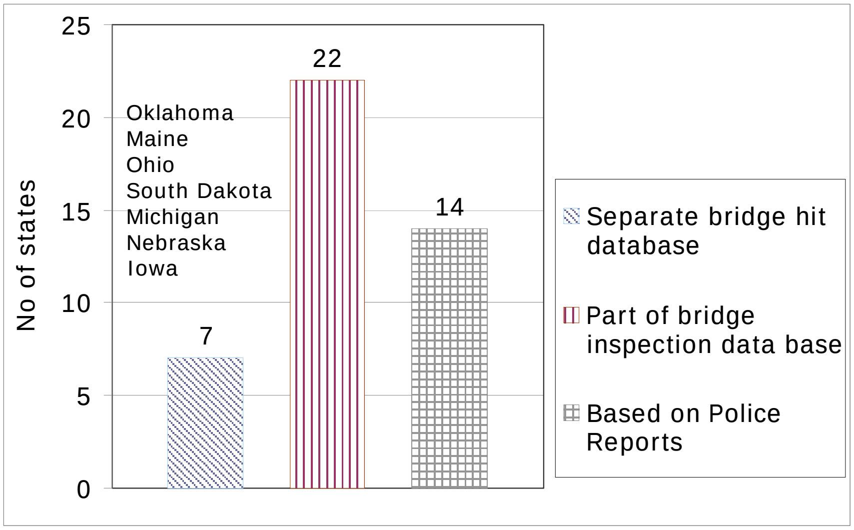


Figure 2-8: Bridge Hits Information Collection and Maintenance.

Q8. Study on Bridge Hits Carried Out in Other States: Participants were asked if their state had carried out (or is carrying out) a study on bridge hits. Only 5 states (Washington, Tennessee, North Dakota, Iowa and Idaho) answered yes to this question, as shown in Figure 2-9.

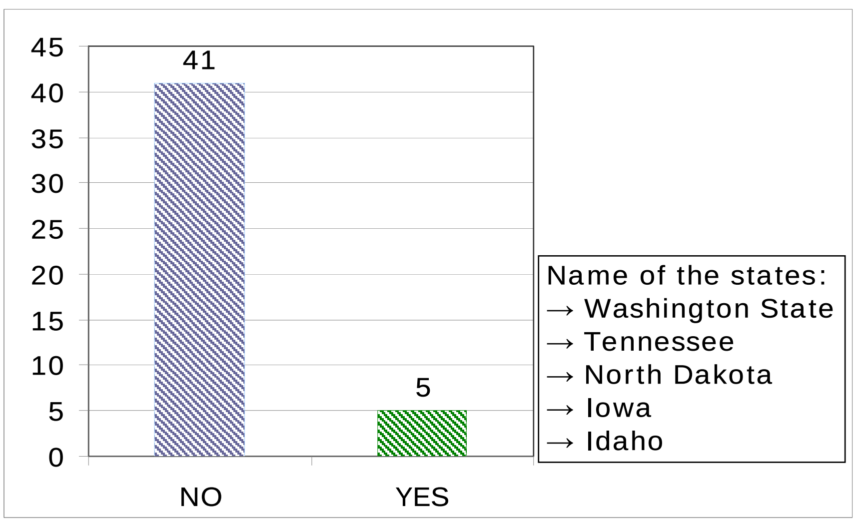


Figure 2-9: Study on Bridge Hits Carried Out in Other States.

Q9. Follow up on Ongoing Study: When asked if NYSDOT can contact the project managers/consultants of the states carrying out the study in Question 8, only two states (Idaho and Tennessee) agreed to allow NYSDOT to contact their project managers/consultants, as shown in Figure 2-10.

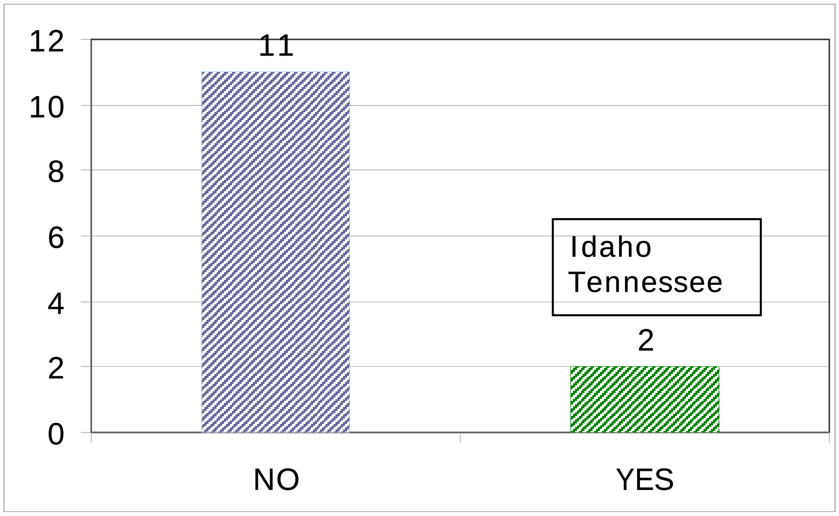


Figure 2-10: Follow up on an Ongoing Study.

Q10. Minimum Design Vertical Under-clearance: Figure 2-11 shows a histogram of minimum design vertical under-clearance on and off the national highway network. It is observed that the minimum vertical under-clearance on the national highway network for a majority of states is between 16 and 17 ft, with a majority of states having 16.5 ft. Only 4 states have a minimum vertical under-clearance less than 16 ft. The value of minimum vertical under-clearance off the national network for states varies between 13.5 and 17 ft, with 11 states having 15.5 ft, 7 states having 15 ft and 10 states having 16.5 ft.

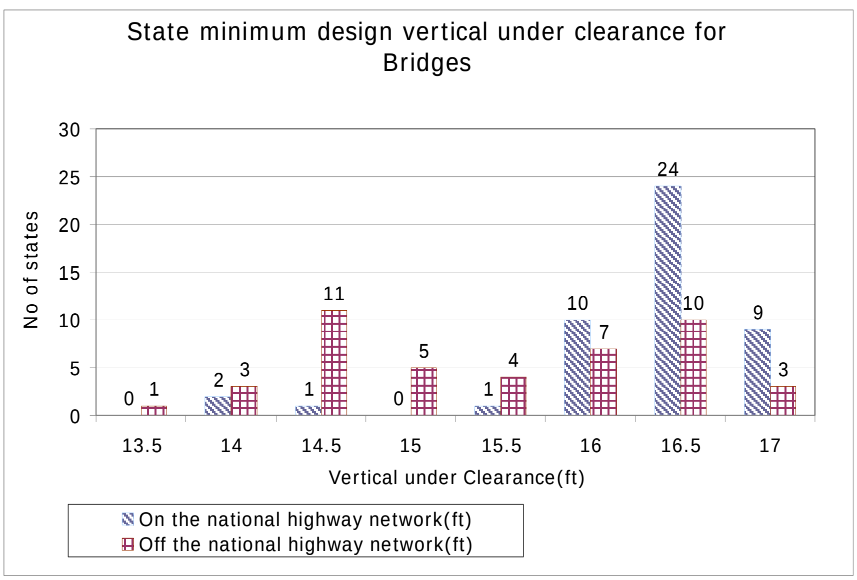


Figure 2-11: Minimum Design Vertical Under-Clearance.

Q11. Maximum Height for Vehicles and Cargo: Figure 2-12 shows the maximum height for vehicles and cargo without and with permit. It is observed that a majority of states limit the height of vehicles or cargo to 13.5 or 14 ft without a permit. Only two states allow heights of 14.5 and 15.5 ft. With a permit, while a few states have height restrictions between 13.5 and 20 ft, a majority of states permit over-height vehicles based on the route.

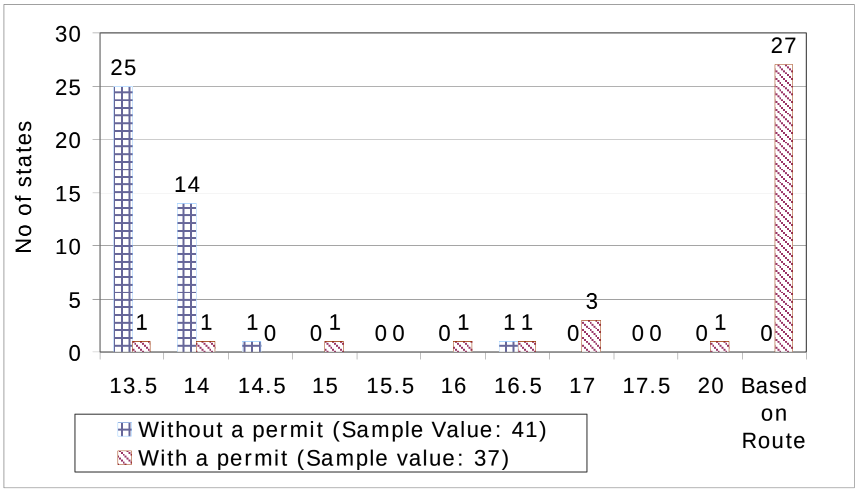


Figure 2-12: Maximum Heights for Vehicles and Cargo.

Q12. Routing of Over-height Vehicles: Figure 2-13 shows a histogram of procedures for routing over-height vehicles by the responding states. It is observed that 35 states require a carrier to propose a route and submit for approval. Sixteen (16) states determine specific route for permitted vehicles whereas three (3) states have regional permitting organizations to route over-height vehicles.

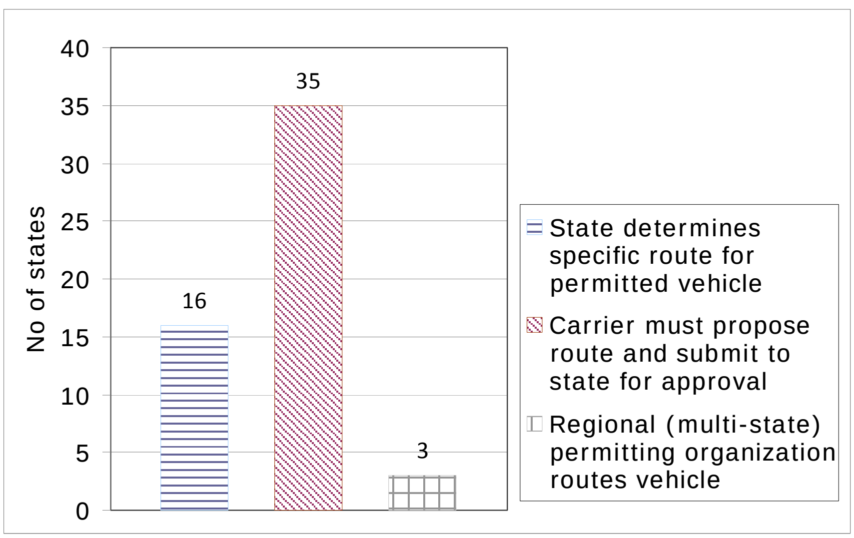


Figure 2-13: Routing of Over Height Vehicles

Q13. Methods Used for Routing of Permitted Vehicles: Figure 2-14 shows a histogram of methods used by responding states to route permitted vehicles. It is observed that ten (10) states use a state map to automatically, route permitted vehicles, twelve (12) states require using a truck routing software prepared for the state, six (6) states use an electronic map prepared for the state and four (4) states use mapping software such as MapQuest, Google Maps, Street Atlas or Street And Trips, etc.

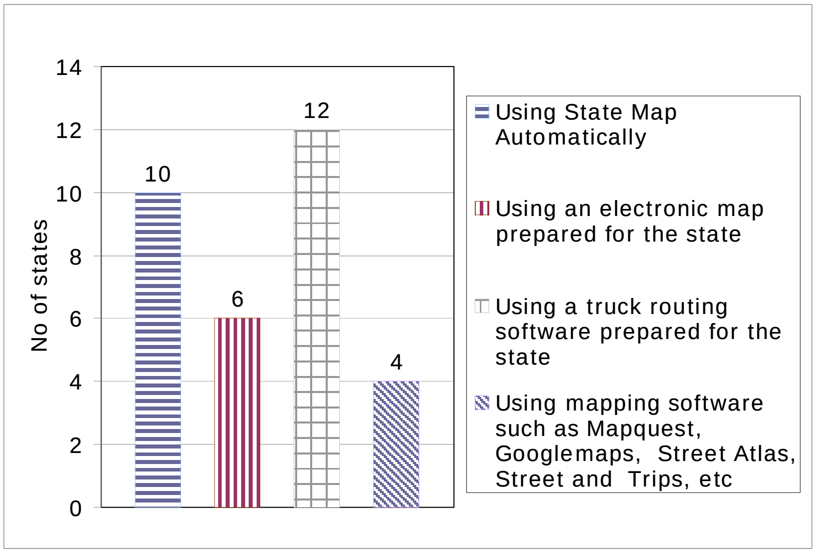


Figure 2-14: Methods used for Routing of Permitted Vehicles.

Q14. Bridge Impacts as a Result of the use of GPS on Unauthorized Routes: Because of an increasing use of GPS for trip routing, participants were asked about the number of bridge hits caused as a result of GPS guiding truck drivers to unauthorized routes. Figure 2-15 shows a histogram of response of the participants. It is observed that a majority of states (35 states) reported not observing the use of GPS by truck drivers on unauthorized routes; four states reported recording 1-5 incidents whereas 2 states reported recording more than 10 incidents.

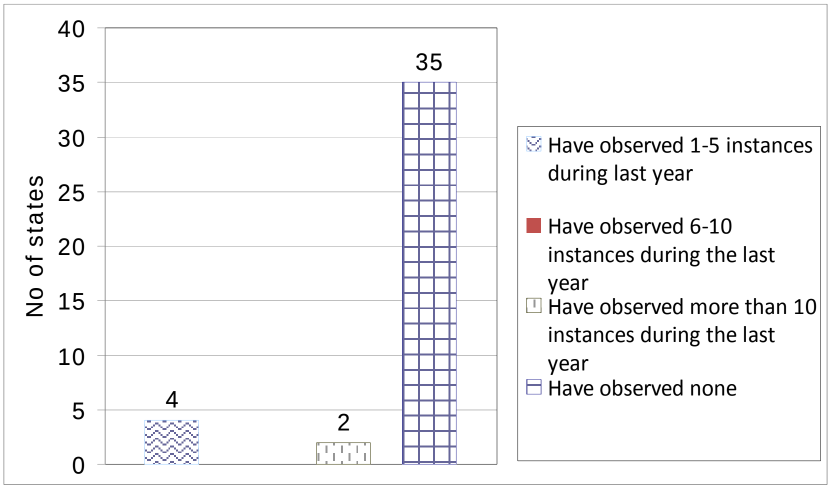


Figure 2-15: Bridge Impacts Because of the use of GPS on Unauthorized Routes.

It should be mentioned that the reason for a majority of states reporting no incidents related to the use of GPS may be because of lack of a protocol to collect such data after an incident. Recently, New York State Troopers have started collecting information on bridge impacts, including the use of GPS on unauthorized routes. It has been observed from the incidents of over 40 bridge impacts on parkways that more than 90% of the truck drivers were using GPS on unauthorized routes.

Q15. Interest in Collaborative Research Effort: Participants were asked if they would be interested in joining a collaborative research effort with NYSDOT in developing an online routing site or GPS system capable of providing real-time information about low vertical under-clearance bridges. Figure 2-16 shows a histogram of the response of states. Six states (Louisiana, Massachusetts, South Carolina, New Mexico, Maine and Pennsylvania) expressed their interest in joining such a study. The remaining 37 states are not interested in joining the study at all, although 28 states expressed interest in receiving updates.

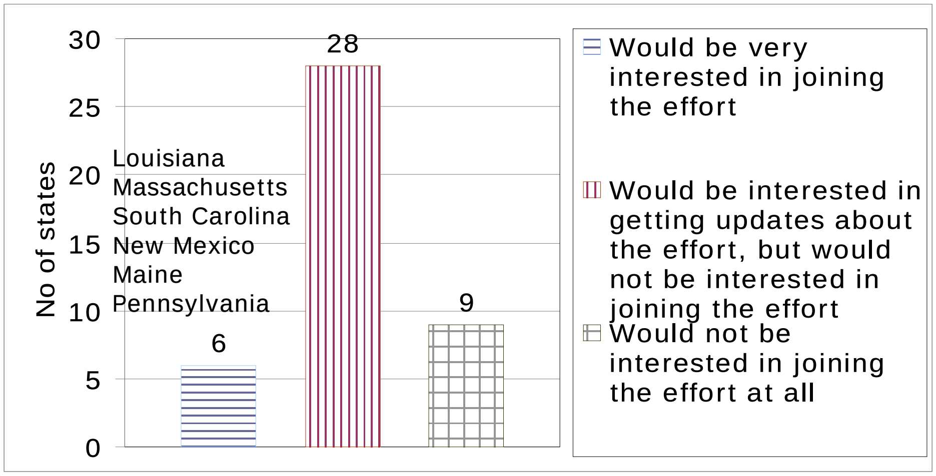


Figure 2-16: States Interested in Collaborative Efforts.

Q16. Enforcement of Over-Height Vehicle Laws: The histogram in Figure 2-17 shows measures taken by states to enforce over-height vehicle laws. It should be noted that a particular state could select more than one method of enforcing over-height vehicle laws. It is observed that 29 states use roving patrols whereas 31 states use manual spot checks at weigh stations. Five states (Maryland, Virginia, Florida, Delaware and Idaho) use an automated measurement system at weigh stations. Maryland uses an automated vehicle measurement system at truck terminals. Hawaii and Idaho use an automated height measurement system on highways. Only Nebraska has reported using an automated vehicle height measurement system with active warning signs.

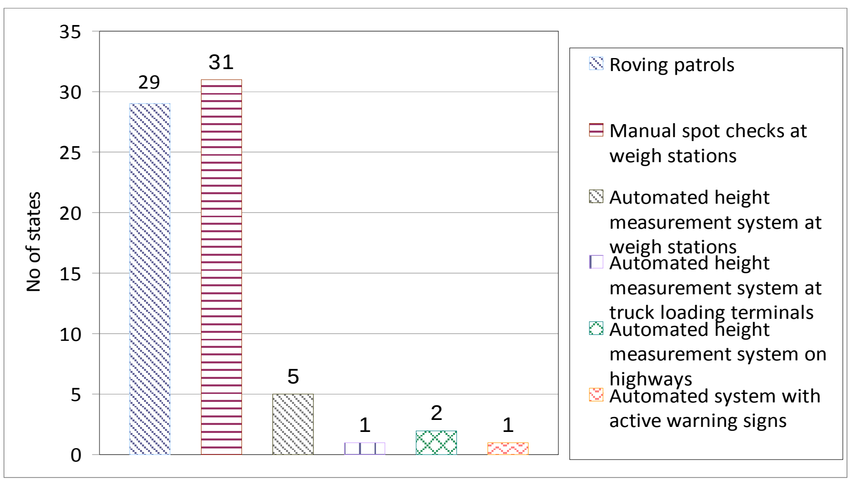


Figure 2-17: Enforcement of Over-Height Vehicle Laws.

Q17. Truck Drivers Knowing Height of Trucks/Cargo: A study done in the United Kingdom on bridge strike mitigation, found that truck drivers aware of the height of their truck/cargo were more likely to react to low-clearance warning signs. Hence, participating states were asked if they require truck drivers to be aware the height of their truck / cargo. Survey results, shown in Figure 2-18, show that forty three states require truck drivers to know the height of their truck/cargo. Among responding states, only New Mexico doesn't have this requirement.

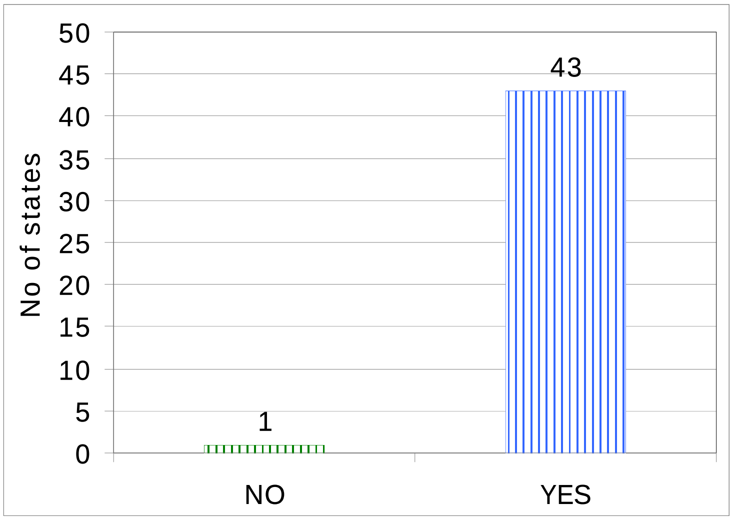


Figure 2-18: Truck Drivers Knowing Height of Trucks/Cargo

Q18. Bridge Under-Clearance Requiring Sign Posting: New York State requires sign posting on a bridge with vertical under-clearance of 14 ft or smaller. Figure 2-19 shows a histogram of maximum bridge under-clearance for which a sign posting is required by different states. It is observed that a majority of states require sign posting for an under-clearance of 14-14.5 ft, followed by 15-15.5 ft and 16-16.5 ft. Three states require sign posting for an under-clearance of 13.5 ft. Alaska and South Carolina require a sign posting for the under-clearance of 17 ft and Texas for an under-clearance of 20 ft.

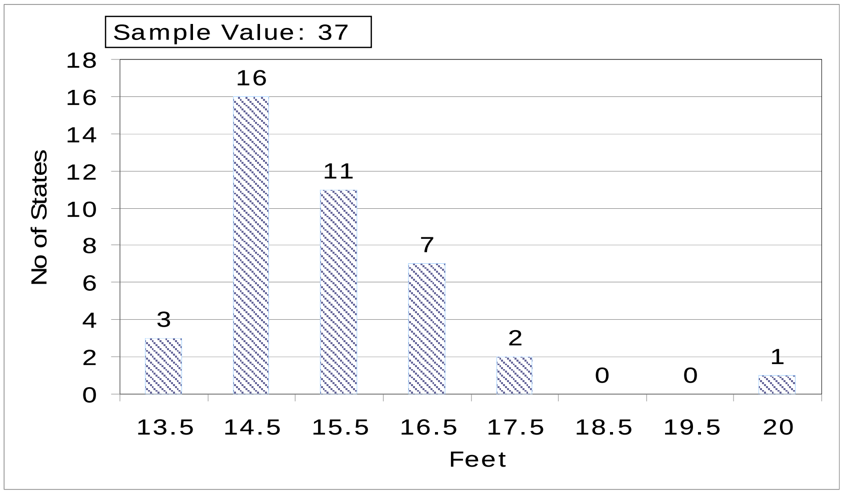


Figure 2-19: Bridge Vertical Under-Clearance Requiring Sign Posting

Actual bridge under-clearance posted near bridges is under-reported by many states to maintain some safety margin. For bridges with vertical under-clearance less than 14 ft, NYSDOT is required by law to post the legal vertical clearance as 1 foot (12 inches) less than the actual clearance. Figure 2-20 shows the histogram of under-reporting in inches by responding states. It is observed that 5 states don't under-report at all, 6 states by 2 inches, 20 states by 3 inches, 3 states by 4 inches and 1 state (Montana) by 6 inches. In Figure 2-20, vertical under-clearance is under-reported by 12 inches in New York, as reported by the New York State Thruway.

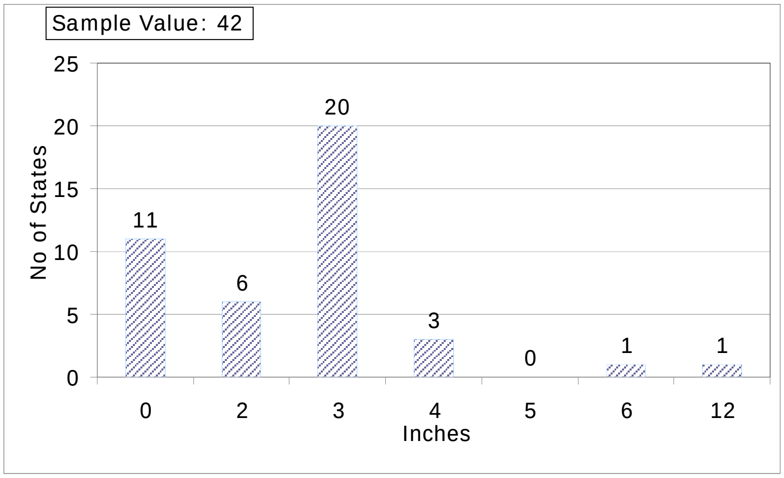


Figure 2-20: Under-Reporting of Actual Vertical Under-Clearance by Responding States.

Q19. Location of Posting of Under-Clearance Sign: Figure 2-21 shows a histogram of the location of sign posting with respect to the bridge. It is observed that a majority of states post the under-clearance sign near the bridge while 16 states also post at other locations (e.g., approach roads, etc.). Eight states post at a certain distance from the bridge and 7 also post near the entrance of the ramp of highway under the bridge. It is noted from the survey responses that states generally post at multiple locations.

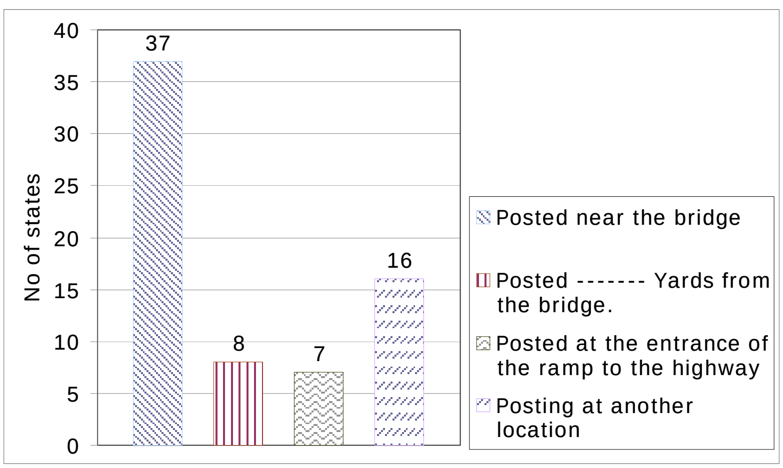


Figure 2-21: Location of Posting of Under-Clearance Sign.

Q20. Typical Messages Posted to Warn Drivers About Under-Clearance Bridges: States were asked about the messages they post on signs near bridges warning truck drivers about under-clearance bridges. Responses of states have been presented in Appendix B. It is noted that a majority of states use typical messages such as "Low Clearance Ahead", No Vehicle Over xx Ft xx in", etc.

Q21. Use of Passive Over-Height Detection System: Passive over-height systems such as chains, headache bars, etc., are used to warn truck drivers about their over-height cargo. It has been observed from the survey that 14 states out of the responding 46 states used passive over-height detection systems, as shown in Figure 2-22.

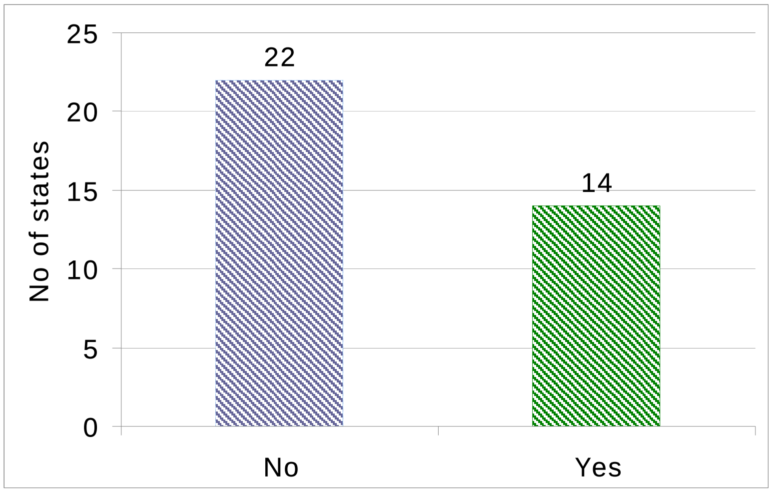


Figure 2-22: Use of Passive Over-Height Detection System.

Q22. Automated Vehicle Height Measurement Systems: Participating states were asked about their use of automated vehicle height measurement systems. Figure 2-23 shows a histogram of responses from states on the use of automated vehicle height measurement systems. It is noted that only 15 out of the 46 responding states have use automated vehicle height measurement systems. These states are: Maryland, Virginia, Maine, South Dakota, Texas, South Carolina, Massachusetts, Idaho, Hawaii, Montana, Wyoming, Minnesota, Missouri, Wisconsin and Alaska. An in-depth second stage survey has been carried to collect detailed information on the performance of various automated vehicle height detection system used by these 14 states. The outcome of this second stage survey is described in detail in the next section of this report.

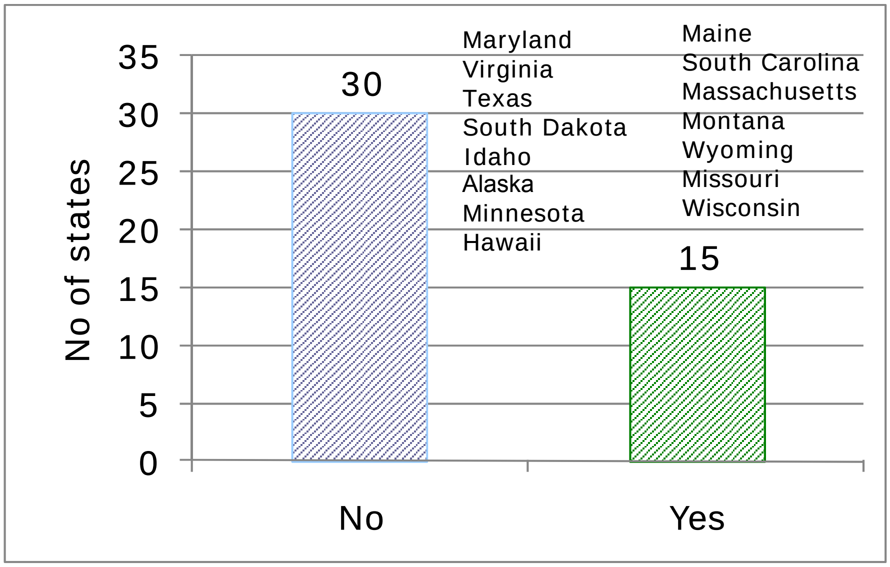


Figure 2-23: Automated Vehicle Height Measurement Systems Usage.

2.4. OUTCOME OF THE SECOND STAGE SURVEY

The second stage survey, which focused on the use of automated vehicle height detection systems used by15 states, was based on the feedback received for Question 23, as shown in Figure 2-23, during the first phase of the survey. These states are: Maryland, Virginia, Maine, South Dakota, Texas, Massachusetts, Idaho, Hawaii, Montana, Wyoming, Minnesota, Missouri, Wisconsin, Alaska and South Carolina. Out of these states, Maryland, Virginia, Maine, Texas, Hawaii, Wyoming, Minnesota, Missouri and Alaska actively responded to the survey, while South Dakota, Massachusetts and South Carolina simply stated that they used automated vehicle height detection systems several years ago and don't have any information on these systems. Idaho, Montana and Wisconsin didn't respond to the survey. Appendix C shows the questionnaire used for the second stage survey. Appendix D shows the response of states to the second stage survey. Table 2-1 also presents the outcome of this survey for an easy comparison of responses of states.

It is observed from Table 2-1, that all responding states, except Alaska, who have installed automated vehicle height detection systems, rated their systems very effective in reducing number of hits, maintenance and overall performance. All of these systems run on a 120V power supply and have been supplemented by advanced signing systems to warn truck drivers about the low vertical under-clearance bridge ahead. The laser system installed by Alaska had significant problems from the beginning and apparently had several design/installation issues. The installed cost of these vehicle over-height detection systems was in the range of $2400 for the "Dual Beam" system installed by Virginia to $100,000 for the "Optic" system installed by Maryland. The expected yearly maintenance costs range between $50 and $10,000. The expected service life is generally more than 15 years for most of the systems. It is noted that several of these systems were affected by lightning strikes, impacts by vehicles, or false positives because of sun light shining directly into the receiver. Several of these systems had false positives because of snow, rains, birds or high pigeon areas. The state of Virginia previously experienced damages to a tunnel that caused repair costs to exceed $1M. The damage was the result of an over-height truck impact that occurred prior to the installation of the detector system. The "Dual-Beam" system, which they installed, has been effective in reducing the likelihood of such damages. The survey also asked states about any specific notable approach that has been effective in reducing the frequency of bridge hits. It is noted that Maryland uses a combination of warning signs (a pre-warning sign for trucks to get off the highway and an alert system for the police to respond), enforcement, and high fines as an effective means in reducing the likelihood of hits on bridges. Alaska has posted bridges with vertical under-clearance less than 16 ft based on the hit frequency. Virginia imposes severe fines and up to 3 points against the driver's CDL.

Overall, it is noted that the Z-Pattern System manufactured by Trigg, with an installed cost in the range of $7,700 - $8,900 and a maintenance cost of $50 per year, is the most effective and economical system with almost no false positives and very few installation/operational issues. Although the cost reported by Maine for a similar system is in the range of $150,000 - $200,000, we are discussing with Maine DOT and Missouri DOT why there seems to be such a wide disparity in costs. However, both of these DOTs have rated this system 9 out of 10 in terms of overall satisfaction. Another cost-effective system is the "Pulsed Infra-Red/Pulse LED & IR" system manufactured by Trigg. This system is used by Hawaii DOT with an installed cost range of $13,000 - $14,300.

In addition to the second stage survey reported above, the research team is also carrying out a detailed survey of manufacturers to identify automated vehicle over-height detection systems and their features, including installation costs and remote monitoring capabilities. The outcome of this survey is reported in Chapter 4 of this report.

Table 2-1: Response of States on Second Stage Survey on Automated Vehicle Over-height Measurement Systems.

Item/Description	Missouri	Maryland	Texas	Hawaii	Minnesota	Maine	Alaska	Virginia
Besides passive and automated over-height detection systems, have you considered any other alternative?	No	Police Enforcement	No	No	No	No	Hanging bar/chains/plastic tubes	No
Type of Device	Z–Pattern System	Optic	Pipes on cable	Pulsed Infra-Red / Pulsed LED & IR	infrared light	Z-Pattern dual beam units	Laser	Dual beam
Manufacturer	Trigg	Sick	Custom	Trigg	Trigg	Trigg	Trigg	Jo-Kell
Initial Cost	$7700-8900	$50-100K	$10,000	$13,000-14,300	$45,231	$150-200K	$1.33 million	$1233-2400
Annual Maint. & Operating Costs	Approximately $50/yr	$5-10K	$1,500	$400.00	N.A.	$600	On Warranty	
Number of Years in Service	4-8 years	10-15 years	10 years	4-12 Years	6	1-3 years	3	12-17
Reduction in bridge hits after installation of automated systems (On the scale of 1 to 10)	8.5	8	9	10	9	8	N/A	10
Reduction in number of trucks on unauthorized highways with restriction on trucks (On the scale of 1 to 10).	N.A.	N.A.		10	N.A.	8	0	N.A.
Satisfaction with Maintenance (Scale of 1 to 10)	10	5	9	8.25	8	9	1 - System off. Fixing false calls.	9
Issues with vandalism (Scale of 1 to 10)	1	1	2	1.5	1	1	1	1
Satisfaction with overall performance (Scale of 1 to 10)	9	8	8	9	8	9	1(Should have been design/ build)	8.5
If you have installed different types of automated vehicle height measuring devices (either by manufacturer / type of device), please list the devices in the order of decreasing overall performance (reduction in bridge hits).								

Do your installations have any operational / maintenance issues?	Systems hit by lightening and by a vehicle.	Insufficient space because of fitting to existing tunnel approach.	Only for low speed/low volume roadways.	Difficult maintenance due to accessibility. OH located on side of a bridge.	Voltage regulator and detection components damaged by lightning.	No	Many issues, Too complex mechanism, Very poor truck discrimination built in, or documentation devices when bridges are hit.	Fake alarms because of the direction of the receiver with respect to the sun, because of bird activity.
Have you observed any operational issues during snow?	No Problems during snow.	Snow, rain, birds, exhaust from trucks will cause false sensor trips. We use multiple sensors to reduce the impacts. e.g.: Two sensors a foot or so apart	NA		No	During cold weather false positives increase	Significant - false calls constant. Snow plowing at truck speeds impact, bend, clog sign boards.	During very heavy snow we sometimes have false alarms.
Do you also use advanced signing to supplement automated over-height detection devices (Y/N)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
What is the frequency of false positives? Do you use any mitigation approaches for false positives?	We don't experience false positives because the unit has directional detection as well as speed indicator.	There are individual false positive hits on sensors. We use multiple sensors to try and reduce the impact. Generally, it is more acceptable to falsely trigger the warning signs than not to trigger the signs at all.		1 per month		One every three months	Constant during snowfall. Loop design poor, Research retrofit for improved truck verification and snowfall screening.	Most of the false alarms are caused by environmental factors, e.g., sun shining directly into the receivers, try to avoid pointing the receivers due east or west.
What is the local power source for the automated over-height detection	120 volt	120V utility company		Using freeway	120 VAC,	hard	Freeway	Tunnel power systems,

system?		feed		lighting 277V down to 120V.	+/-10%, 50/60 Hz	wired	lighting load center.	standard "neighborhood" sources.
Is the environment around the device, such as high bird area, gusty winds, debris, etc., a problem in the detection of over-height vehicles? Please describe below.	No Problem	Birds will false trigger single devices. Poor pavement will cause trucks to bounce limiting accuracy also. It's an IR beam so anything that blocks it will cause a trigger.	Yes - leads to many of the false positives	No	No	High Pigeon area	Gusty area. Not enough room to set devices on stronger posts. Steep interchange embankments.	Minor problem. Most of mainline overheight detectors have backup detectors. We also have some visual coverage with our tower mounted CCTV cameras.
How long do you expect the system to last (functionally and technologically)?	15 years	12-15 years.		20 Years		15 Years	5 years with retrofit.	15 Years
What is your overall opinion of the system and its cost effectiveness?	Very reliable, also used to detect vehicles over 10 feet tall that are traveling faster than 20 mph for advanced flashers for a sharp curve in the road.	It is effective at reducing damage in the tunnel from overheight vehicles. It is effective enough that operations places a high demand on the system being functional.		Very good. After installation cost, the maintenance cost is minimal.	Has worked well so far	Satisfied with the system	Very poor, Used less knowledgeable designer, builder. Need to use a turnkey Design/Build option instead.	Very effective and necessary to protect our tunnel ceilings. In the past, one overheight vehicle caused over $1M in damages to a tunnel ceiling.
Please describe any specific notable approaches / factors (such as unique traffic laws) that have been effective in reducing the frequency of bridge hits.	NA	Our system is focused on over-heights getting into tunnels; a pre-warning system activates a sign prior to the last exit before the		None			Region wide posting of low bridges based on hit frequency.	We have had the support of our local legislature to have laws

tunnel. If the truckers fail to get off, the second system alerts on-duty police and the truck is pulled over and ticketed, the fine is very high. The combination of warning systems, enforcement, and high fines greatly reduce over-heights in the tunnel. They do still occasionally get in though.

implemented to issue severe fines and up to 3 points applied against the driver's CDL license.

2.5. REVIEW OF NYSDOT'S COLLISION VULNERABILITY ASSESSMENT PROCEDURE

A detailed review of the current NYSDOT Collision Vulnerability Assessment procedure has been presented in Chapter 1 by investigating its effectiveness in assessing the collision vulnerability of bridges. Based on the collision vulnerability analysis, bridges are classified into High (H), Medium (M), Low (L), and not vulnerable (N), vulnerability classes. Figure 2-24 shows a histogram of the number of reported bridge hits as related to the vulnerability classes. Note that a large number of bridges in class N (not vulnerable) have been hit by vehicles. These bridges are most likely on parkways. Likewise, 292 bridge hits have been on bridges classified as L (Low).

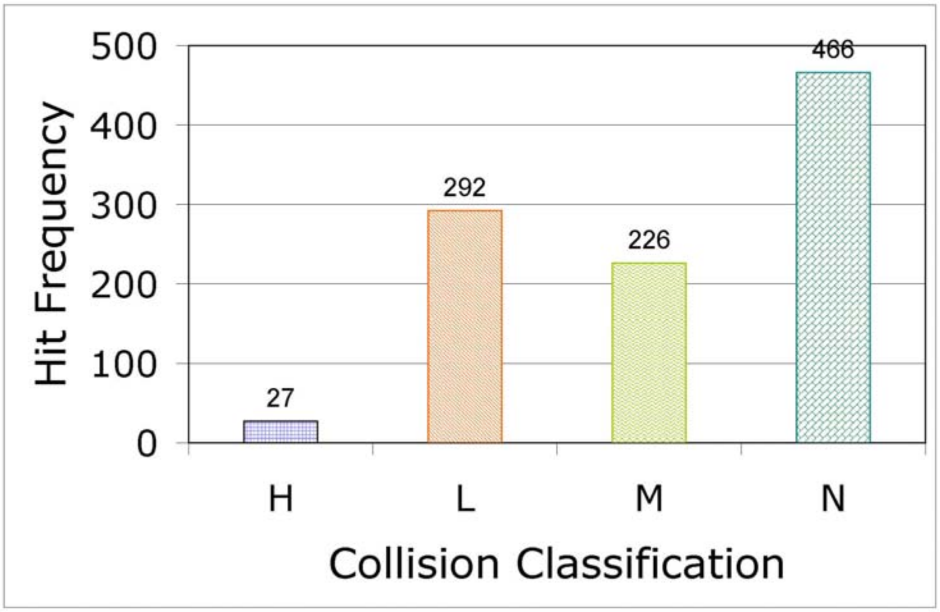


Figure 2-24: Number of Reported Bridge Hits as Related to the NYSDOT BSA Collision Vulnerability Class.

Recently, NYSDOT also provided their proposed changes to the Collision Vulnerability Assessment (CVA) procedure. For Branch 2A (superstructure vulnerability for trucks under bridges), these changes include considering (i) previously hit bridges over parkways, (ii) more main member types, (iii) lower vertical under-clearance, (iv) lower scoring for AADTT, (v) removing lighting under and posted speed limit, (vi) functional classification in place of posted speed limit, (vii) scoring for major, moderate and minor damages, multiple hits and negative scoring for not required posting signs. The consultant has carried out a comparison between the Collision Vulnerability Assessment based on current guidelines and the vulnerability scoring with the proposed changes. Figure 2-25 shows a histogram of the Branch 2A vulnerability scoring for bridges classified under H, L, M and N classes in the BSA tables. As per the proposed changes to the CVA guidelines, the criteria for vulnerability classification are: > 45: High, 30-60: Medium and < 45: Low. It should be noted that the classes (H, L, M and N) assigned to bridges in BSA may be based on all 4 branches of the current CVA guidelines, whereas results shown in Figure 2-25 are only for the Branch 2A by considering the proposed changes to the CVA guidelines.

It is observed from Figure 2-25 that bridges classified under class "N" per current guidelines are likely to be assigned to classes H, L or M following the proposed changes to the CVA guidelines, depending on the scoring, if these bridges have already been impacted. Similarly, some bridges originally assigned to classes L and M may be assigned to the Class H based on the proposed changes to the CVA guidelines. Likewise, many bridges that were assigned to Class H may seem to fall into Classes L or M based on the Figure 2-25. However, these bridges may still be assigned to class H after considering scoring based on the other branches of the CVA procedure.

A more detailed review of the proposed changes to the Collision Vulnerability Assessment procedure is presented in Chapter 6 to identify and propose further changes to the CVA procedure.

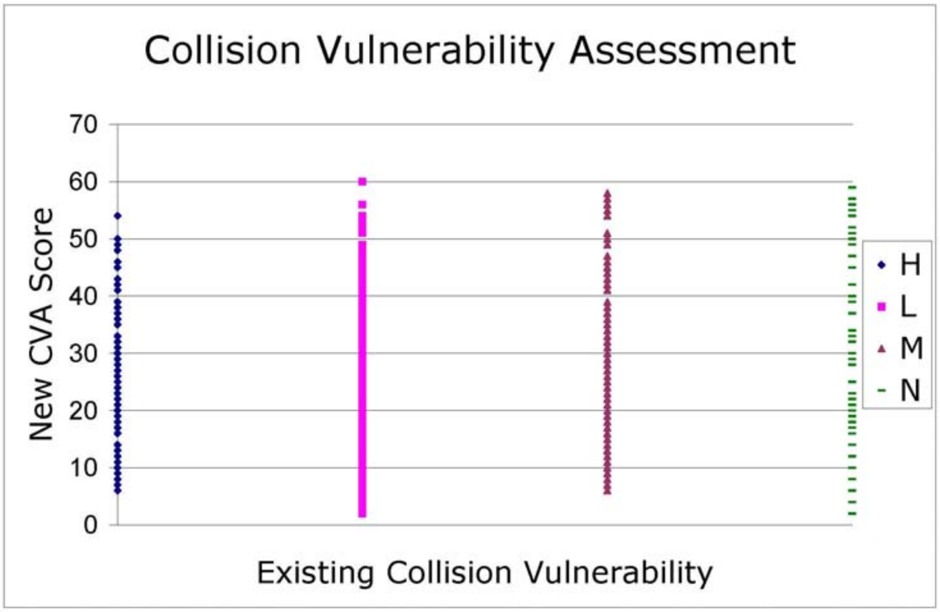


Figure 2-25: Histogram Showing Comparisons between Proposed Changes to the Branch 2A of the CVA Procedure and Vulnerability Classification of Bridges as per Current CVA Procedure.

CHAPTER 3 : BRIDGE HITS IN SELECTED REGIONS OF NYSDOT

3.1. INTRODUCTION

It has been observed from the analysis of NYSDOT bridge hits data that the incidents of multiple hits on bridges in NYSDOT Regions 5 (Buffalo), 8 (Poughkeepsie), 10 (Hauppauge) and 11 (New York City) are significantly higher than other regions. These 4 regions also account for approximately 85.97% of the total bridge hits in the state between 1993 and 2011. Hence, the principal investigator visited these four regions to identify specific causes that may be contributing to hits on these bridges. Appendix E shows bridges hit most frequently in these four regions with bridges visited by the PI shown in bold. This chapter describes in detail specific factors affecting bridge hits in these four regions of the NYSDOT

3.2. REGION 5

The PI visited Buffalo (Region 5) on October 20, 2008 and met with Mr. Richard Kotecki of Region 5 of the NYSDOT. Mr. Kotecki also provided data and photographs of past bridge hit incidents in the region.

3.2.1. BRIDGES VISITED

The PI visited bridges with BIN numbers 5060589, 7708610, 7046420, 7708160 in the Buffalo area during this trip. These bridges are representative of bridges that typically get impacted in NYSDOTRegion 5. BIN 5060589 carries Rte 400 over Rte 240, and is owned by the NYS Thruway Authority but primarily maintained by the NYSDOT. The vertical under-clearance of the bridge is 14.5 feet. However, the bridge has been hit by trucks frequently. The bridge is currently on the program for replacement in 2014.

Bridges with BINs 7708610, 7046420 and 7708160 are representative railway (CSX) bridges with vertical under-clearance lower than the legal limit. Bridge 7708610 is a CSX bridge over George Urban Blvd with a posted vertical under-clearance of 11’-9”. There is significant damage on the approach face of the bridge because of numerous hits, although the interior beams don’t have any damage. The Village of Depew, in conjunction with the Erie County, has installed special traffic signs at several key intersections on the bridge approaches, as shown in Figure 3-1.

Figure 3-1: Low Vertical Under-clearance Sign Installed near the Bridge on George Urban Blvd in the Village of Depew, New York.

The effectiveness of this traffic sign in terms of reducing hits on this bridge is not known yet. Bridge 7046420 is a CSX bridge over Route 354 in Buffalo, NY, with a posted vertical under-clearance of 12'. This route has major trucking outfits located along its corridor. The fascia beams of the bridge have been seriously damaged because of several hits by trucks. Bridge 7708160 is a CSX Bridge over Walden Avenue in Buffalo, New York. The fascia beam of the bridge has undergone extensive damage due to multiple impacts.

In addition to the bridges discussed above, the PI also received information on damages suffered by numerous other bridges. These bridges are again predominantly railway bridges with low vertical under-clearances. Damages to these bridges are shown in photographs attached in the next section.

3.2.2. OBSERVED BRIDGE DAMAGES

Figures 3-2 to 3-14 show damages to bridges in the NYSDOT Region 5 because of multiple impacts by trucks.

Figure 3-2: Damages to the Girder of BIN 5060589 Because of Multiple Hits.

Figure 3-3: Damages to the Girder of Bridge 7708160 Because of Multiple Hits.

Figure 3-4: Damages to the Front Face of the Bridge 7708610 Because of Multiple Hits.

Figure 3-5: Damages to the Front Face of the Bridge 7046420 Because of Multiple Hits (hit 41 times).

Figure 3-6: Damages to the Bridge 1001410 Observed During an Inspection.

Figure 3-7: Damages to the Bridge 1092032 Observed During an Inspection.

Figure 3-8: Damages to the Bridge 1062872 on the Route 400 over Jamison Road Observed During an Inspection.

Figure 3-9: Impact to the Bridge 7050631 on Big Tree Road in Hamburg, New York.

Figure 3-10: Impact to the Bridge 1001410.

Figure 3-11: Impact to the Bridge 5045751 on March 22, 2006.

Figure 3-12: Impact to the Bridge 7050634 on Sept. 24, 2007.

Figure 3-13: Impact to the Bridge 7707520.

Figure 3-14: Impact to the Bridge 1021079 on Cleveland Drive in Buffalo, New York.

3.2.3. FACTORS CONTRIBUTING TO BRIDGE HITS IN REGION 5

Based on the visit to Region 5 and discussions with Mr. Kotecki, the following factors be contributing to a large number of hits in Region 5:

1. More than 98% of the hits in Region 5 are to bridges carrying CSX that typically have low under-clearance (below the legal limit). These bridges typically pass over local streets which have businesses with a large amount of trucking activity. such as American Axle & Manufacturing, are located. In fact, a majority of hits have occurred on bridges in this type of high trucking area. For example, Figure 3-15 shows the locations of 87 out of 139 multiple hits in the Region 5 that occurred on railway bridges in a very small geographical area and are indicated by the encircled area. The figure also shows locations of businesses with trucking activities by square symbols. It is observed that bridges that have been hit multiple times are in an area of significant trucking activity.
2. Although there are low under-clearance signs near bridges hit frequently, these signs are either on the bridge or are very close to it. By the time a truck driver sees these signs, it is already too late for them to stop.
3. A majority of these hits also occur during the night, when trucks pull out from factories and drive on roads with low clearance bridges. Low under-clearance signs on these bridges are hardly visible during the night.

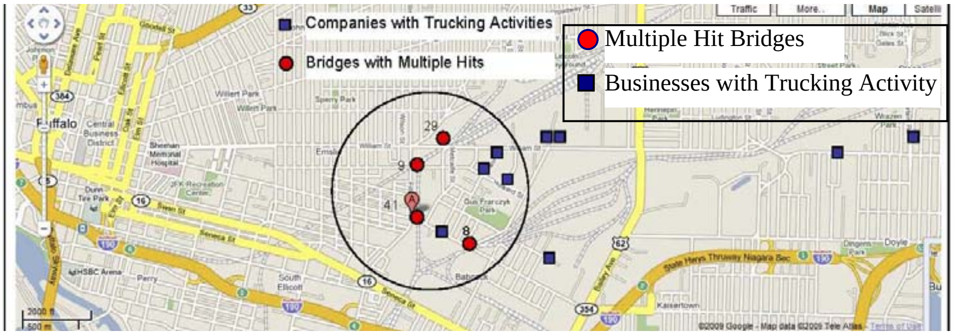


Figure 3-15: Locations of Bridges Hit Multiple Times and Trucking Activity in the Region 5 (based on Google Maps)

4. Multiple hits areas in Region 5 are concentrated in the vicinity of the Canadian border, as shown in Figure 3-16. Confusion in translating between SI and US units may play a role in trucks from Canada hitting low under-clearance bridges in Region 5.
5. The bridge 1022810 on the Kensington Expressway has an under-clearance of 14'10". However, it has been hit as a result of trucks bouncing on a bump on the road under the bridge.

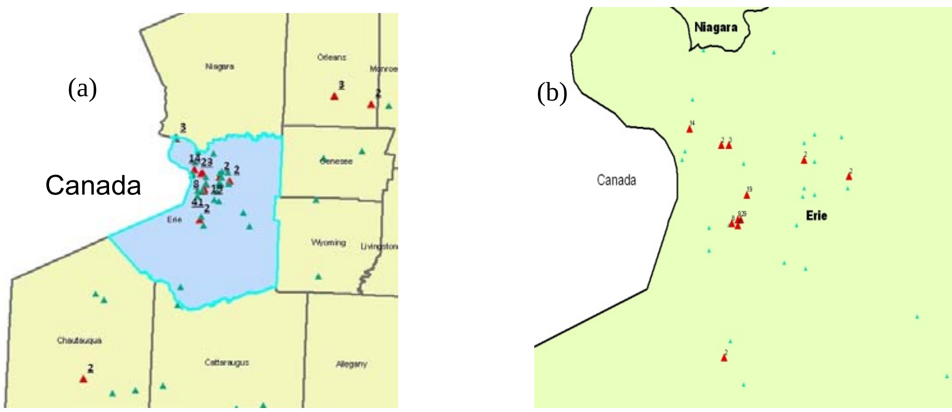


Figure 3-16: (a) Concentration of Bridge Hits in Erie County near the Canadian Border in Region 5 of the NYSDOT; (b) Zoom View of Erie County area in the Figure (a).

3.3. REGION 8

The PI visited bridges that have been hit multiple times in Region 8 on March 9, 2009 with Mr. Eric Foster of the NYSDOT Region 8. Mr. James Flynn and Mr. Winchell Auyeung from the NYSDOT office in Albany also accompanied the visit.

3.3.1. BRIDGES VISITED

The PI visited the 10 bridges in Region 8 listed in Table 3-1 below. Table 3-1 also shows the number of times each of these bridges was hit. It is observed that almost all the bridges that have been hit multiple times in Region 8 are stone arch or frame types of bridges over parkways (primarily the Hutchinson Parkway). Figure 3-17 shows pictures of the bridges in Region 8 that the PI visited.

Table 3-1: Bridges with Multiple Hits in Region 8 Visited by the PI.

BIN	Number of Hits	BIN	Number of Hits
1006160	25	5500100	24
1037390	62	5500150	14
1037570	18	5500160	17
3037170	24	5500200	63
5500050	22	5500860	15

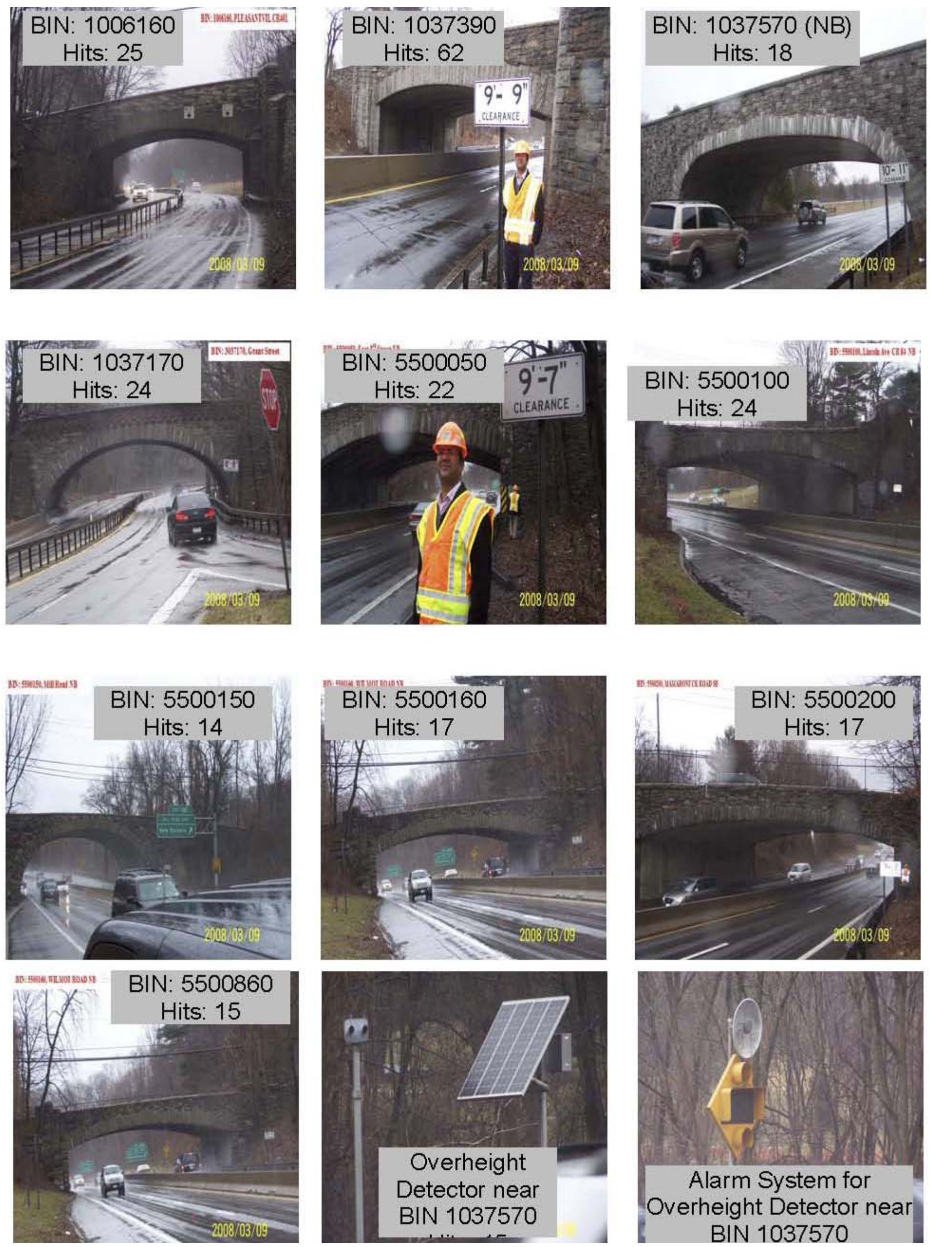


Figure 3-17: Pictures of Most Frequently Hit Bridges in Region 8. Last two pictures show over-height detection system installed near a bridge (system not functional).

3.3.2. OBSERVED BRIDGE DAMAGES

Although some of the bridges have been hit more than 50 times, there was no visible sign of significant damage except for some scratches and scrapes on the underside surface of the bridge. Figure 3-18 shows some typical damages to the bridges in Region 8 as a result of multiple hits.

Figure 3-18: Typical Damages to the Bridges in Region 8 because of Multiple Hits.

3.3.3. FACTORS CONTRIBUTING TO BRIDGE HITS IN REGION 8

Almost all bridge hits can be attributed to an illegal presence of trucks on parkways (most prominently the Hutchinson Parkway (In Connecticut, it becomes Merritt Parkway)). Stone arch and frame type bridges on parkways in the Region 8 typically have a vertical under-clearance in the range of 8 feet to 11 feet.

1. Signs warning drivers about the low vertical under-clearance are not easily visible or obvious. For example, Figure 3-19 shows the ramp to the northbound lane of the Hutchinson Parkway from the King Street Bridge, which has been hit 62 times. The bridge is approximately 100 ft from the end of the ramp. As a truck driver who has entered the ramp by mistake exits from the ramp, he has very small amount of time to stop before hitting the bridge. The only sign warning drivers not to enter the ramp is “Passenger Cars Only”, as shown in Figure 3-20. This sign appears before the entrance to the ramp on King Street, is not easily visible to drivers entering the ramp, and may not be adequate to warn truck drivers about a possible collision with a low under-clearance bridge ahead. This applies to all bridges that have been hit multiple times in Region 8.

Figure 3-19: Ramp from King Street to Hutchinson Parkway (Photo from Google Maps)

Figure 3-20: Sign at the Entrance of Parkways in Region 8.

2. A sign at King Street ramp to the Hutchinson Parkway may also be contributing to increased truck traffic on the Hutchinson Parkway, that itself may lead to increased impacts on the King Street Bridge. Figure 3-21 shows the entrance on the right to the NB Hutchinson Parkway from King Street. The sign on the entrance ramp doesn't warn drivers not to enter the Hutchinson Parkway. On the other hand, there is a sign on the left that prohibits trucks over 4 tons from making a left turn on a local street (Glen Ridge Rd). Since truck drivers are prohibited from turning left, they may be tempted to turn right on the ramp to the Hutchinson Parkway.

Figure 3-21: Entrance to the Hutchinson Parkway from the King Street (Photo from Google Maps)

3. It has been observed from the data collected by the New York State Troopers after a hit on a bridge that a large number of truck drivers use GPS for routing and enter a parkway following the instructions from the GPS device. A majority of these trucks are from out of state locations.

4. It seems that a majority of drivers entering parkways and hitting bridges aren't aware of the height of their truck with the cargo.

5. Almost all hits in Region 8 are to bridges over parkways. Figure 3-22 shows a plot of locations of multiple hits in Region 8. It is observed that a majority of the hits are on bridges over the Hutchinson Parkway. Many truck drivers may be taking the Hutchinson Parkway route for a short cut to New York City or to transfer to another major route.

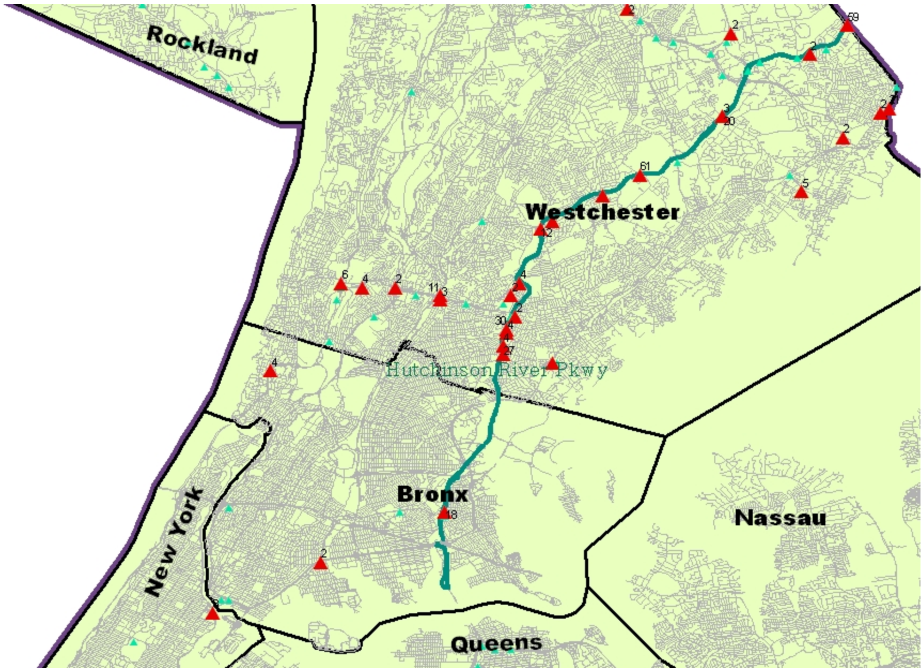


Figure 3-22: Multiple hits on Bridges along the Hutchinson Parkway in Region 8.

3.4. REGION 10

The PI visited 9 bridges that have been hit multiple times in Region 10 with Mr. Paul Besmertnik of NYSDOT Region 10 on March 16, 2009. Detailed information on these bridges, including number of hits, is shown in Table 3-2. It has been observed from analysis of bridge hits data that most of the hits are on bridges over the Northern State Parkway(NSP), except for a bridge (BIN # 1049310) carrying Upper Half Hollow Road over I-495 (Long Island Expressway) and a bridge over the Heckscher State Parkway carrying Route 111 (BIN # 1037019). Figure 3-23 shows pictures of some of the bridges in Region 10 visited by the PI.

Table 3-2: Bridges visited in the Region 11 (as of the date of visit).

BIN	Number of Hits	BIN	Number of Hits
1018399	18	1058259	17
1058080	14	1059440	13
1058210	14	1049310	11
1036799	19	1058950	9
1058260	7	1037019	8

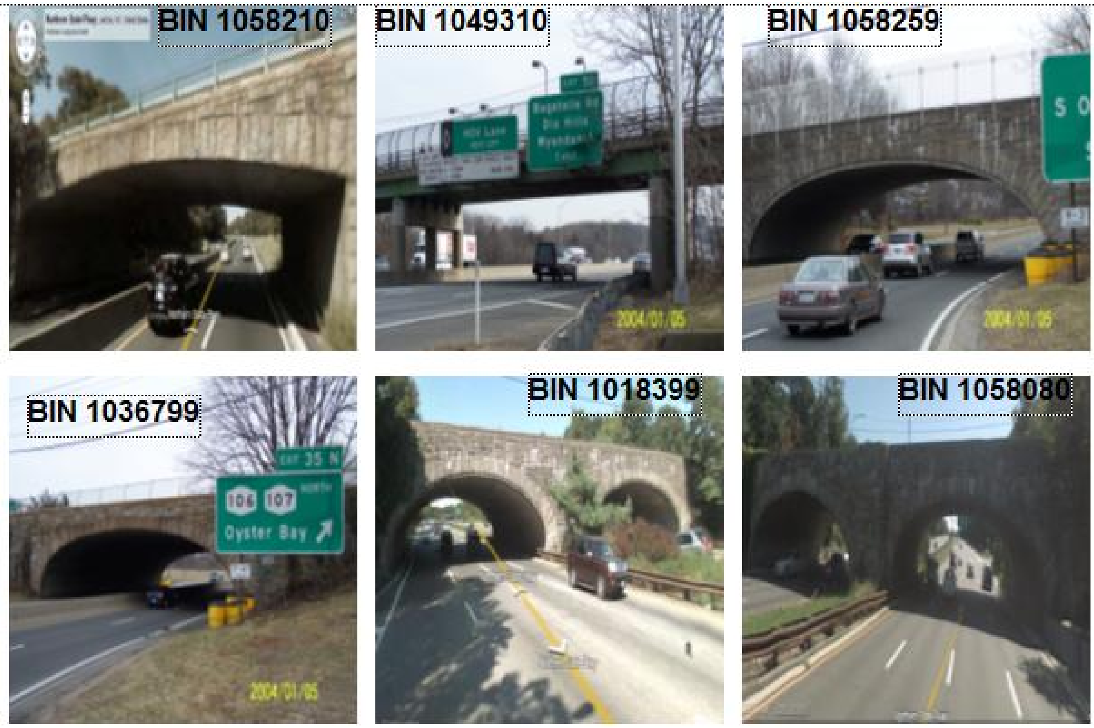


Figure 3-23: Typical Bridges in Region 10 Hit Multiples Times by Trucks.

3.4.1. OBSERVED BRIDGE DAMAGES

Bridges on the Northern State Parkway are typical stone arch or frame type of bridges, similar to those on the Hutchinson Parkway in Region 8. There was no visible damage observed to these bridges. Some damage occurred to the sign on the bridge over I-495 (BIN 1049310) due to an impact from a truck. (See Figure 3-24).

Figure 3-24: Damage to the Sign on the Bridge 1049310 Over I-495.

3.4.2. FACTORS CONTRIBUTING TO BRIDGE HITS IN REGION 10

Unlike other regions of the NYSDOT, numerous signs clearly warning truck drivers not to enter the NSP or other parkways were found. In fact, the PI counted approximately 14 signs from S. Oyster Bay Rd to the ramp of the NSP warning truck drivers not to enter the parkway.

Despite these signs, the following factors may be contributing to multiple hits on bridges in Region 10 of the NYSDOT:

1. The ramps to both the Northern State Parkway and I-495 from the Seaford Oyster Bay Expy are within 0.25 miles of each other (see Figure 3-25). Many truck drivers bound for I-495 may be entering the NSP because of this confusion. Improved planning of locations of signs may be helpful in reducing this confusion.

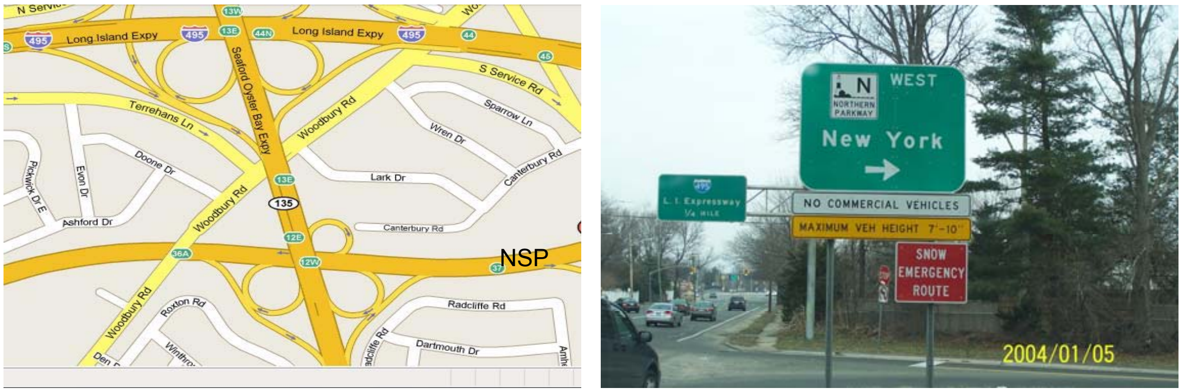


Figure 3-25: Locations of the NSP and the I-495 Ramps from the Seaford Oyster Bay Expwy.

2. Signs at entrances to the NSP allow vehicles with a maximum height of 7'10" to enter the parkway. Many truck drivers, who are aware that the bridge under-clearance is more than this, may be ignoring the sign.

3.5. REGION 11 (NEW YORK CITY)

New York City Department of Transportation has been carrying out a "Bridge Vertical Clearance Signage Pilot Study" to reduce hits to bridges that have been hit multiple times. Figure 3-26 shows a map with locations of bridges being studied in this program. The PI visited several of these bridges with Mr. Andrew Hoang of the NYCDOT on April 20, 2009.

Unlike other regions, bridges in Region 11 have undergone significant damage because of hits by over-height trucks. Figure 3-27 shows recorded damages to some of the bridges in the New York City area because of impacts from trucks. For example, the bridge carrying Westchester Avenue over the Hutchinson Parkway has been damaged so severely that it had to be stabilized by supporting the bridge with tendons hanging from a beam installed across the bridge (see Fig. 3-27(a-c)). One of the spans of the Waterbury Ave Pedestrian Bridge over the Bruckner Expressway (Figures 3-27 (d)-(f)) was completely destroyed by a dump truck. The Willis Ave. Bridge over Bruckner Boulevard (Figures 3-27(g)-(i)) was significantly damaged by multiple hits. A pedestrian bridge over the Belt Parkway (Figures 3-27(j)-(l)) sustained damage because of a truck impact. The bridge, although safe, is twisted about its longitudinal axis. The interior portion of the arch of the bridge 2246160 (and similar other bridges) in Central Park has been severely damaged by dump trucks passing under this bridge illegally. The arch had to be stabilized by plates and anchors over the deck.

3.5.1. FACTORS CONTRIBUTING TO BRIDGE HITS IN REGION 11

The factors affecting bridge hits in the New York City region (Region 11) are mostly related to:

1. Illegal use of Parkways, most notably the Hutchinson Parkway, by trucks.
2. Road geometry and a bump causing damages to a bridge over Brooklyn Queens Expwy near the Brooklyn Bridge.
3. Trucks carrying unsecured construction equipment and dump trucks on the BQE and other expressways. Although trucks are allowed on these expressways, unsecured construction equipment and dump trucks has caused significant damages to pedestrian bridges.

Figure 3-26: Bridge Vertical Clearance Signage Pilot Study Locations in New York City Area.

Figure 3-27: Damages to the Bridges in the New York City Area (Region 11)

3.6. CONCLUSIONS

Based on the visit to the four regions of NYSDOT, it has been observed that the nature of bridge hits in Regions 5 and 11 are different where as those in Regions 8 and 10 are similar. Prevention of or reduction in bridge hits in these regions will need different solutions. Some site specific solutions are presented in next chapter of this report.

CHAPTER 4 : SPECIFIC BRIDGE HIT PREVENTION FOR SELECTED NYSDOT REGIONS

4.1. INTRODUCTION

The PI visited four regions of NYSDOT (Region 5, Region 8, Region 10 and Region 11 (NYC)) to identify prominent factors responsible for high rates of truck impacts to bridges and possible preventive measures. A detailed description on visits to selected bridges in these 4 regions is presented in the Chapter 3 of this report. Based on these field visits, specific measures to reduce bridge hits in these 4 regions are presented in this chapter.

4.2. SPECIFIC BRIDGE HIT PREVENTION FOR REGION 5

As described in the Chapter 3, bridges that typically get impacted by vehicles in Region 5 are railroad bridges that carry the CSX Railroad. The following measures may be effective in reducing frequencies of hits at these locations.

(A) Outreach and Education

Typically, bridges that have been hit multiple times in Region 5 are located over roads that have businesses involved in significant trucking activities. This area is also close to the Canadian border and many truck drivers may be confused between SI or US units and the height of the truck.

Education and outreach to businesses in this area about the risks and economic impacts caused by impacts to low-clearance CSX bridges may be a helpful tool for educating drivers. These outreach activities may include:

- Raising awareness about the frequency of bridge hits in the area through meetings with leading trucking industries.
- Educating the trucking industry about any confusion or misunderstanding that may be leading to increased hits.
- Flyers and posters about damages caused by bridge hits and the detrimental impact on their businesses.
- Requiring truck drivers to post the exact height of their truck (including cargo) in US units in the cabin so that it is within eyesight of the driver.

(B) Signage and Lighting:

Most of the CSX bridges hit multiple times had vertical under-clearance signs on the bridge itself. These signs aren’t sufficient due to poor visibility during nights when the trucking activity is likely to be significant. The recommended Signage and Lighting measures are**:**

- Locate low vertical under-clearance signs both on the bridge and at least before the safe stopping distance from a bridge.
- Lighting to illuminate signs at night.
- Locate low vertical under-clearance warning signs and ‘No Left Turn’ or ‘No Right Turn’ signs on roads from driveways of trucking businesses or businesses with trucking activities in the direction of low under-clearance bridges. These signs should be designed to comply with MUTCD, while conveying intended messages to drivers.

(C) BIN 1022810 has been hit because of a bump in the road, although the vertical under-clearance is 14'10''. It is possible that the under-clearance of this bridge became smaller because of paving. Measures should be taken to:

- Verify under-clearance.
- Smooth bump near the bridge.

4.3. SPECIFIC BRIDGE HIT PREVENTION FOR REGION 8

Almost all hits to bridges in Region 8 can be attributed to the illegal presence of trucks on Parkways. The following measures are recommended in order to reduce incidents of bridge hits in the region:

(A) **Enforcement:** Almost all hits are caused by the illegal presence of trucks on Parkways. This behavior can be discouraged by imposing penalties (e.g., civil penalties by the NYSDOT enforcement division) that will make the use of parkways economically unattractive for trucks. The level of penalties must be decided by local and state agencies. Trucks causing multiple hits because of their presence on parkways should be penalized more strictly.

(B) **Signage:** It has been observed that most of the signs on low under-clearance bridges are located on the bridge itself. Most of the impacts occur because of a truck entering a Parkway ramp and facing the bridge within 50 yards after exiting the ramp. Many of these incidents can be prevented by:

(i) Installing low vertical under-clearance signs at the entrance of a Parkway that are clearly visible to truck drivers before entering the ramp. This is in addition to the sign installed on the bridge.

(ii) Installing "No Commercial Vehicles" and "No Trucks or Tractors" signs at the entrance of the ramp, that are clearly visible to truck drivers before they enter the ramp.

(iii) Installing "TRUCKS STOP ON SIDE" or an equivalent sign complying with the MUTCD 50 yards before the bridge. It should be noted that this sign is not in the MUTCD. Hence, the NYSDOT Traffic and Safety Division must decide on an equivalent sign in the MUTCD or seek a waiver to install this sign.

(iv) The bridge carrying King St over Hutchinson Parkway has been impacted 62 times. Bridges on either side of this bridge over Hutchinson Parkway have been impacted less frequently. This may be occurring due to a misleading "No Left for Trucks" sign, which may imply that a right turn is allowed (See Figure 4-1 below). This confusion should be corrected by installing a "No Trucks or Tractors" sign at the ramp of the Parkway.

(C) **Over-Height Detection Systems (OHDS):** Although improved signage may help in reducing the number of multiple hits on bridges, over-height detection systems may be necessary near some bridges to provide additional warning signs to negligent drivers.

A detailed description of some of the most effective over-height detection systems based on the Phase II survey of various state DOTS is presented in Appendix F. Technical specifications of some selected OHDS are presented in Appendix G. Desirable features of an over-height detection system should be:

(i) Automatic detection, with minimum false positives.

(ii) Applicable for low speed highways.

(iii) Capability to activate red light and warning message.

(iv) Relaying of warning message to police dispatch.

(v) Automatic video-recording during activation.

It is not necessary to install OHDS on all ramps. Ramps to the Hutchinson Parkway in the vicinity of frequently hit bridges may be the best candidates. It should be noted that the installation of an OHVD System with the features described above will facilitate in developing a better understanding of factors contributing to multiple hits (e.g., reasons a truck entered a ramp of parkway, out of state or in-state trucking companies, etc.). This may be helpful in designing effective mitigation strategies in future (e.g., enforcement policies, outreach materials, etc.) to reduce bridge hits.

Figure 4-1: Signs on King Street near the Entrance of Hutchinson (Merritt) Parkway (Photo from Google Maps).

4.4. SPECIFIC BRIDGE HIT PREVENTION FOR REGION 10

Although Region 10 has extensive signage on routes leading to ramps of the Northern State Parkway (NSP) and on the ramps of the Parkway, low vertical under-clearance bridges in this region are still being impacted. Figure 4-2 shows the histogram of annual hits on bridges in this region. It is observed that after a maximum of 68 impacts in 2005, the number of impacts in 2006 and 2007 decreased to 48 and 39, respectively. The significant decrease in impacts in 2006 and 2007 could be attributed to increased signage in Region 10, since most of the signs in Region 10 were installed after 2005.

Based on visits to various bridges in Region 10, the following three prevention measures are proposed:

(A) **Over-Height Vehicle Detection Systems:** It has been observed that ramps to both the NSP and I-495 from the Seaford Oyster Bay Expressway are within 0.25 miles of each other. The resulting confusion due to their proximity to each other results in many trucks entering the NSP and hitting the Seaford Oyster Bay Expressway. An over-Height Vehicle Detection System (OHVDS) with red light and warning message, as described previously for Region 8, may help the truck drivers, that illegally enter the ramp, stop before impacting the bridge.

(B) **Enforcement:** As described for Region 8, enforcement is necessary to discourage truck drivers entering Parkways.

(C) **Signage Message:** All Signs in Region 10 prohibit vehicles with a height more than 7'10'' from entering Parkways. Truck drivers, knowing that bridge clearances are higher than this, may not be taking these signs seriously. Signs showing posted legal height of the bridge may be more effective in preventing truck drivers from entering parkways.

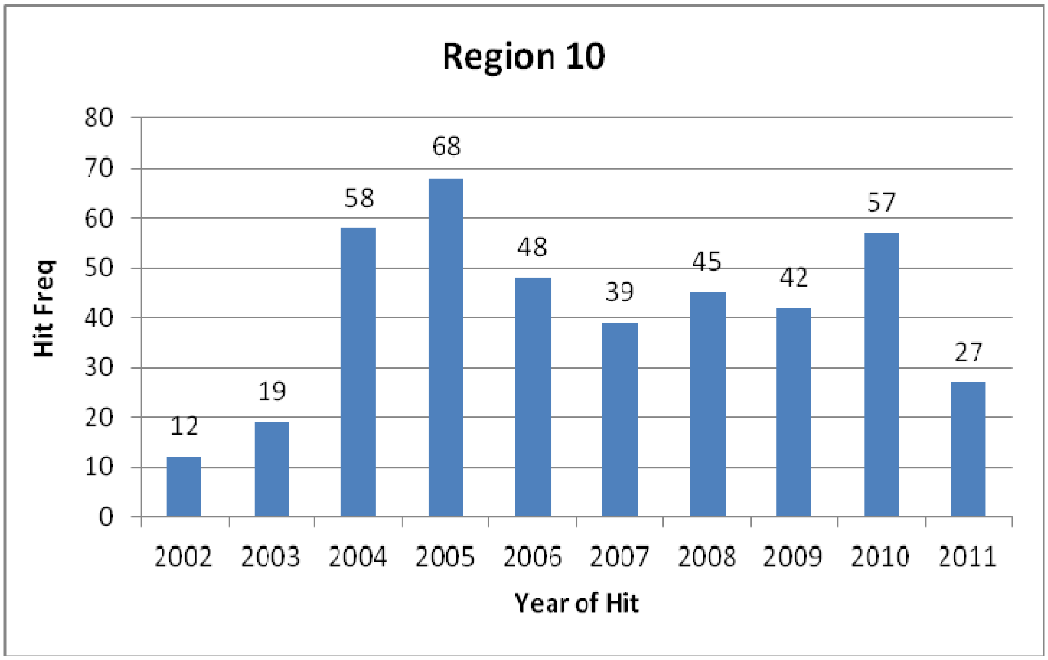


Figure 4-2: Annual Bridge Hit Frequencies in Region 10 of NYSDOT.

4.5. SPECIFIC BRIDGE HIT PREVENTION FOR REGION 11

Based on visits to various bridges, the following specific measures are recommended for Region 11:

(A) **Enforcement:** Like Regions 8 and 10, a significant numbers of impacts occur on bridges over parkways. One proposed measure that would aid in deterring truckers from entering the Parkways is increased enforcement as described for Region 8.

(B) Road geometry and a bump are causing impacts to a bridge over the Brooklyn Queens Expressway (BQE) near the Brooklyn Bridge. At this site,

- Maximum speed limit should be reduced.
- Bump should be removed and placed away from the bridge if speed control is the objective.
- Measures should be taken to increase the bridge vertical under-clearance by milling down the pavement. An increase of under-clearance by only a few inches can make a significant difference.

Bridges over the BQE and other expressways are frequently impacted by improperly secured construction equipment/dump trucks, resulting in serious damages. Over-Height Vehicle Detection Systems should be installed before all such vulnerable bridges.

4.6. OTHER GENERAL MEASURES:

(A) It has been observed from data collected by New York State Troopers after an impact that a large number of drivers use general purpose GPS. These systems don't warn truck drivers about Parkways and associated low vertical under-clearance bridges. Mandating the use of a GPS for trucks, that will automatically avoid Parkways and low vertical under-clearance during routing. Hence, this system could have a significant impact on reducing the frequency of vehicle impacts on bridges. This system is already available, as described in the next chapter.

(B) It is possible that truck drivers may not know the exact height of their cargo, or may not be able to make a decision whether their cargo is higher than the vertical under-clearance of the bridge based on their recollection of the cargo height. A requirement to post the vehicle height inside the truck cabin, within the eyesight of the driver, may be helpful in making a decision to stop the truck before impacting the bridge.

(C) Many drivers, knowing that the posted under-clearance may be less than actual one, may not trust posted vertical under-clearance signs. Posting both legal and actual clearances, combined with education and outreach, may be helpful in reducing any doubts the drivers may have.

4.7. OVER-HEIGHT DETECTION SYSTEMS

Several effective over-height detection systems were identified through the stage-2 survey presented in Chapter 2. Two systems, HISIK 450 by SICK and Double Eye Z-Pattern by Trigg Industries, have been found to perform extremely well on highways by many state DOTs. A product survey has been done to identify important features of these two systems. In addition to these two systems, a survey of systems similar to these two systems has also been carried out. It should be noted that a majority of bridge hit incidences in Regions 8 and 10 might be prevented by systems with lesser features than those of HISIK 450 and Double Eye Z-Pattern systems (e.g., unidirectional, low speed applicability, red light with passive sign to stop on red, etc.). In addition to automatic over-height detection systems, a vehicle height clearance detector manufactured by Han-D Man & Co has also been investigated. The vehicle height clearance detector system costs $875 (without installation) and operates on the principle that an over-height vehicle will hit a flexible arm to activate an alarm. Hence, the system is guaranteed to be successful. However, legal liability issues related to damages caused to a vehicle or injury to occupants caused by the retracting arm needs to be considered by NYSDOT before selecting this system. If acceptable, the system can be installed on the ramps of all parkways to drastically minimize bridge hits on parkways.

CHAPTER 5 : COMPUTER PROGRAM FOR BRIDGE IMPACT ANALYSIS

5.1. INTRODUCTION

A computer program has been developed to analyze bridge hit data in New York State. NYSDOT provided a collision Database containing information collected on impact of bridges by trucks. Almost all hits in the database are for impact of overheight vehicles to low clearance bridges. This database has been combined with selected tables from Winbolts to create a combined hit database, as shown in the schematics in Fig 5-1. This combined database has a total of 29 tables that are used in the analysis of bridge hit data by the program. Table 5-1 shows detailed information on these 29 tables and their origin (Winbolts or collision database). The computer program utilizes the combined hit database to facilitate the analysis of hit data based on numerous factors, e.g., hits by NYSDOT regions, county, bridge characteristics, etc.

When new hit data becomes available, the "Collision Database" will need to be updated with the new data. Then, an update module in the computer program database will allow automatic updating of the Combined Hit Database.

5.2. FUNCTIONALITIES OF THE COMPUTER PROGRAM

The computer program allows the following three types of operations on the combined hit database: (i) Plotting, (ii) Before and After Analysis and (iii) BIN Query. Features of each of these operations are described in the following.

5.2.1. PLOTTING

The program can analyze bridge hit data and generate plots for different scenarios, such as bridge hits by year, by NYSDOT region, etc. Data analysis for any scenario can be done by considering (i) all hit data (including single hit data), (ii) only multiple hit data (i.e., hit data corresponding to multiple (more than 1) hits on bridges), (iii) all hit bridge (including bridges hit single time) or (iv) only bridges hit multiple times. The program can generate statistical data and plots for the following 23 scenarios:

- Bridge hits by year
- Bridge hits by NYSDOT Regions (Histogram)
- Bridge hits by NYSDOT Region (on a GIS Map)
- Bridge hits in NYSDOT Regions without parkways
- Bridge Hits in NYSDOT Regions with parkways
- Bridge hits by county
- Bridge hits by feature carried on
- Bridge hits by feature carried under
- Bridge hits by superstructure design type
- Bridge hits by maximum vertical clearance under (ft)
- Bridge hits by minimum vertical clearance under (ft)
- Bridge hits by posted vertical clearance under (ft)
- Bridge hits by vehicle type

Table 5-1: Data Table in Combined Hit DatabaseName

Table No.	Components	Source
1	BIN	Bridge Hit Database
2	Date of Collision: dd/mm/yy	Bridge Hit Database
3	Span	Winbolts
4	Region	Winbolts/hit database
5	County	Winbolts/hit database
6	Feature carried on	Winbolts RC12
7	Feature carried under	Winbolts RC13
8	Superstructure Design Type	Winbolts RC15
9	Bridge Component Hit	Bridge hit database
10	Maximum Vertical Clearance Under (ft)	Winbolts RC 13
11	Minimum Vertical Clearance Under (ft)	Winbolts RC 13
12	Posted Vertical Clearance Under (ft)	Winbolts RC06
13	Vehicle Type	Bridge hit database
14	Cargo Type	Bridge hit database
15	BSA Collision Class	Winbolts BSA Data
16	BSA Collision Rating	Winbolts BSA Data
17	Necking (ft)	Winbolts RC02 curb-to-curb width vs roadway approach width
18	AADT (on)	Winbolts RC 12 (AADT*Daily Truck Traffic)
19	AADT (under)	Winbolts RC 13 (AADT*Daily Truck Traffic)
20	Damage	Bridge hit database
21	Total Horizontal Clearance (ft)	Winbolts RC 13
22	Left Clearance (ft)	Winbolts RC 13
23	Right Clearance (ft)	Winbolts RC 13
24	Comment	Bridge hit database
25	Report Name	Bridge hit database
26	Picture File Name	Bridge hit database
27	Movie File Name	Bridge hit database
28	Mitigation Device	Bridge hit database
29	Date Mitigation Device installed	Bridge hit database

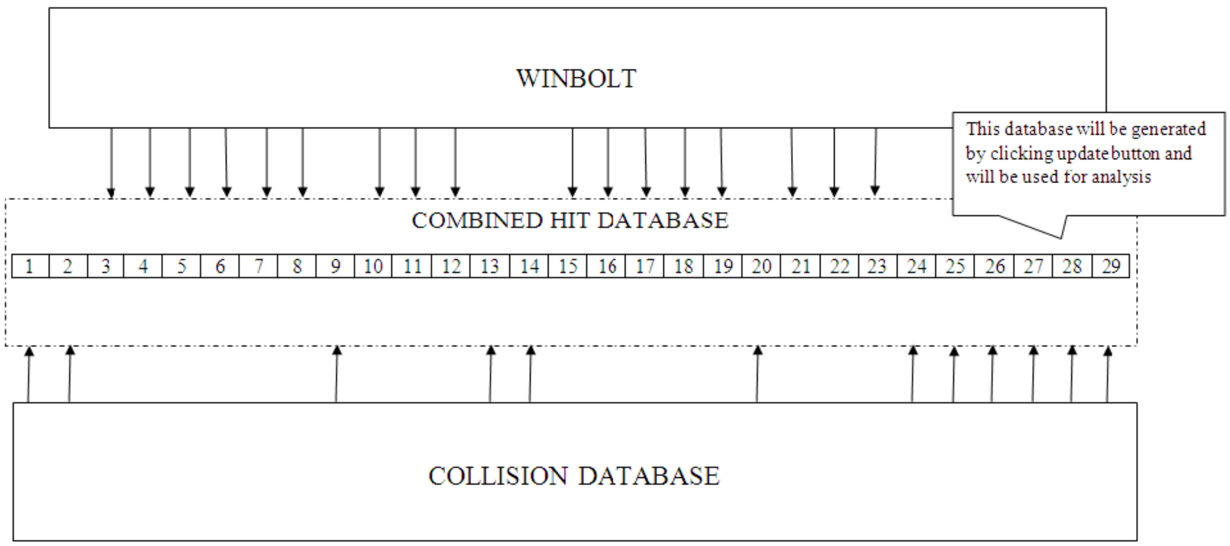


Figure 5-1: Schematics of Generating Combined Hit Database

- Bridge hits by cargo type
- Bridge hits by BSA collision class
- Bridge hits by BSA collision rating
- Bridge hits by necking (ft)
- Bridge hits by AADT (on)
- Bridge hits by AADT (under)
- Bridge hits by total horizontal clearance (ft)
- Bridge hits by left clearance (ft)
- Bridge hits by right clearance (ft)
- Bridge hits by approach speed range

Description of the 23 scenarios:

Bridge Hits by year: Generates histogram of annual bridge hits in New York State.

Bridge Hits by Region (Histogram): Generates histogram of bridge hits in different regions of NYSDOT during a selected period.

Bridge Hits by Region (GIS): Generates GIS map of bridge hits in different regions of NYSDOT during a selected period.

Bridge Hits by Region without parkways: Generates histogram of bridge hits in NYSDOT regions without parkways during a selected period.

Bridge Hits by Region with parkways: Generates histogram of bridge hits in NYSDOT regions with parkways during a selected duration. Regions with parkways are Rochester, Buffalo, Poughkeepsie, Hauppauge and New York City.

Bridge Hits by County: Generates histogram of bridge hits in different counties during a selected period.

Bridge Hits by feature carried on: Generates histogram of bridge hits based on different types of features carried on impacted bridges in New York State during a selected period.

Bridge Hits by feature carried under: Generates histogram of bridge hits based on different types of features carried under bridges in New York State during a selected period.

Bridge Hits by superstructure design type: Generates histogram of bridge hits for different superstructure design types of impacted bridges during a selected period.

Bridge Hits by maximum vertical clearance under (ft): Generates line plot of bridge hits for different maximum vertical clearances under impacted bridges during a selected period.

Bridge Hits by minimum vertical clearance under (ft): Generates line plot of bridge hits for different minimum vertical clearance under impacted bridges during a selected period.

Bridge Hits by posted vertical clearance under (ft): Generates line plot of bridge hits based on different posted vertical clearances under impacted bridges during a selected period.

Bridge Hits by vehicle type: Generates histogram of bridge hits based on different types of vehicles impacting bridges during selected period. Currently, the collision database doesn't have sufficient information on this item. Some information is derived from comment section.

Bridge Hits by cargo type: Generates histogram of bridge hits based on different types of cargos carried by trucks impacting bridges during a selected period. Currently, the collision database doesn't have sufficient information on this item. Some information is derived from comment section.

Bridge Hits by BSA collision class: Generates histogram of bridge hits based on different collision classes for bridges during selected period. Information on collision classes is generated on the basis of NYSDOT Collision Vulnerability Manual and is imported from Winbolts database.

Bridge Hits by BSA collision rating: Generates histogram of bridge hits based on collision rating for impacted bridges during a selected period. Collision rating is generated on the basis of NYSDOT Collision Vulnerability Manual and is imported from Winbolts database.

Bridge Hits by necking (ft): Generates line plot of bridge hits on the basis of necking of impacted bridges during a selected period.

Bridge Hits by AADT (on): Generates histogram of bridge hits based on ADTT (on) ranges for impacted bridges during a selected period.

Bridge Hits by AADT (under): Generates histogram of bridge hits based on ADTT (under) ranges for impacted bridges during a selected period.

Total horizontal clearance (ft): Generates line plot of bridge hits for different horizontal clearance for bridges of New York State during selected duration.

Left clearance (ft): Generates line plot of bridge hits for different left clearance for bridges of New York State during selected duration.

Right clearance (ft): Generates line plot of bridge hits for different right clearance for bridges of New York State during selected duration.

Speed range: Generates histogram of bridge hits for different speed limits near bridges during a selected duration. Currently, the collision database doesn't have sufficient information on this item.

5.2.2. BEFORE & AFTER ANALYSIS

The computer program can be used to analyze "before and after" scenarios for different cases. For example, if a major policy or regulation has been implemented on a certain date, the program can analyze and provide Bridge hit data before & after that date. Before and after analysis can be carried out for the following scenarios:

(i) By BIN: Analysis of impacts to a particular bridge before and after a date

(ii) By Region: Analysis of impacts to bridge in a specific region before and after a date

(iii) By Statewide (Total): Analysis of impacts in the entire New York State before and after a date.

(iv) By Statewide (Region Histogram): Analysis of impacts in each region of NYSDOT before and after a date. The program shows a plot of comparison between histograms for all regions before and after a date.

(v) By Statewide (Region GIS): Analysis of impacts in each region of NYSDOT before and after a date. The program shows a plot of comparison between before and after hits for all regions in a GIS map.

(vi) By Mitigation Device: If a mitigation device, such as overheight detector, has been used, the program can analyze before and after scenario to evaluate the effectiveness of a particular device used across the state. Currently, the database doesn't any data on protective devices. This functionality is incorporated for future use.

5.2.3. BIN QUERY

This function displays following important information for one particular selected bridge by its BIN number: Total Number of Hits, Region, County, Feature Carried (On), Feature Carried (Under), Superstructure Design Type, Maximum Vertical Clearance Under (ft), Minimum Vertical Clearance Under (ft), Posted Vertical Clearance Under (ft), BSA Collision Class, BSA Collision Rating, Necking (ft), AADT (On), AADT (Under), Total Horizontal Clearance (ft), Left Clearance (ft), Right Clearance (ft), and Mitigation Device.

5.3. INSTALLING THE COMPUTER PROGRAM:

The computer program can be installed by following the instructions below. Please make sure that the drive where the program is to be installed isn't written protected.

Step 1: Save all the files in folder "NYSDOT Bridge Hit Analysis"
Step 2: Double Click the folder to open the window containing four folders as shown in Fig. 5-2.

- The database folder contains the source database used by the program.
- The Docs folder contains all reference materials used in the development of the program.
- The Matlab Scripts folder contains the MATLAB programs used by the program.

- The software folder contains two sub-folders: Executables and Source Codes. "Executables "folder contains the Main Program for the analysis and the Matlab Runtime Engine.
- Source Codes folder contains source codes for the program. These source codes can be used in future to expand the capability of the program or to adapt to a newer Windows Operating System.

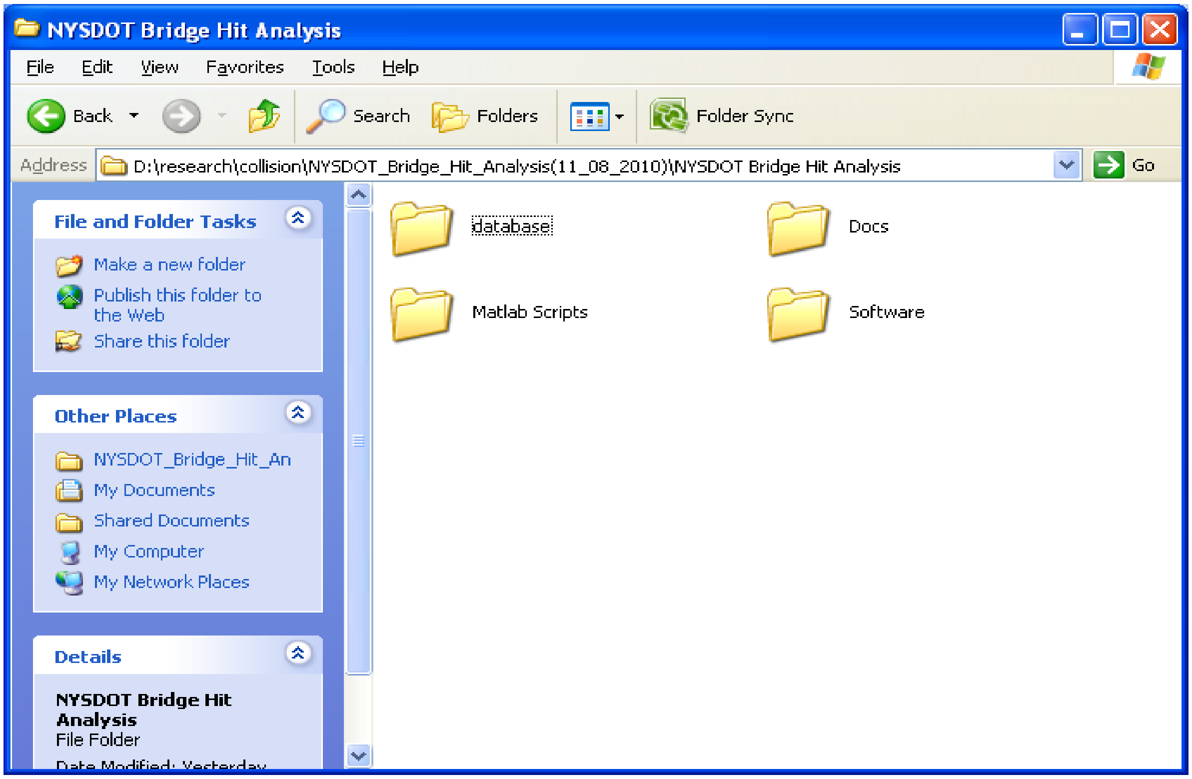


Figure 5-2: Four Main Folders of the Computer Program.

Step 3: Double Click to open software folder (see Fig. 5-3).

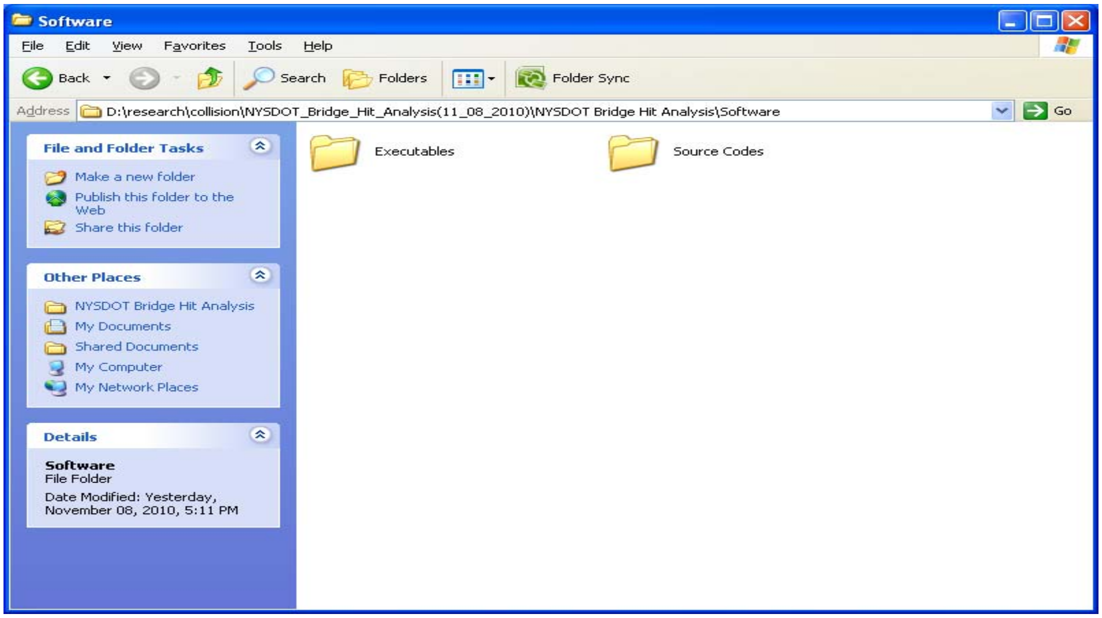


Figure 5-3: Software folder.

Step 4: Double Click to open Executables folder (See Fig. 5-4).

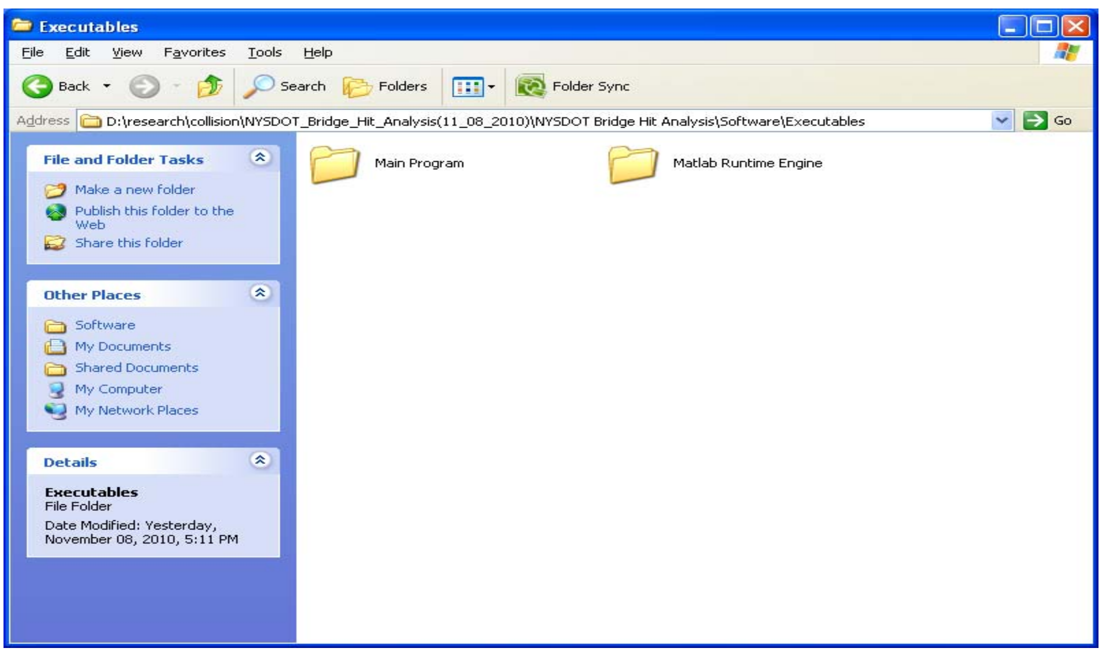


Figure 5-4: Executables Folder

Step 5: Double Click to open “Matlab Runtime Engine” folder (Fig. 5-5).

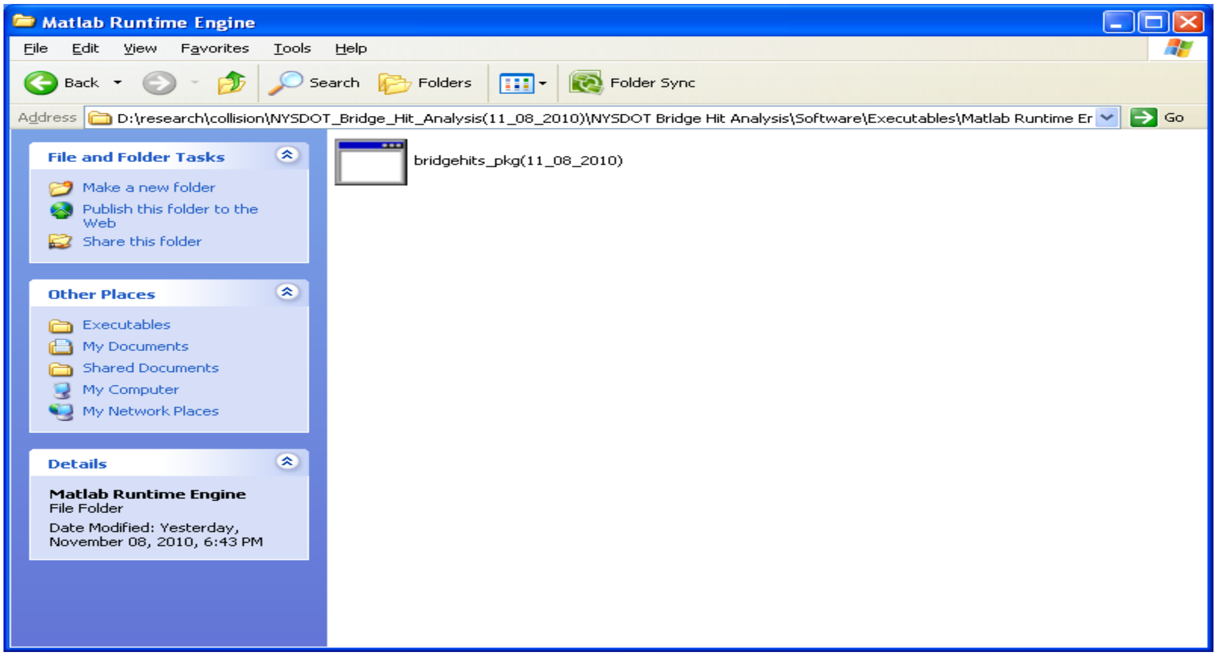


Figure 5-5: Matlab Runtime Engine Folder

Step 6: The Program “bridgehit_pkg(11_08_2010).exe”should by installed by a user with administrative privilege by following Figs. (5-6)-(5-9).

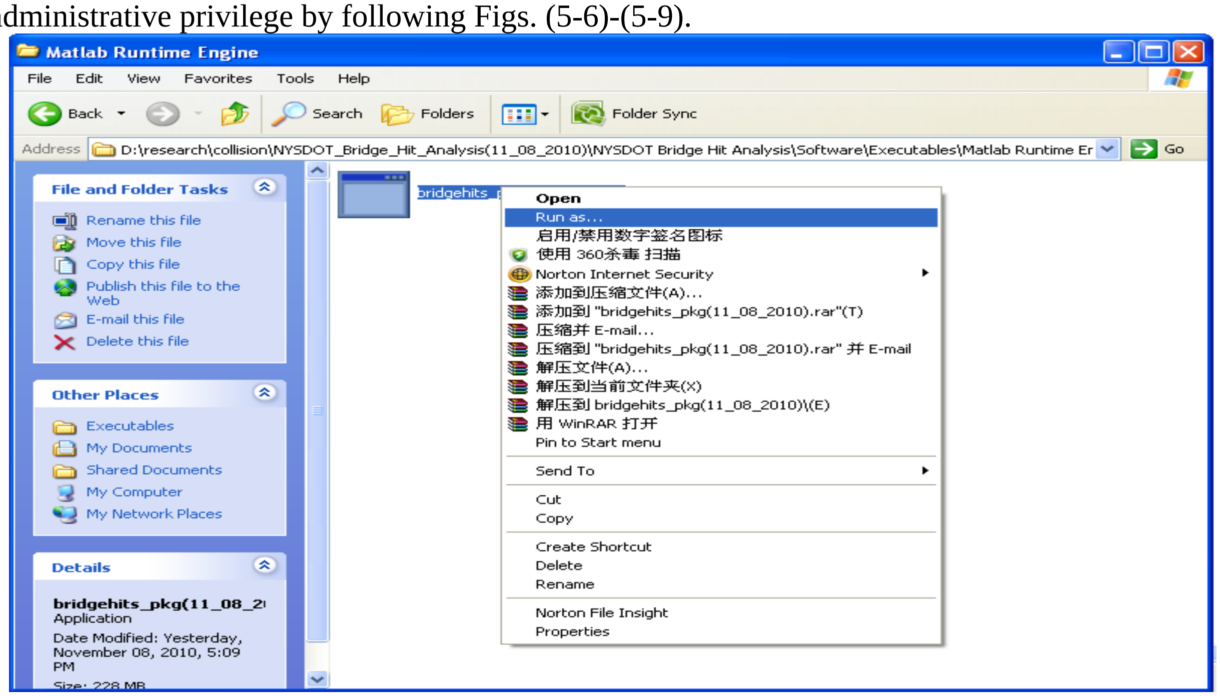


Figure 5-6: Right click “bridgehit_pkg(11_08_2010).exe”

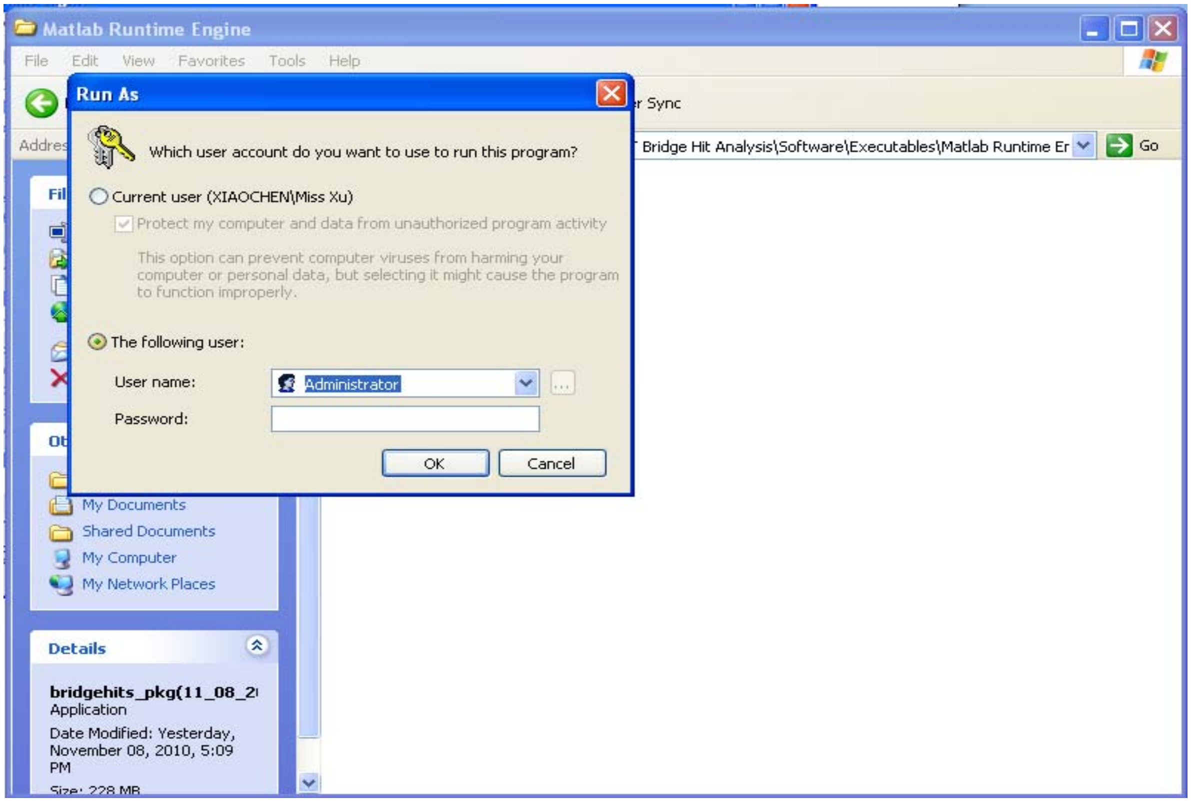


Figure 5-7: Click "Run as…" in the Drop Down Menu and Enter User Name and Password of a User With Administrative Privileges.

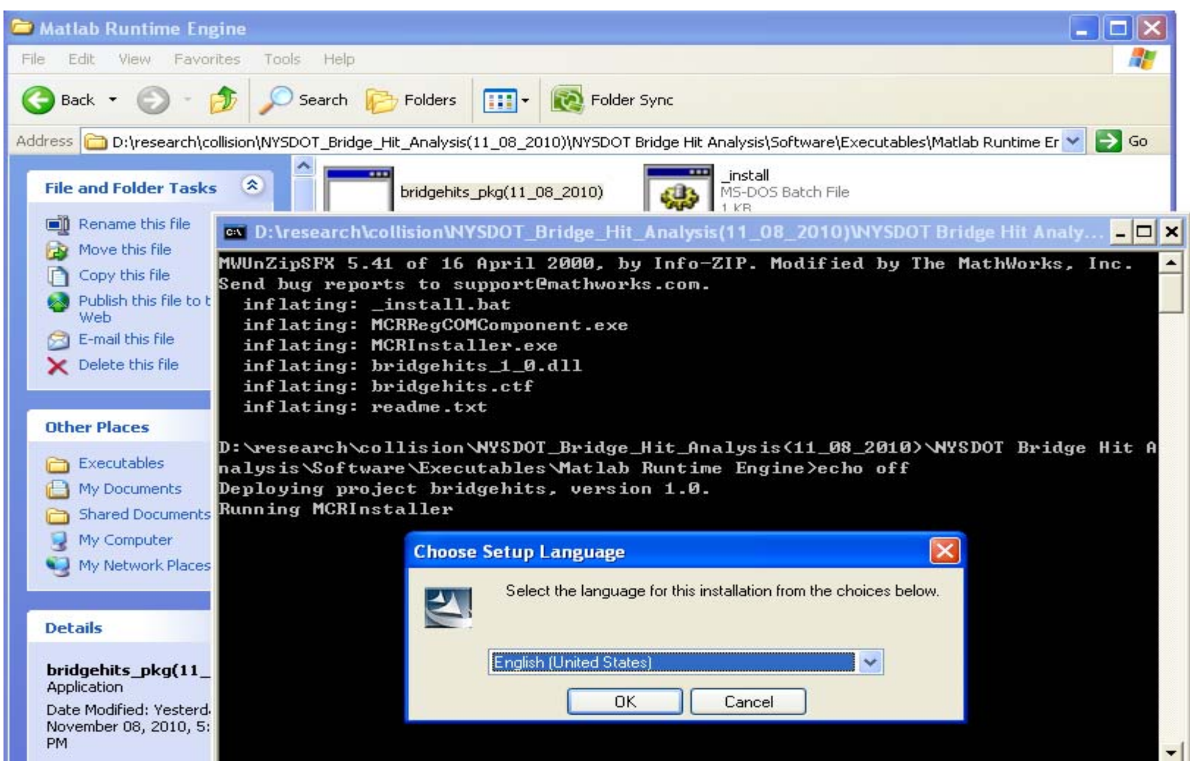


Figure 5-8: Click OK.

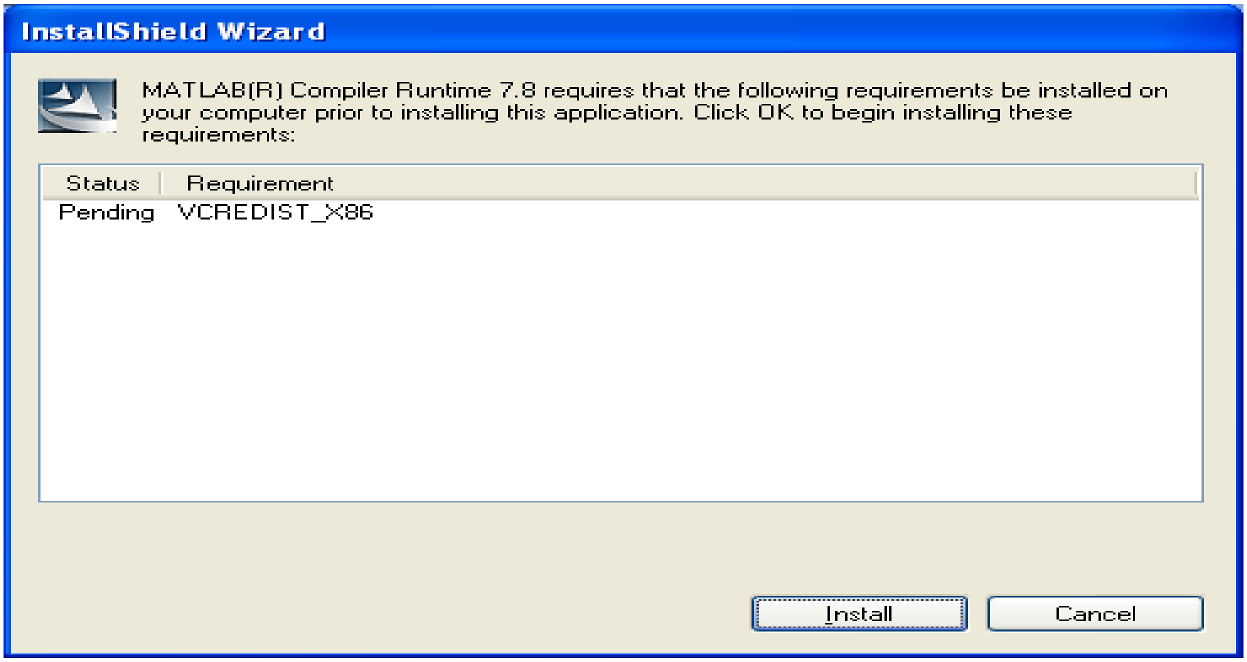


Figure 5-9: Click Install.

Step 7: After finishing, go to the Main Program folder under Executables, and double click BridgeHit.exe to run the program. You can install a shortcut of this program on your desktop for frequent launching of the program.
Step 8: Install ArcGIS runtime engine

5.4. USING THE PROGRAM

Double click the file "BridgeHit.exe" to run the program. By default, the program opens up in database mode as shown in Fig. 5-10. The window shows databases currently being used by the program. Double clicking any database opens up the database table (See Fig. 5-11).

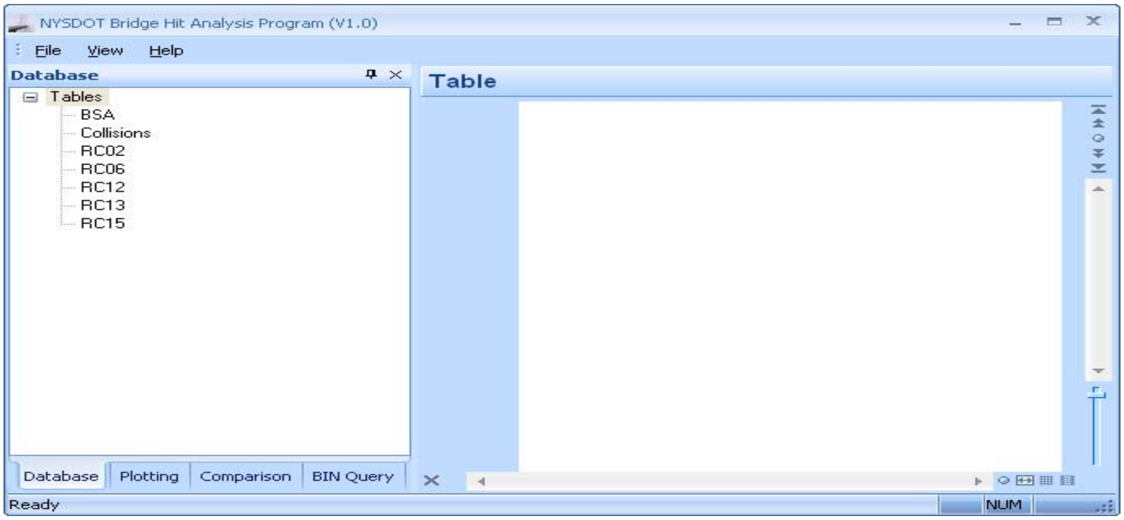


Figure 5-10: Main interface for Bridge Hit Analysis Program.

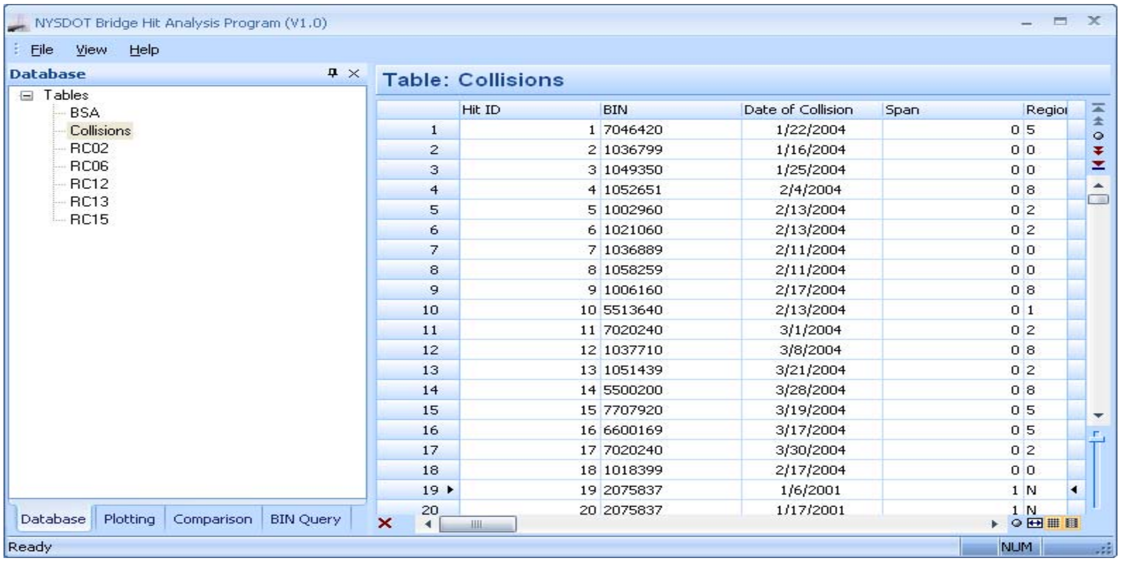


Figure 5-11: Database Interface by Double Clicking Collision Database.

The Collisions database table can be updated as new data on bridge hits become available. The collision database is automatically combined with other tables in Fig. 5-11 to generate combined collision database that is used by the program.

5.4.1. PLOTTING

- Clicking the "Plotting" Button opens the Plot Menu window as shown in Fig. 5-12 below. Functionalities of this option are described below.

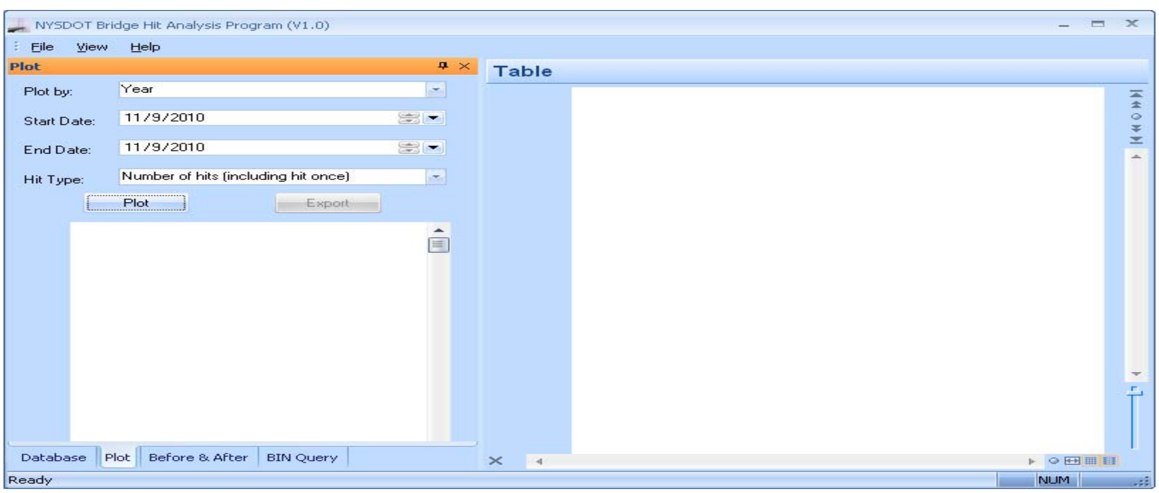


Figure 5-12: Main Interface for Plotting Menu

- *Plot by*: This is a drop down menu with various functions, as shown in Figure 5-13 below. Detailed description of various functionalities of "Plotting" menu has been presented in Section on "***FUNCTIONALITIES OF THE COMPUTER PROGRAM"*** previously**.**

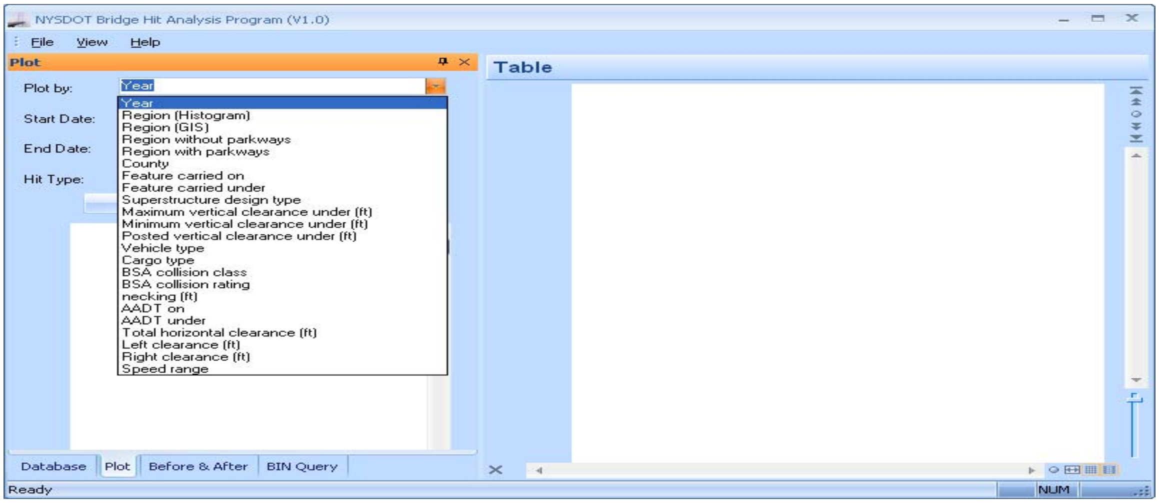


Figure 5-13: Drop Down Menu for "Plot by" Option.

- For example, by choosing "Region (GIS)" option opens up the input window in Figure 5-14 below. Similar to all other options, this option requires the following input:
  - Start Date: Date from which the data is to be analyzed. For example, we choose Start date as 1/1/2000.
  - End Date: Date up to which the data has to be analyzed. For example, we choose End date as 12/31/2007.
  - Hit Type: A drop down menu with Single or Multiple hit analysis options. For example, we choose "Number of hits (including hit once)".
  - Click "Plot" button after the input form in Figure 5-14 is complete. A GIS plot of NYSDOT regions with total number of multiple hits during the period selected appears in a separate plot window (See Figure 5-15).
  - The left window in Figure 5-15 shows multiple hits in each region in a tabular format. This data can be downloaded in a comma separated file format by clicking "Export".

Other options under "Plot" menu are very similar to that described above and can be followed in a similar manner.

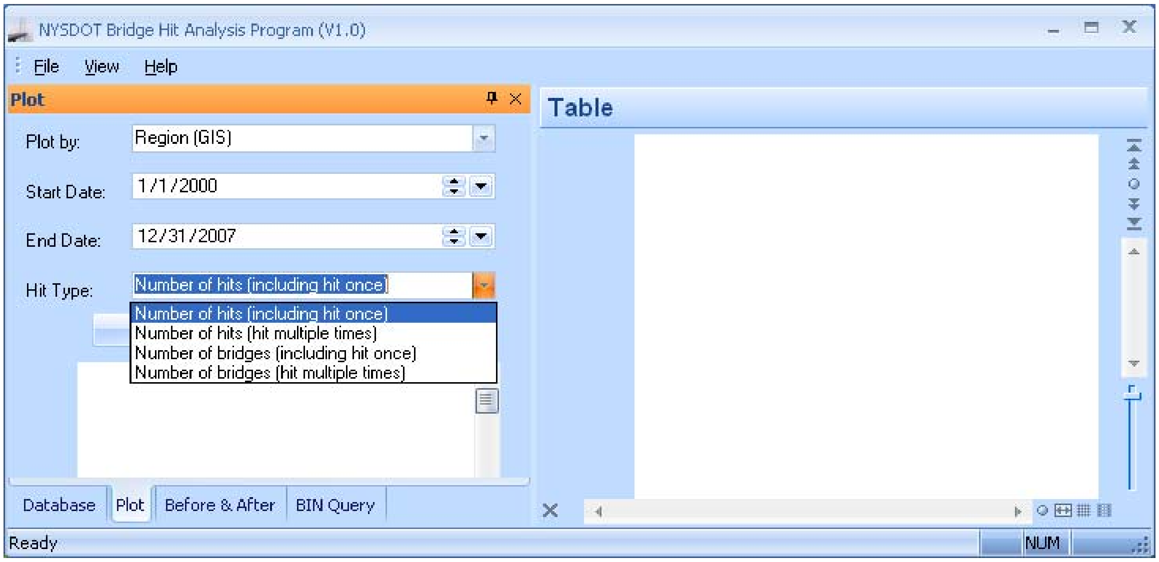
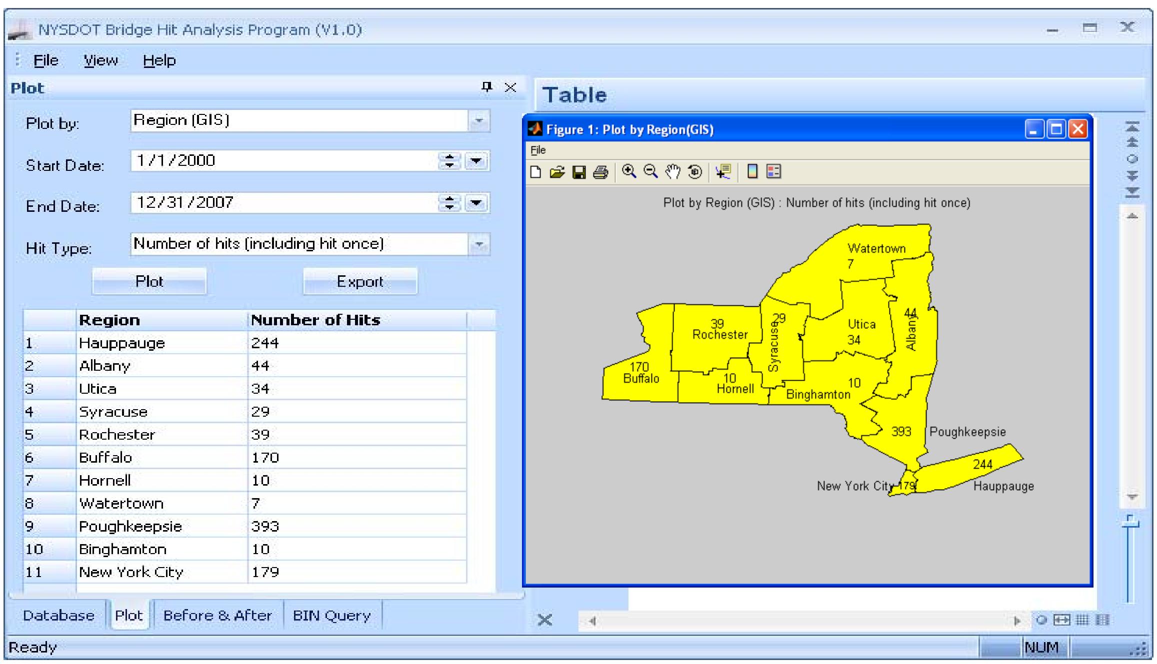


Figure 5-14: Drop Down Menu for Hit Type Analysis Options.



	Region	Number of Hits
1	Hauppauge	244
2	Albany	44
3	Utica	34
4	Syracuse	29
5	Rochester	39
6	Buffalo	170
7	Hornell	10
8	Watertown	7
9	Poughkeepsie	393
10	Binghamton	10
11	New York City	179

Figure 5-15: Example Plot Using "Region (GIS)".

5.4.2. BEFORE & AFTER

This option facilitates a comparison between before and after scenarios, e.g., bridge hits on a bridge or in a region or statewide before and after a date. The "Before & After" window can be opened by clicking the "Before & After" tab at the bottom of the program window as shown in Figure 5-16. Usage of the "Before & After" option is described below.

- *Compare by*: This drop down menu gives 6 options for analyzing "Before & After" scenarios, as shown in Figure 5-17 below. For example, we choose BIN in this menu for a

"Before & After" study. After choosing the first variable, the second variable will be changed according to the first variable you choose. Depending on the selection of the "Compare by" option, the next input option will change. For example, if you choose BIN in the "Compare by" menu, the second input will be BIN, which will also be a drop down menu to select a BIN (see Fig. 5-18). Similarly, if you choose Region in the "Compare by" menu, the second input will be "Region" through a drop down menu. (see Fig. 5-19).

- *Date*: In the "Date" box, enter the date in the format of mm/dd/yyyy before and after which bridge hit analysis is desired.
- Click "Plot" button after completing all the required inputs. A histogram of hits on a selected bridge before and after a selected date appears in a separate plot window (See Figure 5-20).
- The left window in Figure 5-20 shows the number of hits before and after a selected date. This data can be downloaded in a comma separated file format by clicking the "Export" button.

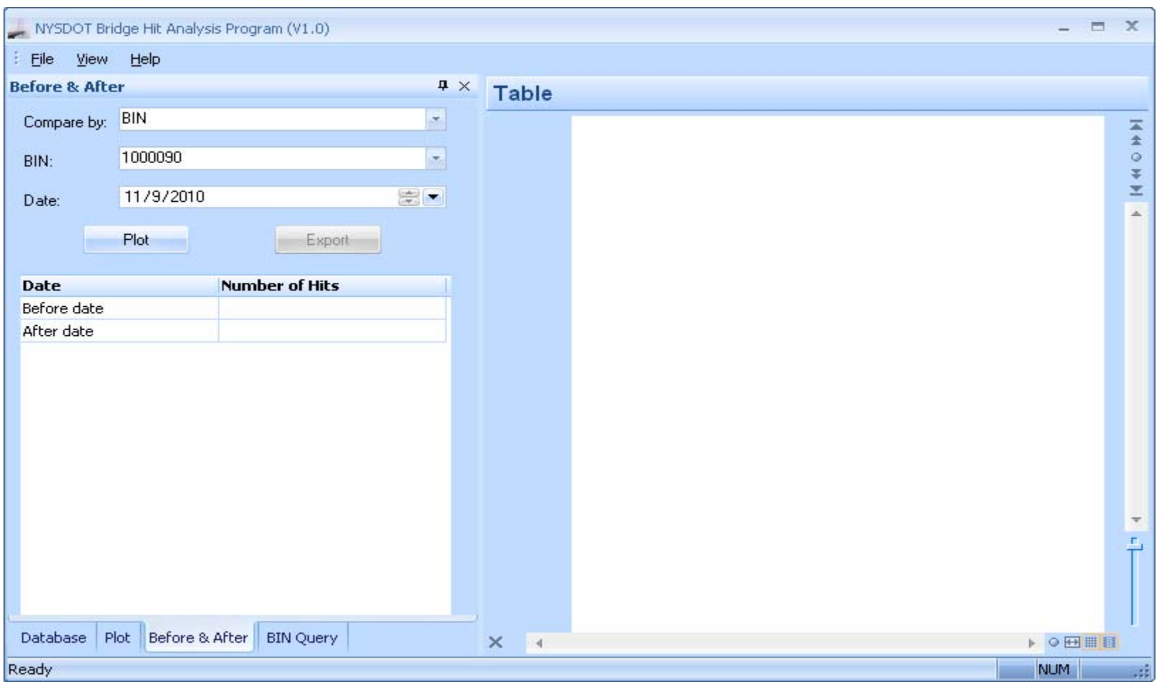


Figure 5-16: Main Interface for "Before & After" Option.

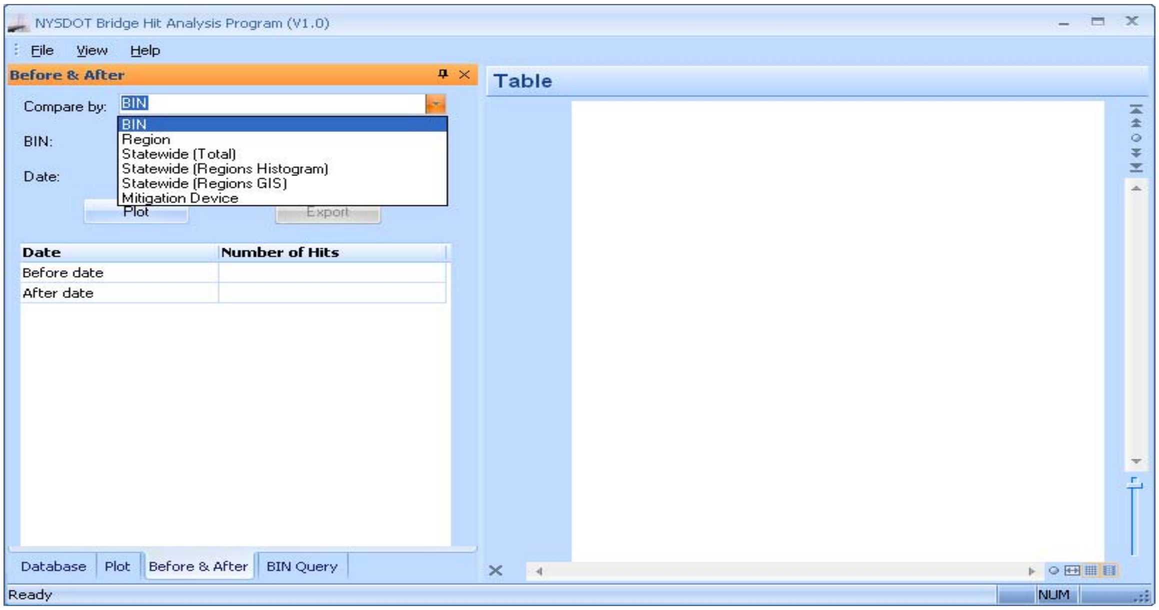


Figure 5-17: Drop Down Menu for "Compare by" in "Before & After" Option.

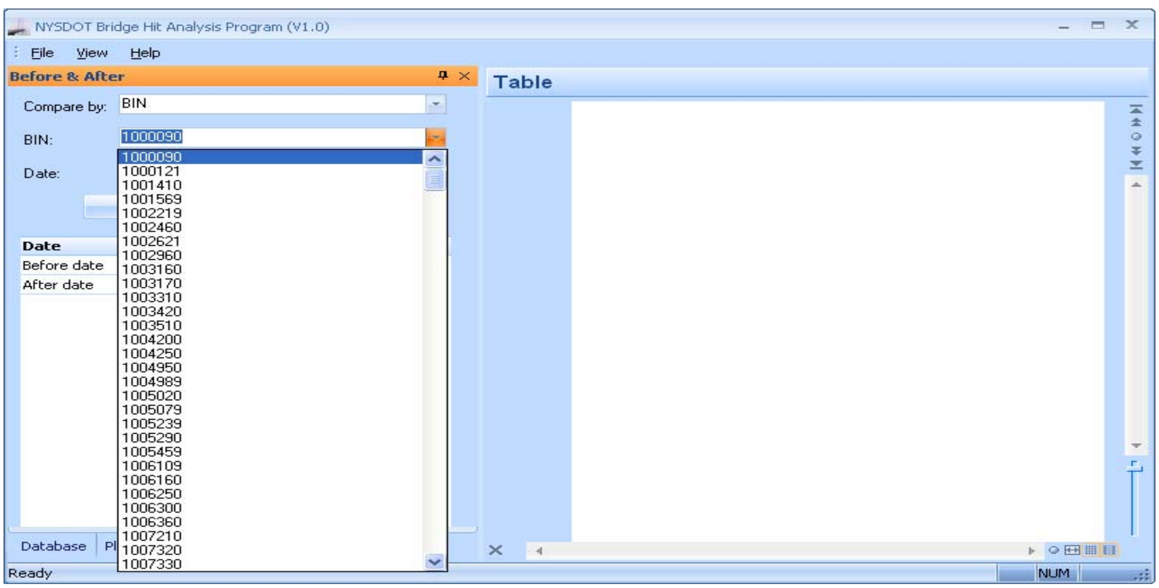


Figure 5-18: Drop Down Menu for BIN in "Before and After" Option.

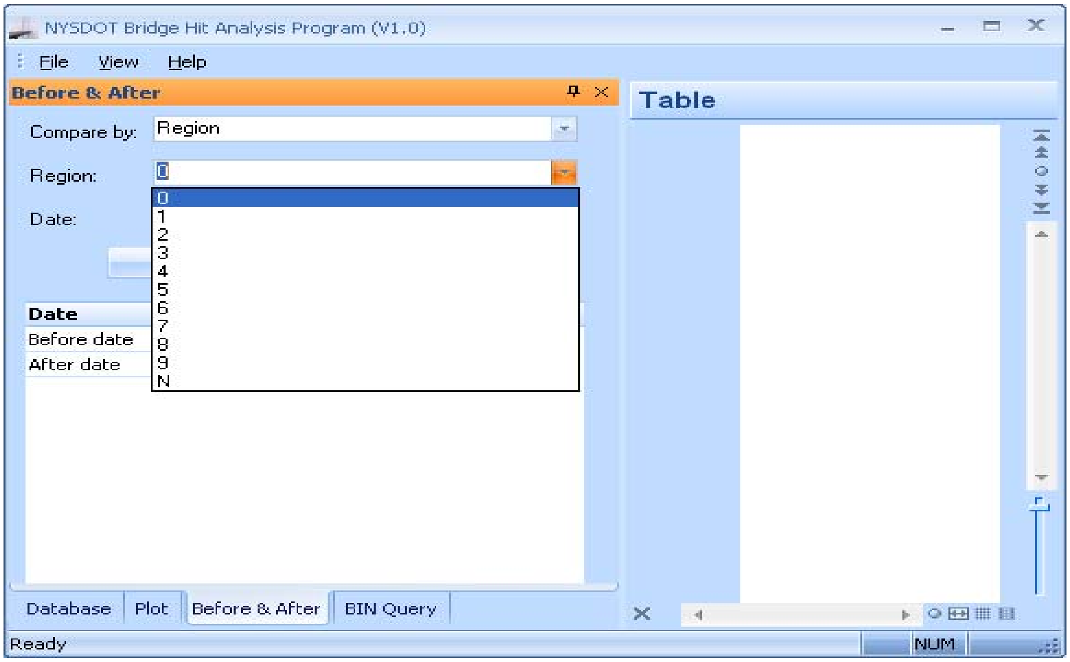


Figure 5-19: Drop Down Menu for "Region" in "Before & After" Option.

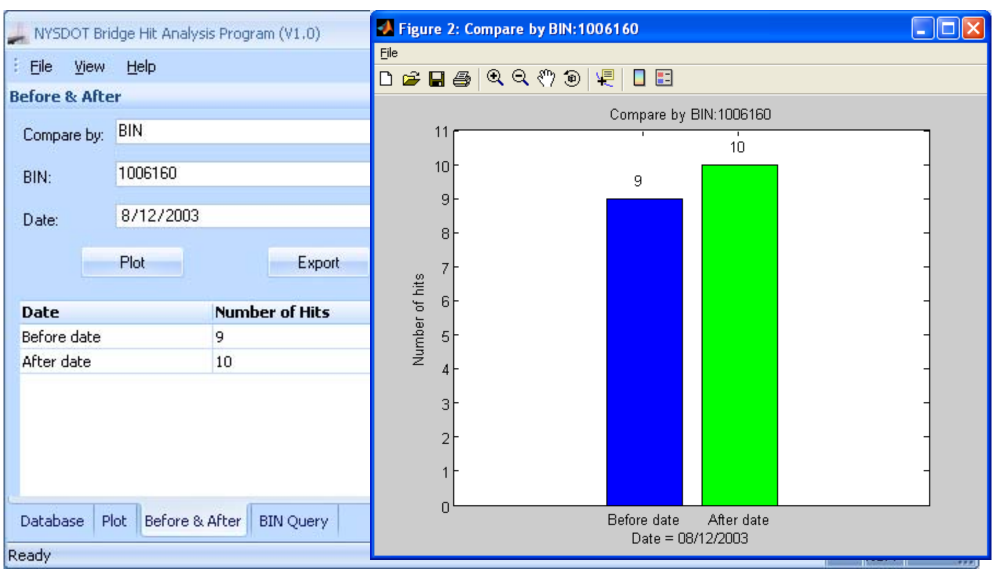


Figure 5-20: Example of Results using "Before and After" Option.

5.4.3. BIN QUERY

This option provides detailed information for one particular bridge. Clicking the "BIN Query" tab at the bottom of the main program window opens the interface which allows the user to enter the BIN number. Then, clicking on the "Query" button on the right of the BIN box displays detailed BIN information in the left window, as shown in Figure 5-21 below. Note that the left window still shows the database table and isn't related to the "BIN Query" option.

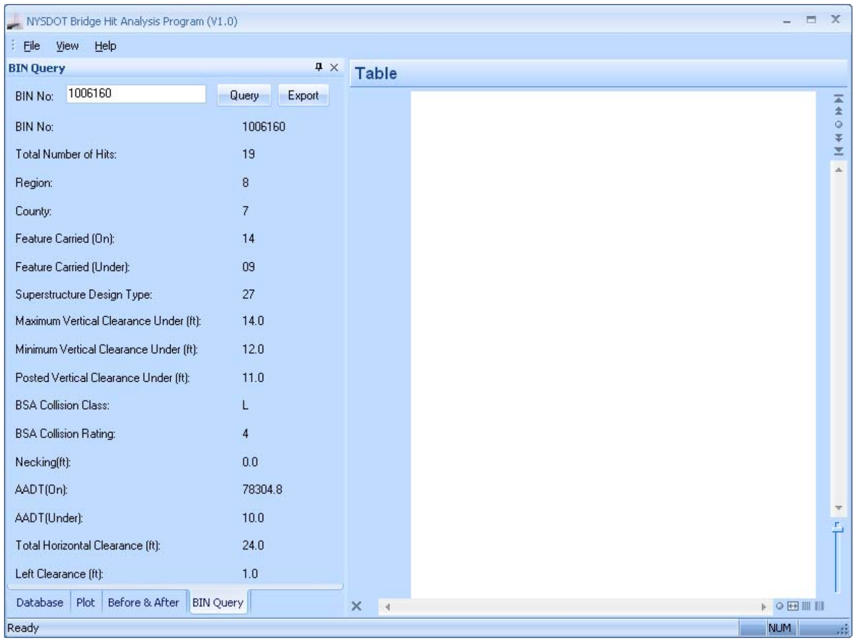
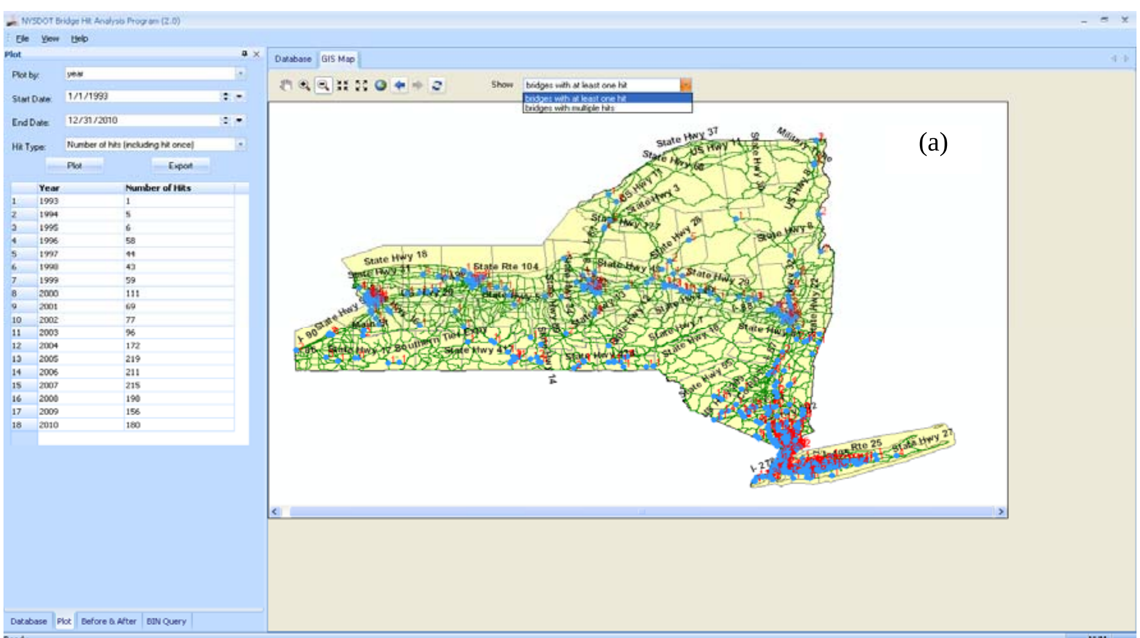
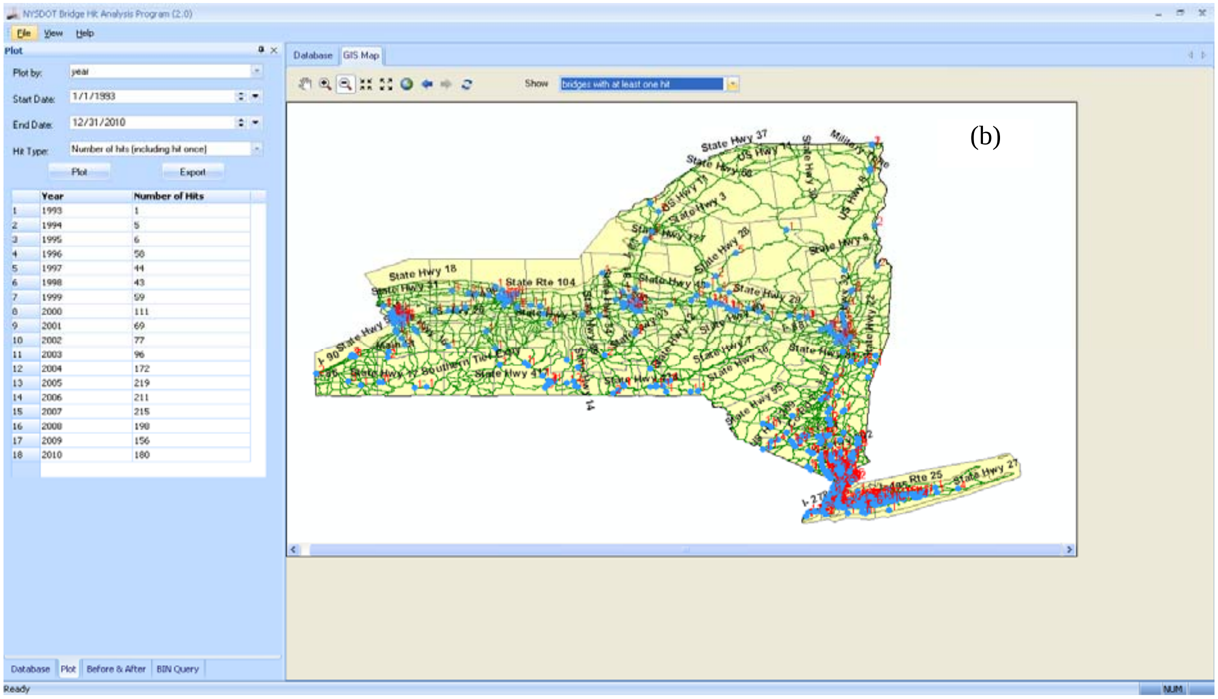


Figure 5-21: Example on "BIN Query" Option.

5.5. GIS FUNCTION

A version of the program with GIS functionality has been provided. This version of the program has a "GIS Map" button next to "Database" (or "Table" button as seen in previous figures) button in the top portion of the right window (See Fig. 5-22(a)). The GIS functionality can be utilized by clicking "GIS Map" button. This functionality allows plotting total and multiple bridge in the database on a state-wide GIS map, as shown in Figure 5-22. The blue dots on the map indicate the location of the bridges that have been hit, and the red numbers are the counts of bridge hit.





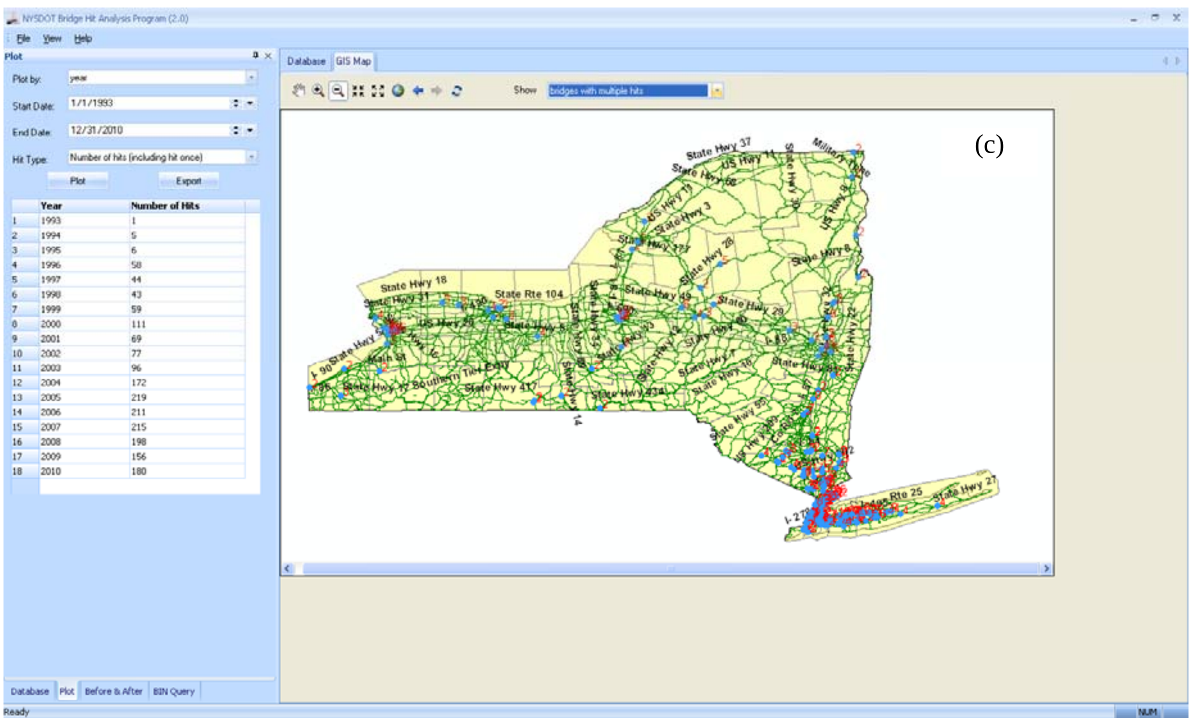


Figure 5-22: (a) Interface of GIS map function; (b) Number of bridge hits (including hit once) on GIS map; (c) Number of bridge hits (multiple times) on GIS map

5.6. CONCLUSION

The computer program described in this report can analyze bridge hit data for all of New York State to identify trends and factors affecting hits to bridges. The program has the ability to automatically update the database as new bridge hits data becomes available.

CHAPTER 6 : IMPROVEMENTS TO THE NYSDOT COLLISION VULNERABILITY PROCEDURE

6.1. INTRODUCTION

The New York State Department of Transportation (NYSDOT) has developed a Collision Vulnerability Assessment (CVA) procedure to identify relative vulnerability of the state's bridges to failures due to impact damages so that necessary vulnerability reduction measures can be implemented in an efficient and effective manner. For a particular bridge, a collision vulnerability rating is calculated on the basis of the CVA procedure which consists of a series of assessment and evaluation steps on specific characteristics of a given bridge. The vulnerability rating describes the likelihood and the consequences of failures in terms of the corrective actions required to reduce the vulnerability and the urgency in which these actions need to be implemented. Moreover, the CVA rating is used in conjunction with vulnerability ratings from other failure modes (e.g., hydraulic and seismic hazards) to develop overall vulnerability of a bridge.

However, the current version of the collision vulnerability manual is 15 years old. Because of deterioration of bridge components and change of standards, some of the existing criteria in the CVA procedure have become outdated and insufficient. For example, the bridge with Bridge Identification Number (BIN) 1006160 has been reportedly hit 20 times during the last 10 years. However, it is classified as having low vulnerability to vehicular collisions based on the current CVA procedure.

New York State Department of Transportation has developed revisions to the current CVA procedures. Tables 6-1 and 6-2 show these proposed revisions for Branches 1 and 2A, respectively. Based on bridge impact data available during the last 10 years, the research team has carried out a critical analysis to identify various factors and their weights that affect the vulnerability rating of a specific bridge. Based on this analysis, further changes to the NYSDOT revisions to the CVA procedures have been proposed. These changes have been developed to ensure that bridges hit frequently are classified as highly vulnerable. The reasonableness of these changes has been investigated by applying modified CVA procedures to 36 randomly selected bridges. It is observed that 12 out of 36 bridges (i.e., 33%) show better correlation with observed bridge impact data when modified CVA procedures proposed in this report are used, while the vulnerability ratings in the case of the remaining 24 (67%) bridges are similar to those by the revised NYSDOT procedures. These results demonstrate that the modifications to the CVA procedures proposed in this report can improve collision vulnerability assessment of bridges in New York.

Table 6-1: Branch 1 Truck on Bridge Collision Vulnerability Assessment Based on Revisions Proposed by NYSDOT.

COLLISION VULNERABILITY ASSESSMENT		
	Scores	Winbolts/Inspection Report
REVISED BRANCH 1: TRUCK ON BRIDGE COLLISION		
A. Bridge Type: Is Main Member a Thru Girder or Truss	Yes (Y), No (N), Branch 1 Total Score=0	Spans Inventory
B. Truck Traffic: Does roadway carry truck traffic	Yes (Y), No (N), If No, Branch 1 Total Score=0. If roadway is a parkway, default to No (N) unless previously hit- Yes (Y)	Feature Carried
C. Lanes of Traffic (On):	>4 (6), 4 (4), 3 (2), 2(1), 1(0)	Feature Carried
D. Width of Travel Lanes (on):	<10' (5), 10'-11' (3), >11'-12' (1), >12' (0)	Feature Carried
E. Min. Vertical Clearance (On):	<13' to 13'11'' (10), 14' to 14'11'' (5), 15' to 15'11'' (3), 16' and greater (or no overhead bracing) (0)	Feature Carried
F. Protective Barriers:	None (20), Substandard (10), Standard (0)	Spans Inventory
G. Volume of Truck Traffic (On) (ADTT)	>5000 (8), >2500-5000 (6), >1000-2500 (4), >200-1000 (2), 200 & below (o)	Feature Carried- (Daily Truck Traffic %) * (AADT)
H. Bridge Width vs. Highway Width:	Severe necking > 10' (10), Mod. Necking 5'-10' (6), Minor necking<5' (2), No change (0)	Structural Details – (Approach width/Bridge width)
I. Approach Roadway Assessment	Substantial speed reduction req'd (10), Minor speed red. req'd (5), No speed red. req'd (0)	Approach Roadway Alignment
J. Present Wearing Surface (On):	Steel Grating-Open or filled (5), Timber (3), Other Surface (0)	Spans Inventory
K. Wearing Surface Condition Rating:	<3 (5), 3 or higher (0)	Spans Inspection
L. Lighting (On):	No Lighting (2), Lighting (0)	Safety
M. Design Type:	Light Truss (10), Heavy Truss (4), Thru Girder (0)	Built before 1928=Light Truss, Built after 1928=Heavy Truss
N. Posted Load	Not Posted (8), 27-36 tons (6), 20-26 tons (4), 12-19 tons (3), 7-11 tons (2), 3-6 tons (0)	Postings
O. Posted Speed Limit	>55mph (8), 40-50mph (4), 30-35mph (2), <30mph (0)	
O. Functional Classification	Interstate (8), Arterial (4), Collector (2), Local (0)	Feature Carried
P1. Previous Impact Damage	Major Damage (15), Moderate Damage (12), Minor Damage (10), Previous impacted, but no damage (5), No evidence of previous impact damage (0)	Collision Database
P2. Multiple Bridge Hits	Hit 2 or more times (15), Hit once or never been hit (0)	Collision Database
Q. VC Warning Signs:	Not Provided (4), Provided But Not Adequate (2), Not Req'd or Provided and Adequate (0), Provided, but Not Req'd (-2)	Input manually
R. HC Warning Signs:	Not Provided (2), Provided But Not Adequate (1), Provided or Not Req'd (0)	Input manually
S. Elev. Curb or SDWLK:	No Elev. Curb or Sdwlk (4), Elev. Curb/Sdwk Exists (0)	Structural Details

Table 6-2: Branch 2A Superstructure Vulnerability to Truck under Bridge Collision Based on Revisions Proposed by NYSDOT.

COLLISION VULNERABILITY ASSESSMENT		
	Revised Score	Winbolts/Inspection Report
REVISED BRANCH 2A: SUPERSTRUCTURE VULN. TO TRUCK UNDER BRIDGE COLLISION		
A. Under Roadway Feature: Is feature under a roadway	Yes (Y), No (N), If No, Branch 2 Total Score = 0	Feature Crossed
B. Truck Traffic: Does under roadway carry truck traffic?	Yes (Y), No (N), If No, Branch 2 Total Score = 0. If Under Roadway is a parkway, default to No (N) unless previously hit – Yes (Y)	Feature Crossed
C. Main Member Type;	FC Deck Girder (20), FC Deck Truss (18), Suspended Spans (16), Tied Arches (14), Cross Girders & Steel Pier Caps (12), P/s I-beams, box-beams or other FC Main Member (10), Other Non FC Main Member (0)	Spans Inventory
D. Pedestrian Bridge:	Yes (5), No (0)	Feature Carried
E. Min. Vertical Clearance (Under)	<11' (15), 11' to 11''-11'' (12), 12' to 12'-11'' (10), 13' to 13'-5'' (8), 13'-6'' to 13'-11'' (6), 14' to 14'-5'' (4), 14'-6'' to 15'-3'' (2), 15'-4'' to 16' (1), >16' (0)	Feature Crossed
F. Structural Redundancy	Simple (4), Continuous (0)	Spans Inventory
G. ADTT (Under)	>5000 (8), >2500-5000 (6), >1000-2500 (4), >200-1000 (2), 200 & below (0)	Feature Crossed: Assume 10% trucks and multiply by AADT under
H. Lighting (Under)	No Lighting (3), Lighting (0)	Safety
I. Posted Speed Limit	>55 mph (8), 40-50 mph (4), 30-35 mph (2), <30 mph (0)	Input manually
I. Functional Classification	Interstate (8), Arterial (4), Collector (2), Local (0)	Feature Crossed
J1. Previous Impact Damage	Major Damage (15), Moderate Damage (12), Minor Damage (10), Previous impacted, but no damage (5), No evidence of previous impact damage (0)	Collisions Database
J2. Multiple Bridge Hits:	Hit 2 or more times (15), Hit once or never been hit (0)	Collision Database
K.VC Warning Signs	Not Provided (4), Provided But Not Adequate (2), Not Req'd or Provided and Adequate (0), Provided, but Not Req'd (-2)	Input manually

Table 6-3: Proposed Modifications to Branch 1 Truck on Bridge Collision Vulnerability Assessment Items in Table 6-1 (Note: Proposed Modifications are highlighted in bold).

COLLISION VULNERABILITY ASSESSMENT		
	Scores	Winbolts/Inspection Report
REVISED BRANCH 1: TRUCK ON BRIDGE COLLISION		
A. Bridge Type: Is Main Member a Thru Girder or Truss	Yes (Y), No (N), Branch 1 Total Score=0	Spans Inventory
B. Truck Traffic: Does roadway carry truck traffic	Yes (Y), No (N), If No, Branch 1 Total Score=0. If roadway is a parkway, default to No (N) unless previously hit- Yes (Y)	Feature Carried
C. Lanes of Traffic (On):	**>4 (6), 4 (5), 3 (3), 2(3), 1(0)**	**Feature Carried**
D. Width of Travel Lanes (on):	<10’ (5), 10’-11’ (3), >11’-12’ (1), >12’ (0)	Feature Carried
E. Min. Vertical Clearance (On):	<13’ to 13’11’’ (10), 14’ to 14’11’’ (5), 15’ to 15’11’’ (3), 16’ and greater (or no overhead bracing) (0)	Feature Carried
F. Protective Barriers:	**None (20), Substandard (18), Standard (5)**	**Spans Inventory**
G. Volume of Truck Traffic (On) (ADTT)	>5000 (8), >2500-5000 (6), >1000-2500 (4), >200-1000 (2), 200 & below (o)	Feature Carried- (Daily Truck Traffic %) * (AADT)
H. Bridge Width vs. Highway Width:	**Severe necking > 10’ (5), Mod. Necking 5’-10’ (5), Minor necking<5’ (4), No change (3)**	**Structural Details – (Approach width/Bridge width)**
I. Approach Roadway Assessment	**Substantial speed reduction req’d (10), Minor speed red. req’d (8), No speed red. req’d (6)**	**Approach Roadway Alignment**
J. Present Wearing Surface (On):	Steel Grating-Open or filled (5), Timber (3), Other Surface (0)	Spans Inventory
K. Wearing Surface Condition Rating:	<3 (5), 3 or higher (0)	Spans Inspection
L. Lighting (On):	No Lighting (2), Lighting (0)	Safety
M. Design Type:	Light Truss (10), Heavy Truss (4), Thru Girder (0)	Built before 1928=Light Truss, Built after 1928=Heavy Truss
N. Posted Load	Not Posted (8), 27-36 tons (6), 20-26 tons (4), 12-19 tons (3), 7-11 tons (2), 3-6 tons (0)	Postings
O. Posted Speed Limit	>55mph (8), 40-50mph (4), 30-35mph (2), <30mph (0)	
O. Functional Classification	**Interstate (8), Arterial (7), Collector (1), Local (0)**	**Feature Carried**
P1. Previous Impact Damage	**Major Damage (12), Moderate Damage (11), Minor Damage (10), Previous impacted, but no damage (8), No evidence of previous impact damage (0)**	**Collision Database**
P2. Multiple Bridge Hits	**Hit 2 or more times (11), Hit once or never been hit (4)**	**Collision Database**
Q. VC Warning Signs:	Not Provided (4), Provided But Not Adequate (2), Not Req’d or Provided and Adequate (0), Provided, but Not Req’d (-2)	Input manually
R. HC Warning Signs:	Not Provided (2), Provided But Not Adequate (1), Provided or Not Req’d (0)	Input manually
S. Elev. Curb or SDWLK:	No Elev. Curb or Sdwlk (4), Elev. Curb/Sdwk Exists (0)	Structural Details

Table 6-4: Proposed Modifications to Branch 2A Superstructure Vulnerability to Truck Under Bridge Collision Vulnerability Items in Table 6-2 (Note: Proposed Modifications are highlighted in bold).

COLLISION VULNERABILITY ASSESSMENT		
	Revised Score	Winbolts/Inspection Report
REVISED BRANCH 2A: SUPERSTRUCTURE VULN. TO TRUCK UNDER BRIDGE COLLISION		
A. Under Roadway Feature: Is feature under a roadway	Yes (Y), No (N), If No, Branch 2 Total Score = 0	Feature Crossed
B. Truck Traffic: Does under roadway carry truck traffic?	Yes (Y), No (N), If No, Branch 2 Total Score = 0. If Under Roadway is a parkway, default to No (N) unless previously hit – Yes (Y)	Feature Crossed
C. Main Member Type;	FC Deck Girder (20), FC Deck Truss (18), Suspended Spans (16), Tied Arches (14), Cross Girders & Steel Pier Caps (12), P/s I-beams, box-beams or other FC Main Member (10), Other Non FC Main Member (0)	Spans Inventory
D. Pedestrian Bridge:	Yes (5), No (0)	Feature Carried
E. Min. Vertical Clearance (Under)	**<11' (15), 11' to 11''-11'' (8), 12' to 12'-11'' (5), 13' to 13'-11'' (8), 14' to 14'-11'' (13), 15'to 15'-11'' (2), 16'to 16'11'' (2), >=17' (0)**	**Feature Crossed**
F. Structural Redundancy	Simple (4), Continuous (0)	Spans Inventory
G. ADTT (Under)	**>4500 (8), >1800-4500 (4), >820-1800 (3), >200-820 (1), 200 & below (0)**	**Feature Crossed: Assume 10% trucks and multiply by AADT under**
H. Lighting (Under)	No Lighting (3), Lighting (0)	Safety
I. Posted Speed Limit	>55 mph (8), 40-50 mph (4), 30-35 mph (2), <30 mph (0)	Input manually
I. Functional Classification	**Interstate (8), Arterial (7), Collector (1), Local (0)**	**Feature Crossed**
J1. Previous Impact Damage	**Major Damage (12), Moderate Damage (11), Minor Damage (10), Previous impacted, but no damage (8), No evidence of previous impact damage (0)**	**Collisions Database**
J2. Multiple Bridge Hits:	**Hit 2 or more times (11), Hit once or never been hit (4)**	**Collision Database**
K.VC Warning Signs	Not Provided (4), Provided But Not Adequate (2), Not Req'd or Provided and Adequate (0), Provided, but Not Req'd (-2)	Input manually

6.2. COMPARISONS BETWEEN COLLISION VULNERABILITY RATING USING REVISED CVA PROCEDURES

Applicability of the modified CVA procedures for Branches 1 and 2A in Tables 6-3 and 6-4, respectively, has been investigated for 36 randomly selected bridges. Vulnerability scores for these bridges have been calculated by considering weights in Tables 1 to 2 for revised NYSDOT procedures and those in Tables 6-3 and 6-4 for modified CVA procedures by the research team. Table 6-5 shows vulnerability scores and ratings by the two approaches and the total number of hits for each of the bridges. In Table 6-5, bridges whose vulnerability rating improved by the modified CVA procedure (Column 4) are highlighted in bold. It is observed that 12 out of 36 bridges have vulnerability ratings more consistent with observed bridge hits data when the modified CVA procedure is used. Vulnerability ratings for remaining 24 bridges are the same by the two approaches.

A vulnerability rating indicates the likelihood of a bridge getting hit. A low collision vulnerability rating means low likelihood of unacceptable collision damage. It is observed from Table 6-5 that although BIN 1006160 has been hit 20 times, it was rated low (L) using the revised NYSDOT CVA procedure. On the other hand, this bridge is rated medium (M) using the modified CVA procedures in this report. Based on actual hits and resulting damage to this bridge, a medium (M) vulnerability rating is more appropriate. From Table 6-5, we can consider BIN 1001429 as another example. Based on the revised NYSDOT CVA procedure, this bridge is rated medium (M), whereas it is rated low (L) using the modified CVA procedure in this report. Since this bridge hasn't been hit yet, a vulnerability rating of L is more appropriate for this bridge. Hence, vulnerability ratings based on the modified CVA procedure in this report are more consistent with actual hits on bridges.

6.3. BASIS OF REVISIONS

Revisions to CVA procedures in this report are mainly based on calibration of weights assigned to members of a particular group (e.g., “Interstate”, “Arterial”, “Collector” and “Local” in “Functional Classification” group) based on historical bridge hits data during the last 10 years. However, consideration has also been given to the function that each component plays in the collision hazard. This has been done by calculating relative frequencies and/or relative cumulative frequencies for each of the groups as per Eqs.(1) and (2) using actual bridge hits data.

$$[\text{Relative Frequency}]_i = [Number\ of\ Hits]_i / \sum [Number\ of\ Hits]_i \tag{1}$$

$$[\text{Relative Cumulative Frequency}]_i = \sum_{n=1}^{i} [Relative\ Frequency]_n \tag{2}$$

6.3.1. REVISIONS IN BRANCH 1: TRUCK ON BRIDGE COLLISION

Lanes of Traffic on: Using the available bridge hits data, the number of hits for different number of lanes has been generated, as shown in Column 2 of Table 6-6. Relative frequencies in Column 3 of Table 6-6 are calculated by dividing hits for each number of lanes by the total number of hits (i.e., sum of all rows in Column 2). Intuitively, the probability of hits will increase with an increase in the number of lanes, which represents cumulative frequency behavior. Hence, relative cumulative frequency in Column 4 of Table 6-6 is calculated by adding relative frequencies in previous rows to the current row i.e., relative cumulative frequency for 1 lane is the same as its relative frequency, the relative cumulative frequency for 2 lanes will be the sum of relative frequencies for 1 and 2 lanes, etc. Figure 6-1 shows the histogram of relative cumulative frequencies for different number of lanes. It is observed that the increase in relative cumulative frequencies is very minimal when the number of lanes is greater than 4. Hence, the number of lanes beyond 4 can be combined in one relative cumulative frequency category, as shown in Table 6-7.

Table 6-5: Comparison between Vulnerability Ratings Based on Revisions Proposed by NYSDOT and Modifications to NYSDOT Revisions.

BIN	Total Score Based Modifications to NYSDOT Revisions	Total Score Based on NYSDOT Revisions	Classification Based on Revisions Proposed by NYSDOT	Classification Based on Proposed Modifications	Total Number of Hits
1001410	**42**	**62**	**H**	**L**	**1**
1001429	**16**	**39**	**M**	**L**	
1001439	**16**	**47**	**M**	**L**	
1001569	**18**	**54**	**H**	**L**	**1**
1001579	**39**	**44**	**M**	**L**	
100157A	14			L	
1003160	55	72	H	M	3
1003170	55			M	2
1003180	21	25	L	L	
1004250	56	64	M	M	2
1004261	17	58	L	L	
1004262	28	58	L	L	
1006160	**41**	**23**	**L**	**M**	**20**
1006190	**10**	**54**	**M**	**L**	
1006200	**16**	**55**	**M**	**L**	
1006921	**40**	**41**	**M**	**L**	**1**
1008169	**43**	49	**M**	**L**	**1**
1008332	**31**	**45**	**M**	**L**	**1**
1008400	25	36	L	L	
1008431	**19**	**41**	**M**	**L**	
1002460	58	49	M	M	1
1007330	50	37	M	M	1
1007370	54	52	M	M	1
1014500	63	51	M	M	2
1021240	52	45	M	M	1
1027600	58	54	M	M	1
1034950	52	38	M	M	1
1040660	58	56	M	M	1
1044100	48	37	M	M	1
1048240	54	48	M	M	1
1051270	58	44	M	M	1
1058492	54			M	1
2267680	59			M	1
2502040	56			M	1
4001970	51	44	M	M	1
4445130	76	83	H	H	3

Table 6-6: Relative Frequencies and Relative Cumulative Frequencies for Different Number of Lanes.

Total Number of Lanes	Counts	Relative Frequencies	Relative Cumulative Frequencies
1	68	0.050	0.050
2	549	0.402	0.452
3	176	0.129	0.581
4	307	0.225	0.806
5	106	0.078	0.884
6	114	0.083	0.967
7	6	0.004	0.971
8	34	0.025	0.996
9	2	0.002	0.998
11	2	0.001	0.999
12	2	0.001	1.000

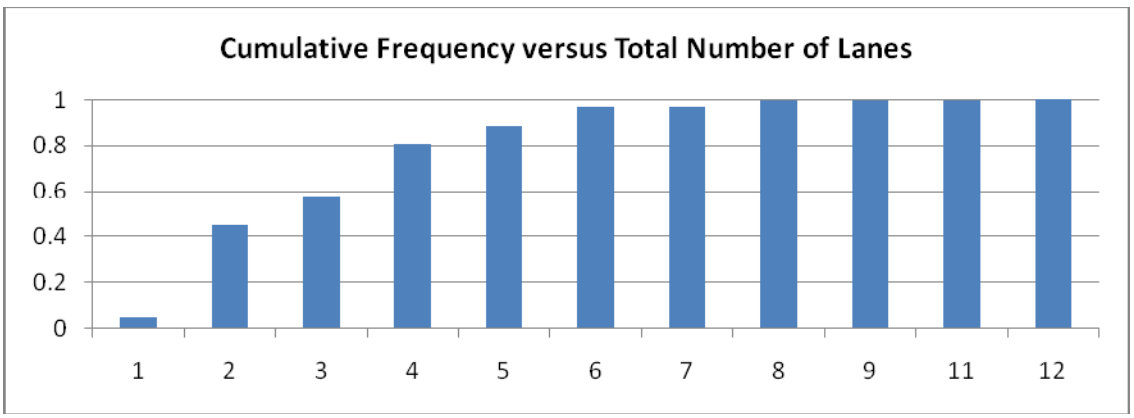


Figure 6-1: Histogram of Relative Cumulative Frequency versus Number of Lanes.

Table 6-7: Number of Lanes versus Relative Cumulative Frequencies.

No. of Lanes	Relative Cumulative Frequencies	Original Score
1	0.050	0
2	0.452	1
3	0.581	2
4	0.806	4
>4	1	6

Assuming a weight of 6 for "> 4" category in Table 6-7 above (the same weight proposed by NYSDOT in Table 6-1), weights for other number of lanes can be calculated by multiplying corresponding relative cumulative frequencies by 6 and then approximating the outcome to its nearest integer. It is observed that the weights for the number of lanes 2 and 3 are the same. Hence, final weights for different number of lanes are obtained as shown in Table 6-8.

Table 6-8: Final Weights for "Lanes of Traffic On" in Branch 1.

Lanes of Traffic On	Score
1	0
2-3	3
4	5
>4	6

Protective Barriers: The primary function of a protective barrier is to minimize the loss of life. Barriers are installed to meet hazard elimination, vehicle retention, and vehicle redirection objectives. The collision vulnerability procedure considers three types of barriers: "No Railing", "Conforms to AASHTO Standards", and "Does not Conform to AASHTO Standards". Considering the function of barriers, a bridge with no railings should have the highest vulnerability weight, whereas the one conforming to AASHTO standards should have the lowest vulnerability weight. Hence, after arranging three barriers in an increasing order of their vulnerability, we calculate relative cumulative frequencies, as shown in Table 6-9.

Table 6-9: Cumulative Hit Frequencies for Protective Barriers.

Type of Railing	Counts	Relative Frequencies	Relative Cumulative Frequencies
Conforms to AASHTO Standards	385	0.272	0.272
Doesn't Conforms to AASHTO Standards	912	0.644	0.916
No Railing	120	0.084	1

Based on revisions proposed by NYSDOT, we assign highest weight of 20 to the case of "No Railings". Then, we can calculate weights for other types of barriers by multiplying corresponding relative cumulative frequencies to 20 and then approximating the number to its nearest integer, as shown in Table 6-10.

Table 6-10: Proposed Weights for Protective Barriers.

Type of Railing	Proposed Weights
Conforms to AASHTO Standards	5
Doesn't Conforms to AASHTO Standards	18
No Railing	20

Bridge Width vs. Highway Width: Bridge Width vs. Highway Width is also known as necking and is used to describe the difference between the usable roadway width of the approach to the bridge and the curb to curb width or face of rail to face of rail width of the bridge. Severe necking should have the highest vulnerability weight in the necking group, which includes severe necking, moderate necking and minor necking. It is observed from Table 6-1 that severe necking is assigned a weight of 10, although it is observed from Table 6-11 that bridges with the most severe necking have been hit the least, compared to other bridges in the necking group. This may be because of the fact that the most contributing cause of hits is overheight trucks and necking may just be a peripheral factor. Hence, total weight of 18 assigned by the NYSDOT to the necking group should be distributed to different items in this group in the proportion of cumulative frequency in Table 6-11, with maximum weight still being assigned to the most severe necking case. Assuming the weight for “>10” case is W, the total weight is distributed as: W+0.937W+0.866W+0.684W = 18. This gives W = 5 (rounded to nearest integer). Then, using W = 5 for >10 case, weights for “5-10”, “< 5” and “0” necking cases are calculated as 0.937W, 0.866W and 0.684W, respectively, as shown in Table 6-11.

Table 6-11: Calculation of Weights for Necking Group.

Necking	Hit Count	Relative Frequency	Relative Cumulative Frequency	Revised Weights
0	784	0.684	0.684	3
<5	209	0.182	0.866	4
5-10	82	0.072	0.938	5
>10	72	0.062	1	5

Approach Roadway Assessment: Approach Roadway Assessment reflects the adequacy of the approach roadway alignment in terms of reduction in vehicle operating speed. For example, a substantial reduction in vehicle operating speed indicates a substandard horizontal and vertical alignment problem at the bridge. Hence, a substantial speed reduction should be assigned the largest vulnerability weight in this group. Table 6-12 shows hit counts, relative frequencies and relative cumulative frequencies for the three cases of approach roadway assessments in the increasing order of vulnerability. Substantial speed reduction has been assigned a weight of 10 by NYSDOT. Hence, we also assume a weight of 10 in this work. Then, weights for other cases are calculated by multiplying respective relative cumulative frequencies by 10. Based on this, weights for minor speed reduction and no speed reduction are calculated as 8 and 6, respectively, as shown in Table 6-12.

Table 6-12: Calculation of Weights for Approach Roadway Assessment Group.

Approach Roadway Assessment	Hit Counts	Relative Frequency	Cumulative Frequency	Proposed Weights
No Speed Reduction	737	0.639	0.639	6
Minor Speed Reduction	201	0.174	0.813	8
Substantial Speed Reduction	216	0.187	1.000	10

Functional Classification: Functional Classification indicates the importance of the bridge highway, and is categorized as: “Interstate”, “Arterial”, “Collector”, and “Local”. Interstate is the most important one, whereas Local is the least important one. Hence, Interstate should be assigned the highest vulnerability weight in the “Functional Classification” group. Table 6-13 shows number of hits, relative frequencies and relative cumulative frequencies for functional classification group. Assuming a weight of 8 for “Interstate” (the same as that proposed by

NYSDOT in Table 6-1), weights for "Arterial", "Collector" and "Local" categories are obtained by multiplying respective relative cumulative frequencies by 8, as shown in Table 6-13.

Table 6-13: Calculation of Weights for Functional Classification Group.

Functional Classification	Counts	Relative Frequency	Cumulative Frequency	Proposed Weights
Local	58	0.051	0.051	0
Collector	115	0.102	0.153	1
Arterial	849	0.752	0.905	7
Interstate	107	0.095	1	8

Previous Impact Damage: Data on **"**Previous Impact Damage" and the "Multiple Bridge Hits" are obtained directly from the bridge hit database. These two quantities represent actual vulnerability of the bridge to impacts by overheight trucks. Previous impact damage is categorized into "None", "Minor", "Moderate" and "Major" categories and is based on visual inspection of an impacted bridge. A bridge suffering major damage has the vulnerability to suffer moderate or minor damage too. Similarly, a bridge suffering moderate damage also has the vulnerability to suffer minor damages. Table 6-14 shows hit counts, relative frequencies and relative cumulative frequencies for previous impact group. Since the previous impact damage group is assigned a total weight of 42, we keep the same total weight in our calculations too. Hence, assuming that the weight for "Major" damage is W, we can calculate this weight by writing W+0.961W+0.935W+0.694W=42. This results in W = 11.69. Weights for other "Previous Impact Damage" categories are found by multiplying this W by respective relative cumulative frequencies. All weights are approximated to the nearest integer and are listed in Table 6-14 below.

Table 6-14: Calculation of Weights for Previous Impact Damage Group.

Previous Impact Damage	Counts	Relative Frequencies	Relative Cumulative Frequencies	Proposed Weights
None	696	0.694	0.694	8
Minor	242	0.241	0.935	10
Moderate	26	0.026	0.961	11
Major	39	0.039	1	12

Multiple Bridge Hits: The current collision vulnerability manual assigns a weight of 0 to bridges never hit or hit once. However, if a bridge has been hit once, this indicates a greater vulnerability. Based on this observation, information on past hit history is incorporated in the vulnerability assessment by classifying the group into the following two categories: "Hit Once or Never Been Hit" and "Hit 2 or More Times". Table 6-15 below shows hit counts and relative frequencies for these two categories. The total weight of 15 assigned by NYSDOT to this group is divided into these two categories based on their relative frequencies, as shown in Table 6-15. It is observed from Table 6-15 that the category "Hit Once or Never Been Hit" is assigned a weight of 4 instead of 0 to account of a greater vulnerability of a bridge never hit or hit once.

Table 6-15: Calculation of Weights for Multiple Bridge Hits Group.

Multiple Bridge Hits	Counts	Relative Frequency	Proposed Weights
Hit once or never been hit	370	0.263	4
Hit 2 or more times	1038	0.737	11

6.3.2. REVISIONS IN BRANCH 2A: SUPERSTRUCTURE VULNERABILITY TO TRUCK UNDER BRIDGE COLLISION

Minimum Vertical Clearance Under: "Minimum Vertical Clearance Under" is one of the most important factors affecting the vulnerability of bridges to impacts by overheight trucks. This quantity indicates the actual minimum vertical clearance from a point on the under roadway to the bottom of the superstructure or other obstruction. In general, a bridge with lower vertical under-clearance will have an increased vulnerability to impacts. Table 6-16 shows hit counts and relative frequencies for different vertical under-clearances. The current collision vulnerability manual assigns a total weight of 58 to the vertical under-clearance group. We can distribute this weight to different vertical under-clearances on the basis of their respective relative frequencies to calibrate the vulnerability because of vertical under-clearance based on observed hit behavior. Column 4 of Table 6-16 shows proposed weights on this basis.

Table 6-16: Calculation of Weights for the Minimum Vertical Under Clearance.

Minimum Vertical Clearance	Counts	Relative Frequency	Proposed Weights
<11	375	0.267	15
11-11'11''	194	0.138	8
12-12'11''	131	0.0933	5
13-13'11''	194	0.138	8
14-14'11''	335	0.239	13
15-15'11''	37	0.0264	2
16-16'11''	46	0.033	2
>16	92	0.066	0

ADTT Under: "ADTT Under" denotes current Average Daily Track Traffic for the highway under the bridge. A high value of ADTT for a particular bridge implies a higher level of vulnerability of the bridge to impacts by trucks. It is observed from Table 6-17 that the ADTT is categorized into 5 categories: 200 & Below, 200-820, 820-1800, 1800-4500 and > 4500. Table 6-17 shows hit counts, relative frequencies and relative cumulative frequencies for different categories of ADTT. We assume a weight of 8 for ">4500" as per NYSDOT Revisions in Table 6-2. Then, weights for other categories are derived by multiplying respective relative cumulative frequencies by 8, as shown in Table 6-17.

Table 6-17: Calculation of Weights for ADTT.

ADTT	Counts	Relative Frequency	Cumulative Frequency	Proposed Weights
200 & below	67	0.050	0.050	0
200-820	163	0.122	0.172	1
820-1800	189	0.141	0.313	3
1800-4500	192	0.143	0.456	4
>4500	730	0.544	1	8

Functional Classification: This group is the same as that in Branch 1 with a highest weight of 8 assigned to "Interstate". Following the procedure described in Branch 1, weights for this group are calculated on the basis of relative cumulative frequency, as shown in Table 6-18. It is observed that the weights are the same as those derived in Branch 1.

Table 6-18: Calculation of Weights for Functional Classification in Branch 2A.

Functional Classification	Counts	Relative Frequency	Relative Cumulative Frequency	Proposed Weight
Local	47	0.035	0.035	0
Collector	66	0.049	0.084	1
Arterial	1075	0.802	0.886	7
Interstate	153	0.114	1	8

Previous Impact Damage: Weights adopted for this group are the same as those for Branch 1.
Multiple Bridge Hits: Weights adopted for this group are the same as those for Branch 1.

6.3.3. BRANCH 2B: PIER VULNERABILITY TO TRUCK UNDER BRIDGE COLLISION:

Since we don't have sufficient data for this case, revisions proposed by NYSDOT are recommended to be adopted for this branch.

6.4. CONCLUSIONS

The New York State Department of Transportation (NYSDOT) uses a Collision Vulnerability Assessment (CVA) procedure to identify relative vulnerability of the state's bridges to failures due to impact damages. In this report, we have carried out a detailed statistical analysis to identify various factors and their weights that affect the vulnerability rating of a specific bridge. Based on this analysis, further changes to the NYSDOT revisions to the CVA procedures have been proposed. A case study of 36 randomly selected bridges shows that the modified CVA procedure proposed in this report improves the collision vulnerability assessment of approximately 33% of bridges selected for the case study.

CHAPTER 7 : GENERAL BRIDGE HIT PREVENTION RECOMMENDATIONS

7.1. INTRODUCTION

Based on the detailed study carried out in this project, general recommendations for preventing bridge hits can be classified broadly into the following three categories:

- **Regulatory**: It has been observed from the analysis of bridge hits data in the New York State that a majority of multiple hits to bridges are caused by trucks on unauthorized roads, such as parkways and local roads restricted to truck traffic. Hence, regulatory measures can have significant effects on reduction of multiple hits to bridges by discouraging truck drivers from using parkways and other restricted highways.
- **Technological**: It has been observed from data collected by New York State Troopers that most of the drivers involved in bridge hits incidents on parkways were using consumer GPS system, which isn't programmed to avoid parkways and low clearance bridges. Hence, technological solutions, such as Truck GPS system, smart phone apps and overheight detector systems can be very effective in warning drivers actively as they approach a low clearance bridge.
- **Education and Outreach:** Making truck drivers aware about consequences of driving on restricted highways and parkways through continuous educational outreach efforts, e.g., flyers, seminars, safety courses, etc., can be an effective tool for mitigating bridge hits. This helps in prevention by modifying truck driver's behavior.

In addition to these measures, NYSDOT should also actively collaborate and coordinate with other state agencies such as motor vehicles services (MVS), other state DOTs such as Connecticut DOT (currently collects data) or initiatives such as I-95 Corridor to identify and implement effective measures.

7.2. DETAILED DESCRIPTION OF PROPOSED RECOMMENDATIONS

A detailed description of recommendations under above three categories is presented in the following.

7.2.1. REGULATORY RECOMMENDATIONS

Since a majority of bridge hits in New York State are because of unauthorized presence of trucks on parkways, regulatory recommendations may have impacts all over the state and may be the most cost-effective measures. Following regulatory recommendations are proposed to be further explored or implemented:

Prohibiting Consumer GPS: It has been observed from data collected by NY State Troopers that truck drivers frequently use consumer GPS system. These consumer GPS systems should be prohibited for use in trucks all across the state.

Coordination with Local Authorities: Several local routes under CSX bridges (e.g., routes under bridges hit frequently in Region 5) may not be restricted to trucks. NYSDOT, in collaboration with local authorities, should review all local routes with low height bridges to restrict such routes from truck traffic.

Fines and Penalties: It is noted that truck drivers pay minimal fines if they are caught on parkways or restricted highways. New York State Department of Transportation should explore the possibility of imposing stiff fines, points and penalties for unauthorized presence of trucks on parkways and restricted highways. This measure will create significant psychological barrier as well as awareness towards low clearance bridges. Implementation of this recommendation will have state-wide impacts.

Additional Liability Insurance: Requiring truck drivers with history of multiple violations or hits on bridges on unauthorized routes purchase additional liability insurance will increase the perception of trucking companies to the cost of violations. This can also be achieved by imposing significantly higher number of traffic violations points compared to other common moving traffic violations.

Electronic Monitoring and Summons: Using electronic remote monitoring to identify trucks on unauthorized routes (parkways, local roads) and issuing summons / penalties by mail will create a psychological barrier to using parkways and other unauthorized routes.

Tests and Mandatory Education: Including a section on "bridge strikes: its cause and consequences" in Commercial Driving License (CDL) tests will increase the awareness of truck drivers towards risks and consequences of driving on unauthorized routes. Requiring truck drivers undergo mandatory continuing education on various aspects of bridge hits will increase the awareness of truck drivers towards risks and consequences of driving on unauthorized routes.

Amber Alert for Low Bridge Regions: Similar to Amber Alert system for missing children, an alert system for low bridge region should be developed. This system can be designed to alert drivers about low vertical under-clearance bridge region and encourage them to report any truck on parkways to police. For this system, Signs have to be placed along parkways informing drivers about restrictions on truck traffic.

7.2.2. TECHNOLOGICAL RECOMMENDATIONS

The main goal of technological recommendations is to provide active routing and active warning to truck drivers who are already on unauthorized routes. Following technological recommendations are proposed to be implemented.

Installation of Overheight Detection Systems: It has been observed from results presented previously that a majority of bridge hits occur on low clearance bridges over parkways and local highways that are restricted to overheight trucks. It is possible that truck drivers aren't aware of their height or believe that they will pass under the bridge without impacting it. Installing an overheight detector system on the ramp of parkways before a low clearance bridge will provide truck drivers an active warning based on the height of the truck and vertical under-clearance of trucks. This warning can be in the form of a digital warning sign or red light. These systems can also be programmed to automatically notify local law enforcement office about the possible impact to the bridge, if a truck driver doesn't stop on the warning. It has been observed from the feedback of state DOTs using these systems that they are effective in reducing impacts to bridges through active intervention. Moreover, the presence of these systems on parkways also creates psychological barriers in the minds of truck drivers about using unauthorized parkways, thereby preventing future hits.

Several overheight detection systems have been identified through the detailed survey of several state DOTs using these systems. In particular, it has been observed that HISIC450 system manufactured by SICK MAIHAK, Inc. and Trigg detectors have been used by many state DOTS and have been found to be reliable. These systems have a service life of 15-20 years, require minimal maintenance and have an installation cost in the range of $15,000-$20,000 per unit (for a system with digital sign options). For parkways, simple systems with single direction detection, low speed, red /green light options can be configured at significantly lower costs. It should be noted that benefits derived by installing these systems far outweigh installation costs.

Truck escort area (parking area) should be provided after the OHDS system so that a truck driver can park the truck and call police for help.

NYCDOT has installed infrared sensors on Bronx River Parkway at Westchester Ave and has marked the pavement of the ramp to the parkway with “Cars Only”. Infrared sensors have been activated 9 times and there hasn’t been anu incident since November 2010.

Google Maps: Many drivers rely on Google maps for routing their vehicles. Embedding vertical under-clearance information in these maps can be helpful in preventing the entry of trucks on parkways.

Transmission on CB Radio Transmitters: Truck drivers regularly use CB radio transmitters to communicate with each other. Transmitting information to truck drivers about low clearance bridge ahead through a CB radio transmitter may make the trucker driver aware about the risk. The cost of a CB radio transmitter with antenna is approximately $300 and it is effective in the range of approximately 15 miles. Hence, CB radio transmitters need to be setup near bridges that are being hit multiple times. Other issues related to costs are maintenance and regular broadcasting on CB radio. This process can be made automatic through a recorded message. Hence, this measure can be an extremely cost-effective approach to reduce impacts on bridges hit multiple times.

Truck GPS: With widespread availability of GPS systems for routing, it has been observed that many truck drivers end up on parkways because of the use of consumer GPS units. Since GPS units are being used more frequently because of their ability to reroute in real time, mandating the use of GPS units customized for trucks will have a significant contribution in reducing bridge hits. Several newer GPS units, e.g., Rand McNally TND 510 Truck GPS, have been designed and are being marketed for trucks. These GPS systems seem to consider truck characteristics into routing. Their maps have bridge under-clearances embedded. Hence, a route planned by these devices will automatically avoid routes with low under-clearance or restricted bridges. During telephone conversation with representative from Rand McNally, the PI was told that the device uses vertical under-clearance data posted at the NYSDOT website as it becomes updated.
NYSDOT should actively collaborate with these companies to ensure that these GPS systems do use most recent data on vertical under-clearances of bridges. Availability of a truck GPS system will be very effective in preventing bridge hits by (i) avoiding routes with low clearance bridges and (ii) providing real-time warning to truck drivers who are already on a route with low clearance bridges as truck approaches a low clearance bridge. The issue related to the use of the most recent vertical under-clearance information can be addressed by providing the vendor, such as Rand McNally, updated information regularly. New York State Department can also require truck drivers update their GPS unit while planning a route. In fact, the GPS device connected to

wireless network through a cell phone can be programmed to automatically update as updated map becomes available.

It has been noted that a truck GPS system typically costs approximately $500. These systems also have routing based on the use of real-time traffic data. This feature may require additional monthly expense of approximately $20. This is quite cheap and cost-effective solution, given the risks and costs involved after a truck has impacted a bridge. New York State Department of Transportation should actively promote the use of GPS units customized for trucks through outreach to trucking companies.

Smart Phone Apps: A majority of smart phones have GPS capabilities. Hence, an App for smart phones can be developed to embed maps with low vertical clearances as an alternative to TRUCK GPS. Truck drivers can download the app directly from NYSDOT website. The app can have the ability to automatically update as new information on vertical under-clearance of bridges becomes available. However, this option will require significant funding to develop and maintain the app.

Signage and Warnings: Following measures on signage and warning should be adopted to increase driver awareness towards low-clearance bridges or restricted parkways.

- It has been observed that many regions, such as Regions 5 and 8, have inadequate signs warning truck drivers about a low vertical under-clearance bridge ahead. On the other hand, Region 10 of NYSDOT has well planned and sufficient number of signs. Although effectiveness of these signs in reducing hits on bridges isn't clearly understood, their presence does help in drivers being aware about the risk of impacts.
    - NYSDOT should develop a comprehensive approach to evaluate signs near under-clearance bridges and install signs as per MUTCD.
    - Marking parkway entrance pavements with warning about low under-clearance bridges may deter truck drivers from proceeding further.
    - Many signed warning drivers about low vertical under-clearance may not be visible because of vegetations. Vegetation should be removed to ensure clear visibility of signs.
    - Warning signs should also be placed on both sides of roads (e.g., ramp of a parkway) approaching the bridge.
    - Larger and repeated signs should be placed along the route before the bridge.
    - An alternate route sign should be provided before the driver enters the region of the low-clearance bridge so that a truck driver can safely exit before the bridge. If an exit is not available before the bridge, the driver should be provided instructions to wait on the shoulder of the route and then call for help.
    - Recommended minimum distance for an advance warning sign placed before a low clearance bridge should be increased to provide the driver enough reaction time to make a decision.
    - It has been noted that truck drivers sometimes ignore the low vertical under-clearance sign because they believe that the actual clearance is higher than the posted one. In New York State, for all bridges with vertical clearance of 14 feet or less, posted clearance is 12

inches (1 foot) less than the actual clearance. However, this practice makes truck drivers distrust posted clearances. Placing both legal and actual vertical under-clearance of the bridge will help drivers under the risks of hitting a bridge better while making a decision about stopping.

- o It is likely that truck drivers may not be aware about the height of their cargo or may not be able to immediately correlate with under-clearance of the bridge in a short reaction time available. Hence, truck drivers should be required to post height of their truck / cargo in the cabin within their eyesight. They should also carry appropriate tools to measure height of the truck / cargo in case of changes in truck cargo.

7.2.3. EDUCATION AND OUTREACH RECOMMENDATIONS

Following education and outreach measures are recommended for reducing bridge hits:

Bridge Strike Mitigation Website*:* A website dedicated to the problem of bridge hits and possible solutions should be developed. Latest information on the issue of bridge hits can be posted on this website, including photographs of any recent bridge hits. The website can also be linked with similar sites by other agencies.

Outreach with Motor Carrier Association: Motor Carrier Associations coordinate with major trucking industries and can be very helpful, in outreaching the trucking industries to seek feedback about possible solutions.

Outreach with Independent Operators: While it may be easier to outreach truck companies with fleet, it has been observed from data collected by the New York State Troopers that independent operators are frequently involved in bridge hits. Hence, NYSDOT should develop an approach for outreaching independent operators.

CDL Tests**:** Including a section on "bridge Hits: its cause and consequences" in Commercial Driving License (CDL) tests for both new and renewal CDL licenses can have significant long-term impacts. This section can include statistical information from this study, consequences of being on an unauthorized highway, consequences of using consumer GPS, etc. This report or a condensed version of this report can be made available as a study guide for such tests.

Educational Materials**:** Educational materials, such as posters, handouts and other materials illustrating severity and consequences of bridge strikes should be made available to local trucking companies and out of state trucking companies requesting permit. These materials should illustrate:

- Photographs of trucks hitting bridges
- Photographs of traffic congestion caused because of bridge hits
- Statistical data on bridge hits, including an estimate of damages caused.

Newsletters: Including data on bridge hits in regular NYSDOT newsletter and distributing to local trucking companies in New York State or to out of state companies requesting permits will keep them aware about the issues.

Seminars: Organizing a series of seminars on bridge hits mitigation and requiring/encouraging trucking agencies and drivers attend these seminars will keep them aware about the problem.

Outreaching Driving Schools: Outreaching trucking driving schools and requesting/requiring them to include a module on "Bridge Hits: Its Causes and Consequences" in driver education curriculum will help in making future drivers aware of the issue.

Annual Safety Course: Requiring truck drivers undergo an annual safety course that includes a detailed module on "Bridge Hits: Its Causes and Consequences" will help them understand the bridge hits problem and factors responsible for it.

The cost of developing education/outreach materials is minimal, since a majority of required information is available in the final report of this project. The cost of implementing proposed education/outreach activities is also minimal if the safety seminar is conducted by the NYSDOT engineer at a desired interval. A majority of "Education and Outreach Recommendations" can be implemented as a part of various existing programs.

7.3. CONCLUSIONS

This report presents three categories of general recommendations for reducing hits on bridges in New York State. These recommendation categories are: Regulatory, Technological and Educational / Outreach. Several recommendations under each of these categories are presented and their costs implications are discussed. It should be noted that while both regulatory and education/outreach recommendations are likely to have impacts over the entire New York State region, implementation of technological recommendation, except for Truck GPS, is more suitable for reduction of bridge hits to a specific bridge. Truck GPS, if implemented successfully, will have significant impact on the reduction of bridge hits because of its ability of real-time routing and active warning.

CHAPTER 8 CONCLUSIONS

This report presents a detailed investigation on overheight trucks hitting bridges in New York State on the basis of all relevant and available literature on bridges hits and bridge hits database of New York State. It is observed from the analysis of the NYSDOT bridge hits database that a majority of bridge hits are by overheight vehicles on parkways or other highways restricted to truck traffic. Increased use of consumer GPS by truck drivers has been seen to be contributing to the problem. Several overhead detection devices that have been found to be effective by other states are available. From the analysis of bridge hits in New York, it is observed that NYSDOT regions 8, 10, 5 and 11 have the highest incidence of hits in the state. Among the counties in New York State, Westchester, Erie, Nassau, Suffolk and Rockland counties have the highest incidence of hits. In fact, only 32 bridges contribute to 595 hits (44% of total hits in the New York State) out of a total of 815 bridge hits in Westchester, Erie and Nassau counties. Among the factors contributing to increased bridge hits are feature carried under, superstructure design type and maximum and minimum vertical clearance under. Analysis of the bridge hits data shows that a majority of bridges that have been hit were rated 'not vulnerable' to collision or have not been considered candidates for a collision vulnerability analysis. Detailed work has been done to propose changes to the collision vulnerability assessment procedure so that bridges can be categorized for vulnerability to collision more realistically. A computer program has also been developed so that future bridge hits database could be analyzed to identify issues related to bridge hits in future. Based on detailed research carried out, several recommendations on regulatory, technological and outreach countermeasures have been proposed to NYSDOT for implementation.

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APPENDIX A: PHASE 1 SURVEY QUESTIONNAIRE

Bridge Vehicle Impact Assessment Survey
New York State Department of Transportation

State: Person Preparing:
Date Prepared: Contact Telephone No.:
E-mail:

During the last 5 years, bridges in New York State have been experiencing on the average 200 bridge hits per year. Several of these hits have caused significant damages to bridge components. The New York State Department of Transportation initiated the "Bridge Vehicle Impact Assessment" study to identify primary factors responsible for bridge hits and mitigation approaches. While bridges over navigational waterways are frequently hit by vessels/barges, the main objective of this study is to focus on **vehicular impacts on bridges**. Please answer the questions in this survey based on data/incidents related to vehicular impacts on bridges in your state. We appreciate your participation in the survey very much.

General Bridge Hits Problem

1. Do you consider bridge hits to be a major problem in your state (Y/N)?
2. How many bridges have been hit in your state in each of the last four years:
   (a) Bridge Hits in 2005:
   (b) Bridge Hits in 2006:
   (c) Bridge Hits in 2007:
   (d) Bridge Hits in 2008:
3. Please describe the types of bridges hit most often (i.e. concrete frame, multi-girder, etc…).
4. What is the perceived prime cause of bridge hits (in terms of percentage of the whole problem) (Place a percentage next to selection)
   (a) Over height Trucks:
   (b) Reckless Driver:
   (c) Accidental equipment storage:
   (d) Other (please specify):
5. Bridge hits have caused (Place a check or X next to all that apply)
   (a) Serious damages to bridges:
   (b) Minor damages to bridges:
   (c) Mostly scrapes, however, they cause serious traffic congestion problems:
   (d) It is not a problem:
6. New York State has many "Parkways" on which trucks and trailers are not allowed because of low vertical clearance bridges.
   (a) Does your state have "Parkways" or similar roadways systems on which truck/trailer traffic is not allowed? (Yes/No)
   (b) If the answer to the above question is yes, can you provide an estimate of the percentage of bridge hits on these roadway (parkway) systems (ratio of recorded hits on parkways to total recorded hits in state)?
7. How do you maintain information on bridge hits (Place a check or X next to selection(s)):
   (a) Separate bridge hit database
   (b) Part of bridge inspection data base

(c) Based on Police Reports
(d) Other means (please describe):

8. Have you carried out any studies on the bridge hit problems in your state (Y/N)?
If yes, please provide a brief summary on the study and the availability of a report.
9. If it is an ongoing study, can we follow up with the project manager /consultant to discuss interim outcomes (Y/N)? If yes, please provide the project manager's name and contact details.

Overheight Regulations

10. What is the state minimum design vertical under clearance for bridges?
(a) On the national highway network?___________
(b) Off the national highway network?___________
11. What is the state maximum height limit for vehicles and cargo?
(a) Without a permit?___________
(b) With a permit? ___________
12. How is a permitted overheight vehicle routed through the state? (Please check all that apply.)
(a) State determines specific route for permitted vehicle: ___________
(b) Carrier must propose route and submit to state for approval: ___________
(c) Regional (multi-state) permitting organization routes vehicle: ___________
(d) Other (please describe):____
13. What method is used to route trucks/over-height vehicles? (Place a check or X next to selection)
(a) Using State Map Automatically:
(b) Using an electronic map prepared for the state:
(c) Using a truck routing software prepared for the state:
(d) Using mapping software such as Mapquest, Googlemaps, Street Atlas, Street and Trips, etc.
(e) Other (describe):
14. New York State has observed instances of trucks impacting bridges after the driver has gone on an unauthorized route using GPS guidance. Have you observed bridge impacts that were a result of GPS guiding drivers on to unauthorized routes? (Place a check or X next to selection)
(a) Have observed 1-5 instances during last year:
(b) Have observed 6-10 instances during the last year:
(c) Have observed more than 10 instances during the last year:
(d) Have observed none:
15. Would your state be interested in joining a collaborative effort to develop an online routing site for trucks or a GPS system that can warn trucks about a low under-clearance bridge ahead? (Place a check or X next to selection)
(a) Would be very interested in joining the effort:
(b) Would be interested in getting updates about the effort, but would not be interested in joining the effort:
(c) Would not be interested in joining the effort at all:
16. How does the state enforce overheight vehicle laws? (Place a check or X next to all that apply.)

(a) Roving patrols: ___________
(b) Manual spot checks at weigh stations: ___________
(c) Automated height measurement system at weigh stations: ___________
(d) Automated height measurement system at truck loading terminals:___________
(e) Automated height measurement system on highways: ___________
(f) Automated system with active warning signs: ___________
(g) Other (please describe):____

17. Does your state require truck drivers to know about the height of the truck/cargo (Y/N)?

Posting of Bridge Under-Clearance

18. According to state policy on posting bridge clearances:
(a) What is the maximum bridge underclearance for which a sign is required? ___________
(b) By how many inches do the signs under-report the actual underclearance? ___________

19. What is your policy regarding the location of posting of underclearance (Place a check or X next to all that apply)
(a) Posted near the bridge:
(b) Posted ------- Yards from the bridge:
(c) Posted at the entrance of the ramp to the highway:
(d) Posting at another location (Please specify):_____________________

20. Please list typical messages posted to warn about low underclearance bridges (e.g., “NO TRUCKS”, “NO COMMERCIAL TRAFFIC”, etc.)
(a)
(b)
(c)
(d)
(e)
(f)

Automated Over-height Detection

21. Has your state used passive vehicle over-height systems such as chains, headache bars? If yes, please describe the type of system used.

22. Has your state used automated vehicle height measuring devices (laser, infrared, etc?) (Y/N)?

23. If your answer to Question 22 is “Yes”, please provide the contact information of person responsible for the installation and maintenance of the system in your organization and contact information of the manufacturer.

We want to thank you very much for your feedback and participation in the survey. Upon completion of the study, it will be our pleasure to share the outcome of the study with you.

Please e-mail the completed survey to <Agrawal@ccny.cuny.edu>. Paper copies can be sent to:

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APPENDIX B: STAGE 1 SURVEY DATA

State/Question	Q1	Q2(a)	Q2(b)	Q2(c)	Q2(d)	Q3
Washington	Y	20	20	20	24	prestressed concrete multi-girder, steel plate girders and trusses
Pennsylvania	Y	10	12	18	10	Multi-girder bridges - typically steel beams or concrete beams over the Interstate. We believe the bridge hits are unreported as only obvious damage is reported immediately.
Tennessee	Y	22	23	19	25	Steel I-beam and prestressed concrete I-beam
Oklahoma	Y	15	15	15	15	multi-girder steel I-beam or plate girder
Maryland	N					Steel Beam/Girder
NYSTA	Y	1--4	1--4	1--4	1--4	Thru-truss X-bracing, Multi-Girder Overpass,
Virginia	N	<10	<10	6	15	All types including...Multi-girder steel, Steel Truss, Concrete Prestressed, Concrete Tee, Concrete Box Beam
Maine	Y	30	30	30	30	through trusses and steel girder overpasses
ILLINOIS	Y	25	25	25	25	steel multi-girder
Arkansas	Y	NA	NA	NA	NA	Truss bracing; Multi-girder
Ohio	Y	10	9	13	13	steel beam/girder (no of hits do NOT include scrapes and minor hits - only hits that cause damage that needs repaired)
Arizona	N	25	25	25	25	Concrete I Girders, PT box girders and steel I girders
South Dakota	N	0	1	6	1	The majority of the bridges are steel multi-girder type.
New Jersey	Y	Unknown	Unknown	Unknown	Unknown	Bridges with clearances above highways that are <14'-6"
New Mexcio	Y	Unknown	Unknown	Unknown	Unknown	pre-stressed girders
North Carolina	Y	10	10	10	10	Grade crossings involving steel beams, steel girders, prestressed AASHTO shaped concrete beams
Texas	Y	100	100	100	100	multi-girder bridges: Prestressed concrete or steel I beam
D.C.	N	2	1	1	0	Multi
South Carolina	Y	20	25	35	40	multi-girder (PSC and steel)
Massachusetts	N	56	68	56	55	multi girder
Kansas	N	4	5	3	2	Multi-Girder
Hawaii	N	1	1	0	0	Multi-girder.
North Dakota	N	4	3	3	2	Multi girder bridges either Steel or Prestressed concrete beams
NJTPK	Y	5	5	7	17	Steel multi-stringer/girder
Montana	Y	8	1	7	4	Mostly Multi-girder PS concrete, but occasionally a through truss
Wyoming	N				12	steel girder, concrete T - Beam, concrete slab
Georgia	Y	12	15	13	12	multi-girder beam bridges
Michigan	N	38	71	50	11	multi-girder
Louisiana	Y	10	10	10	10	Interstate overpasses I beam bridges concrete and steel
Minnesota	N	50	50	50	50	Multiple steel beam bridges and prestressed concrete bridges over Interstate Highways
Florida	Y	55	45	55	40	Multi Girder Bridges
Delaware	N	5	5	5	5	steel multi-girder
Alabama	Y	150-200	150-200	150-200	150-200	Multi-Girder and Truss
NEBRASKA	Y	5	4	5	6	multi-girder
Oregon	N	3	2	3	2	multi-girder and through trusses
Missouri	N	426	400	427	438	concrete frame, girder (most hits do not cause serious property damage)
Idaho	Y				69 in last 10 years	Prestressed Concrete Stringer/Girder (45+ hits), Concrete Stringer/Girder (~15 hits), Steel (~10 hits)
Iowa	N	11	18	9	6	Pre-stressed concrete beams and multigirder steel beams
New Hampshire	Y					
Wisconsin	Y	N/A	N/A	N/A	N/A	Predominant type is prestressed girder
Alaska	Y	5	6	3	4	Through Trusses; Prestressed Concrete Girders
Nevada	Y	NA	NA	NA	NA	steel multi-girder; cast in place, post-tensioned box girder
Kentucky	Y	50	50	50	50	Reinforced concrete T-Beams and steel multi-girder bridges
California	Y	N/A	N/A	N/A	N/A	All different types of bridges in California have been hit by overheight loads
Mississippi	Y					Prestressed Concrete Girder Overpasses, Steel Thru-Truss
Rhode Island	N	N/A	N/A	3	2	multi-stringer

State/Questions	Q4(a)	Q4(b)	Q4(c)	Q4(d)	Q5(a)	Q5(b)	Q5(c)	Q5(d)
Washington	90%	5%	5%		1	0	0	0
Pennsylvania	5%		95%	The 95 % hits are due to imporperly stowed boom type equipment,.	1	1	0	0
Tennessee	30%	10%	40%	20% permitted truck off of prescribed route	1	1	1	0
Oklahoma	97%	3%			1	1	1	0
Maryland	50%		50%		0	1	0	0
NYSTA	95%			5% Equipment Failure - Bed raises, Boom raises	0	1	1	0
Virginia	90%		10%		1	1	1	0
Maine	40%	30%	30%		1	1	1	0
ILLINOIS	100%				1	1	0	0
Arkansas	2%	1%	0%	Items on towed trailer - 98%	1	1	1	0
Ohio	5%	5%	70%	cargo shifting (hydraulic arms not tied down and raise up during transit) or not measured corectly to start with.	1	1	1	0
Arizona	40%	60%			1	1	1	0
South Dakota			95%	For those that are caught, typically they are trucks hauling equipment where the boom seems to either creep up or is secured too high to begin with. Many accidents are hit & run type where we do not know what caused the damage.	1	1	0	0
New Jersey	75%		25%	Assume 'accidental equipment storage' means improperly stored equipment on truck trailers	1	1	1	0
New Mexcio	25%	25%	50%		1	1	0	0
North Carolina	20%	20%		60% - Trackhoes being hauled on lowboy trailers	1	1	1	0
Texas	90%	10%			1	1	1	0
D.C.					0	0	0	0
South Carolina	35%	30%	35%		1	1	1	0
Massachusetts	75%	25%			0	1	1	0
Kansas	90%	5%	5%		1	1	1	0
Hawaii	100%				1	0	0	0
North Dakota	100%				1	1	1	0
NJTPK	4%	1%	95%	Equipment extending above vehicle	1	1	0	0
Montana	65%		35%		1	1	1	0
Wyoming	90%		10%		1	1	1	0
Georgia	15%		75%	15% dump truck beds in up position when placing asphalt or aggregate base	1	1	1	0
Michigan	80%		20%		1	1	1	1
Louisiana	50%		50%		1	1	0	0
Minnesota	90%	5%	5%		1	1	1	0
Florida	95%	5%			1	1	1	0
Delaware	80%	15%	5%		1	1	0	0
Alabama	20%	80%			1	1	1	0
NEBRASKA		60%			1	0	0	0
Oregon	100%				1	0	0	0
Missouri	20%	70%	10%		1	1	1	0
Idaho	85%	15%			1	1	1	0
Iowa	27%	25%	39%	9%	1	0	0	0
New Hampshire					1	1	1	0
Wisconsin	3%	2%	4%	1%	1	1	1	0
Alaska	80%		20%		1	1	0	1
Nevada	15%	40%	40%	5%	1	1	1	0
Kentucky	90%	5%	5%		1	1	1	0
California	99%				1	1	1	0
Mississippi	99%		1%		1	1	0	0
Rhode Island	90%	10%			1	1	1	0

State/Questions	Q6(a)	Q6(b)	Q7(a)	Q7(b)	Q7(c)	Q7(d)	Q7(d)
Washington	N		0	1	0	0	Damaged bridges can be identified through a query of our database.
Pennsylvania	N		0	0	0	1	Bridge hits are included in a database for critical deficiencies.
Tennessee	N		0	1	1	0	
Oklahoma	N		1	1	1	0	
Maryland	Y	0	0	0	1	1	Do not keep a seperate hit list. Treat as an out of cycle inspection. Not that many to warrant seperate list.
NYSTA	Y	No	0	1	0	0	
Virginia	N		0	0	1	1	Bridge Inspection Report
Maine	N		1	0	1	0	database is new and held by the legal department
ILLINOIS	N	N/A	0	0	0	1	We do not have a bridge hit data base but we do collect information by region/district through our bridge enginners and polic reports to our communications center
Arkansas	N		0	1	1	0	Data not in one location; would have to be researched if needed
Ohio	N		1	0	0	0	It's not really a database - it's a spread sheet. We capture all hits that cause damage - does not include scrapes. For all trucks that we catch we collect damages from thier insurance carriers.
Arizona	N		0	1	0	0	
South Dakota	N		1	0	0	0	An excel file including all overheight vehicle impacts to bridges is maintained to include items such as year of impact, location, bridge type, vertical clearance, traffic restrictions, hit and run (Y/N), repair costs, etc. Repair plans and documentation (hard copies) are included in the bridge inventory files.
New Jersey	Y	No data available--Garden State Parkway owned by NJ Turnpike	0	1	0	0	We collect information during bridge inspection where collision impacts are present, but do not collect information on specific impact incidents.
New Mexcio	N		0	0	0	0	NMDOT does not track bridge hits
North Carolina	Y	Blue Ridge Parkway - no incident records	0	1	1	0	
Texas	N		0	1	0	1	we don't have good records because most hits are not reported. we find many of them with routine inspections
D.C.			0	0	0	0	
South Carolina	N		0	0	0	1	verbal notice and BI reports
Massachusetts	Y	60%	0	1	0	0	Damage Inspection reports are completed
Kansas	Y	Less than 2%	0	1	0	0	
Hawaii	N		0	0	0	1	We don't keep official record. Information provided is only my personal knowledge of incidents.
North Dakota	N		0	1	1	0	If the strike is significant the police are involved and we (if we catch the offender) can get insurance to pay for damages.
NJTPK	Y	50	0	1	1	1	Maintain an incident database
Montana	N		0	1	0	0	Traffic impact smart flag. This tracks any impact on any superstructure element, including bridge rails (so, this doesn't apply only to overheight impacts). Severity can range from just a scrape to destroyed. The numbers in question 2, correspond to only overheight vehicle impacts that required some sort of repair. Question 2 does not include "scrapes" or rail impacts that are tracked in the BMS using the impact smart flag.
Wyoming	N		0	1	0	1	Notification by district maintenance folks and subsequent inspection and documentation of findings by bridge personnel. Major damage is repaired by contractor, minor damage has been repaired by maintenance forces.
Georgia	N		0	1	0	0	
Michigan	N		1	0	0	0	
Louisiana	N		0	0	1	1	District bridge staff reports the damage
Minnesota	N		0	0	0	1	Records kept in the District bridge files. We do not have a central database that tracks bridge hits.
Florida	N		0	1	0	0	We do not specifically separate overhead hits from other types of accident inspections.
Delaware	N		0	1	0	0	
Alabama	N		0	1	1	0	No formal procedure, Some Divisions track this others do not unless major
NEBRASKA	N		1	0	0	0	
Oregon	N		0	0	1	1	We file the photos, description of damage, propose fix and response in an emergency response file
Missouri	N		0	0	1	0	
Idaho	N	Our POE and Permits department will map out routes for overheight trucks to find the best route from start to finish of their destination.	0	1	0	0	Right now some is captured by the bridge inspection reports and some is in a spreadsheet that the bridge department maintains on construction costs. Idaho does not an established tracking method and much of the information is getting lost. We hope to put together a procedure statewide for recording these incidences.
Iowa	N		1	0	0	0	Motor Carrier services manitains a database of all reported bridge hits.
New Hampshire	N		0	0	0	0	
Wisconsin	N		0	0	1	1	SINS- State Incident reporting System
Alaska	N		0	0	0	1	No formal method used. Alaska's bridge inventory is small enough to identify most by memory.
Nevada	N		0	1	0	0	
Kentucky	N		0	1	0	0	It is mentioned in the comments section of our Bridge Inspe. Reports.
California	Y	Not available	0	0	0	0	California does not maintain a data base on bridge hits.
Mississippi	N		0	0	0	1	Information is not formally maintained
Rhode Island	Y	0	0	0	1	0	

State/Questions	Q8(a)	Q8(b)	Q9(a)	Q9(b)
Washington	Y	Effect of concrete varying diaphragm depth to limit damge to prestressed concrete beam bridges.		
Pennsylvania	N		N	
Tennessee	N			
Oklahoma	N			
Maryland	N			
NYSTA	N			
Virginia	N		N	
Maine	N			
ILLINOIS	N	N/A		N/A
Arkansas	N		N	
Ohio	N			
Arizona	N			
South Dakota	N			
New Jersey	N			
New Mexcio	N			
North Carolina	N	Some have been hit due to low vertical clearances, but most hits are due to equipment being hauled.		
Texas	N		N	
D.C.				
South Carolina	N			
Massachusetts	N			
Kansas	N		N	
Hawaii	N			
North Dakota	Y	Several years ago, a vertical clearance study was performed. This study has caused us to lower roadways where possible and replace bridges where necessary.	N	Not ongoing.
NJTPK	N		N	
Montana	N			
Wyoming	N			
Georgia	N			
Michigan	N		N	
Louisiana	N			
Minnesota	N			
Florida	N			
Delaware	N			
Alabama	N			
NEBRASKA	N			
Oregon	N			
Missouri	N			
Idaho	N	We just put together a white paper on starting a pilot program to utilize overheight vehicle detection systems. In it has information concernign our bridge hit history. I'd email the document to you if you deem it useful to your study.	Y	The pilot program Bob Koeberlein is ITD's Mobility Services Engineer. phone: (208) 334-8487 e-mail: Robert.Koeberlein@itd.idaho.gov
Iowa	Y	The study looked ways to help prevent overheight load hits and made recommendations to improve signig and permitting. The report can be provided upon request.	N	
New Hampshire	N			
Wisconsin	N		N	
Alaska	N			
Nevada	N			
Kentucky	N			
California	N			
Mississippi	N		N	
Rhode Island	N			

State/Questions	Q10(a)	Q10(b)	Q11(a)	Q11(b)	Q12(a)	Q12(b)	Q12(c)	Q12(d)	Q12(d)
Washington	16.5		14	16	0	1	0	1	Pilot car with a measuring pole is required ahead of the over-height vehicle that is14 ft 6 in or higher.
Pennsylvania	16.5	14.5	13.5	Evaluated based on the route.	0	1	0	0	We use an automated permit review system based on bridge management data. We have not experienced any overhieght hits by a truck with valid permits issued by teh system (14 years the system has been used). Most hits are by unpermitted vehicles.
Tennessee	16.5	16.5	13.5	Depends on route	1	1	0	0	
Oklahoma	16.75	16.75	13.5	Varies	0	1	0	0	
Maryland	16.75	15	16.5	None	0	0	0	0	N/A We require the trucking company to be responsible for furnishing proposed route.
NYSTA	17	17	13.5	17	0	1	0	0	
Virginia	16	16	13.5	Unlimited	0	1	0	0	
Maine	15.5	14.5	14	No limit on approved route	0	1	0	0	
ILLINOIS	16.25	14.5	13.5	Unlimited	1	1	0	0	N/A
Arkansas	16	15	13.5	17	0	0	0	1	See question 13
Ohio	16	14	13.5	4 in below under bridge	0	1	0	0	
Arizona	16.5	16.5	13.5	Anything over 13' - 6"	0	1	0	1	Over 16' - Carrier submits a route survey
South Dakota	16	16	14	Restricted by Clearence	0	1	0	0	
New Jersey	16.5	14.5	13.5	No limit	0	0	0	1	NJ is developing an internet accessible permitting system (Bentley Superload) that will allow trucks to be routed automatically or check per proposed routes
New Mexcio	16.5	15.25	14	no limit	0	1	0	0	
North Carolina	16.5	15.5	13.5	unlimited	0	0	0	1	Manually by NCDOT Oversize/Overweight Permit Office
Texas	16.5	16	14	19	1	1	0	0	
D.C.					0	0	0	0	
South Carolina	17	17'-0"	13.5	Varies	1	1	0	0	
Massachusetts	16-6	14.5	13.5	16.5	0	1	0	0	
Kansas	16	15.33			1	0	0	0	
Hawaii	16.5	15.5	14	Depends on route.	0	1	0	0	
North Dakota	16.5	16.5	14	unlimited	1	1	0	0	Some carriers can self issue permits from 14-0 to 15-6. All over 15-6 must go thru permit process with HP.
NJTPK	14				0	1	0	0	
Montana	17	16.5	14	Depends on route	0	1	0	0	
Wyoming	16.5	16.5	14	14	0	1	0	0	Clearances for routes are posted on the web, where user can electronically search route for vertical clearances on line. Carrier selects route,department reviews and if clearance is exceeded, route is modified by carrier and resubmitted.
Georgia	16.5	16.5	13.5	Varies	1	0	0	0	
Michigan	16.25	14.75	13.5	na	0	1	0	0	
Louisiana	15.5&16.5	15.5&16.5			1	0	0	0	
Minnesota	16.33	16.33&14.5	13.5		1	1	0	1	State permit office approves for state routes. Local agency approval for local routes
Florida	16.5	16.5	13.5	Unlimited	0	1	0	0	If vehicle load is 15 ft or higher, then the carrier must submit a certified route height survey, and load must be preceded by a escort vehicle with a height pole.
Delaware	16.5	14.5	13.5	Limited by route	0	1	0	0	
Alabama	17	14	13.5	Restricted by Route	0	1	0	0	
NEBRASKA	16	16	14.5	unlimited	1	1	0	0	Nebrasha has had for last 6 years a fully automated routing system
Oregon	17	16	14	17	0	1	0	0	
Missouri	14	13.5	13.5&14	20	1	0	0	0	
Idaho	16&17		14	Depends on route	1	0	1	0	On regional - No overheight allowed
Iowa	16.5	15	13.5	Unlimited	0	1	0	0	
New Hampshire	14.5	14.5	13.5	na	0	1	1	0	
Wisconsin			13.5	No maximum	1	1	0	0	
Alaska	16.5	16.5	Depends		0	1	0	1	Above certain heights local agencies also review
Nevada	16.5	14.5	14	15	1	0	0	0	
Kentucky	16.5	14.5	13.5	No limit	1	1	1	0	
California	16	14	14	No limit	0	1	0	0	
Mississippi	17	16.5	13.5	Depends on route	1	1	0	0	
Rhode Island	16.25	14.5	13.5	Not specified	0	1	0	0	

State/Questions	Q13(a)	Q13(b)	Q13(c)	Q13(d)	Q13(e)	Q14(a)	Q14(b)	Q14(c)	Q14(d)	Q15(a)	Q15(b)	Q15(c)
Washington	1	0	0	0	1	0	0	0	1	0	1	0
Pennsylvania	0	0	1	0	0	1	0	0	0	1	0	0
Tennessee	0	0	1	0	1	0	0	0	1	0	0	1
Oklahoma	0	0	0	0	1	0	0	0	1	0	1	0
Maryland	0	0	0	0	0	0	0	0	0	0	1	0
NYSTA	0	0	0	0	0	0	0	0	1	0	1	0
Virginia	0	0	0	0	1	0	0	0	1	0	1	0
Maine	0	0	0	1	0	0	0	0	1	1	0	0
ILLINOIS	1	1	1	1	1	0	0	0	1	0	1	0
Arkansas	0	0	1	0	0	0	0	0	1	0	0	1
Ohio	0	0	1	0	0	0	0	0	0	0	1	0
Arizona	0	0	1	0	0	0	0	0	1	0	1	0
South Dakota	0	0	1	0	0	1	0	0	0	0	1	0
New Jersey	0	0	0	0	1	0	0	0	1	0	1	0
New Mexcio	0	0	0	0	1	0	0	0	1	1	0	0
North Carolina	0	0	0	0	1	0	0	1	0	0	1	0
Texas	0	0	0	0	1	0	0	0	1	0	1	0
D.C.	0	0	0	0	0	0	0	0	0	0	0	0
South Carolina	0	0	1	0	0	0	0	0	1	1	0	0
Massachusetts	0	0	0	0	1	0	0	1	0	1	0	0
Kansas	0	0	0	0	1	0	0	0	1	0	1	0
Hawaii	1	0	0	0	0	0	0	0	1	0	1	0
North Dakota	1	0	0	0	0	0	0	0	1	0	1	0
NJTPK	0	0	0	0	1	0	0	0	1	0	0	1
Montana	0	0	0	0	1	0	0	0	1	0	1	0
Wyoming	0	0	0	1	0	0	0	0	1	0	1	0
Georgia	0	0	0	0	1	0	0	0	1	0	1	0
Michigan	1	1	0	0	1	1	0	0	0	0	1	0
Louisiana	1	0	0	0	0	0	0	0	0	1	0	0
Minnesota	0	0	1	0	0	1	0	0	0	0	1	0
Florida	0	0	0	0	1	0	0	0	1	0	0	1
Delaware	0	0	0	0	1	0	0	0	1	0	0	1
Alabama	0	0	1	0	0	0	0	0	1	0	1	0
NEBRASKA	1	1	0	0	0	0	0	0	1	0	0	1
Oregon	0	0	0	0	1	0	0	0	1	0	1	0
Missouri	1	1	1	0	0	0	0	0	1	0	0	0
Idaho	0	0	0	0	1	0	0	0	0	0	1	0
Iowa	0	0	1	0	1	0	0	0	1	0	0	0
New Hampshire	0	0	0	0	1	0	0	0	1	0	1	0
Wisconsin	0	0	1	0	0	0	0	0	1	0	0	1
Alaska	0	0	0	0	1	0	0	0	1	0	1	0
Nevada	0	1	0	0	0	0	0	0	1	0	1	0
Kentucky	0	0	0	1	0	0	0	0	1	0	0	1
California	0	0	0	0	0	0	0	0	1	0	0	1
Mississippi	1	1	0	0	0	0	0	0	1	0	0	1
Rhode Island	1	0	0	0	1	0	0	0	1	0	1	0

State/Questions	Q16(a)	Q16(b)	Q16(c)	Q16(d)	Q16(e)	Q16(f)	Q16(g)	Q16(g)	Q17
Washington	0	0	0	0	0	0	1	Specifying s piolt car for all vehicles 14 ft 6 in or higher at the time permit is issued.	Y
Pennsylvania	0	1	0	0	0	0	0		Y
Tennessee	1	1	0	0	0	0	1	As requested	Y
Oklahoma	0	0	0	0	0	0	0		Y
Maryland	1	1	1	1	0	0	0		Y
NYSTA	0	0	0	0	0	0	0		Y
Virginia	1	0	1	0	0	0	0		Y
Maine	0	1	0	0	0	0	0		Y
ILLINOIS	1	1	0	0	0	0	0		Y
Arkansas	1	1	0	0	0	0	0		Y
Ohio	1	0	0	0	0	0	0		Y
Arizona	0	0	0	0	0	0	1	Responsibility of carriers	Y
South Dakota	0	1	0	0	0	0	0		Y
New Jersey	0	0	0	0	0	0	0	Unknown	Y
New Mexcio	1	1	0	0	0	0	0		N
North Carolina	1	1	0	0	0	0	0		Y
Texas	1	0	0	0	0	0	0	Rarely	Y
D.C.	0	0	0	0	0	0	0		
South Carolina	1	1	0	0	0	0	0		Y
Massachusetts	0	0	0	0	0	0	1	No enforcement	Y
Kansas	0	1	0	0	0	0	0		Y
Hawaii	0	1	0	0	1	0	0		Y
North Dakota	1	1	0	0	0	0	0		Y
NJTPK	1	0	0	0	0	0	1	Inspection stations	Y
Montana	1	1	0	0	0	0	0		Y
Wyoming	0	1	0	0	0	0	0		Y
Georgia	1	1	0	0	0	0	0		Y
Michigan	1	1	0	0	0	0	0		Y
Louisiana	0	0	0	0	0	0	1	No active enfrocement. Substandard heights are noted on the bridge	
Minnesota	1	1	0	0	0	0	0		Y
Florida	1	1	1	0	0	0	0		Y
Delaware	1	1	1	0	0	0	0		Y
Alabama	1	1	0	0	0	0	0		Y
NEBRASKA	1	1	0	0	0	1	0		Y
Oregon	0	1	0	0	0	0	0		Y
Missouri	1	0	0	0	0	0	0		Y
Idaho	1	1	1	0	1	0	0	Automated height measurement system on highways Only in some areas. For Question #18...Whoever is ordering the permit needs to know and provide the height of the vehicle and load. Those companies operating under annual permits are responsible for knowing and avoiding the low vertical clearances. A map is provided with the annual permit listing all vertical clearances 15' 6" or less.	Y
Iowa	1	1	0	0	0	0	0		Y
New Hampshire	1	0	0	0	0	0	0		Y
Wisconsin	1	1	0	0	0	0	0	State Patrol	Y
Alaska	1	1	0	0	0	0	0		Y
Nevada	1	1	0	0	0	0	0		Y
Kentucky	1	1	0	0	0	0	0		Y
California	0	1	0	0	0	0	0		Y
Mississippi	1	1	0	0	0	0	0		Y
Rhode Island	1	0	0	0	0	0	0		Y

State/Questions	Q18(a)	Q18(b)	Q19(a)	Q19(b)	Q19(c)	Q19(d)	Q19(e)
Washington	15.25	3	0	0	0	1	Posted on the bridge superstructure near the point of minimum clearance.
Pennsylvania	14.5	3	1	0	0	1	Advance signing is posted at an near intersection and at the bridge.
Tennessee	15	2	1	0	1	1	posted on the bridge girder
Oklahoma	No max	2--3	0	0	0	1	Posted on the bridge
Maryland	14.5	none	0	0	0	1	Posted at bridge and far enough in advance of bridge for alternate route.
NYSTA	13.5	12	1	0	0	0	
Virginia	14.5	0	1	1	0	0	500 yards from the bridge
Maine	14.33	2	1	0	0	0	The bridge is posted at a distance proportional to the posted speed
ILLINOIS	See e-mail	See e-mail	0	0	0	0	see e mail
Arkansas	15	0	1	0	0	1	Mostly posted on feature causing the underclearance
Ohio	14	4	1	1	0	0	Post 1/4 mile from the bridge & at the closest intersection
Arizona	16	3	0	0	1	1	On the bridge facia. Also at turnoffs prior to low bridges.
South Dakota	15.25	0-3	1	0	1	0	
New Jersey	Below 14'-6" requires a sign	3	1	0	0	1	Posting is required on the bridge and at the last safe exits approaching the bridge.
New Mexcio	16	0-3	1	0	0	0	posted over the lane containing low point
North Carolina	14.5	3	1	0	0	0	
Texas	20	3	1	1	1	1	site specific
D.C.			0	0	0	0	
South Carolina	17	1 or 2	1	0	0	0	
Massachusetts	14.5	3	1	0	0	0	
Kansas	15.33	3	1	0	0	0	
Hawaii	14	Varies. No policy.	1	0	0	0	
North Dakota	15.25	3	1	0	0	0	posted at the bridge and ahead of last exit/entrance before obstruction
NJTPK	Unknown	0	1	0	1	0	
Montana	16'-0" interstate only, 15'-0" all the rest	6	1	0	0	0	We have an internal memo - contact me if you would like a copy.
Wyoming		report actual minimum dimension	1	1	0	0	Beginnning to post 750 feet in advance of structure on a grounded mounted sign
Georgia	14.5	1	1	0	0	0	
Michigan	NA	3	1	0	0	0	
Louisiana	Less than standard for the class of highway	0	0	0	0	0	Hang it off the bridge rail
Minnesota	14.5	3	1	0	1	1	Advance warning signs placed at prior intersections
Florida	14.5	Varies	1	0	0	1	We follow the MUTCD for where the vertical clearance sign should be posted.
Delaware	14	3	1	0	0	1	post at nearest detour point
Alabama	16' on interstate 14'6" other routes	0	1	1	0	0	NO specifc yardage and only used for less than 14'6"
NEBRASKA	15.5	3	0	1	1	0	
Oregon	Anything less than 15 ft	4	1	0	0	0	
Missouri	16 ft 2 in in comm. zones, 15 ft 2 in otherwise	2	1	1	0	1	250 yards, a third sign is posted at a prior turnaround if the height is 13 ft 6 in or less
Idaho	15	3	1	0	0	0	
Iowa	14.75	3	1	0	0	1	Advanced posting is required to inform the driver of an upcoming low clearance so they have the opportunity to take an alternate route.
New Hampshire	14.5	3	1	0	0	0	we try to post advance warning signs at the intersection prior to a bridge
Wisconsin	Lower than 14` 06		0	0	0	0	Posted in advance
Alaska	17	3	1	0	0	1	Signs mounted to bridge. Signs placed at Advance Warning Distance and/or 1st Upstream Intersection.
Nevada	Less than 16'0" NHS; Less than;14'0" non-NHS	0	1	0	0	0	
Kentucky	14	0	1	1	0	0	100yds
California	It varies from site to site	Signs show actual clearance	1	0	0	0	
Mississippi	14	4	1	0	0	0	
Rhode Island	Not specified	2	1	0	0	1	sign on the structure

State/Questions	Q20	Q21	Q22
Washington	Permissible clearance value or "low overhead clearance."	None.	N
Pennsylvania	Low Clearance with a value in feet and inches	We have used headache bars to prevent damage to historic covered bridges.	N
Tennessee	It ia yellow diamond sign with the dimensions with arrows up and down	yes chains hanging from a cantilever sign structure frame overhanging the traffic lane ahead of the bridge	N
Oklahoma	Low Clearance Ahead	Once used a sacrifial barrier on a construction project - many years ago	N
Maryland	Reduced Clearance indicates maximum height	No	Y
NYSTA	Max. Clearance 13'-0"	Overhead Gantry with plastic sleeves over chains - Construction Overhead Limit, 3 year term.	N
Virginia	Emailed memorandum regarding this requirement to "salampalli@dot.state.ny.us"	steel beams suspended by chains	Y
Maine	The underclearance height is shown on a diamond shaped black on yellow sign	portals outside our covered bridges	Y
ILLINOIS	N/A	N/A	N
Arkansas	No	PVC cross pipe on chains (one location)	N
Ohio	Low Clearance _(dimension)__	NO	N
Arizona		During construction only	N
South Dakota	Low Clearance ( ) FT ( ) IN	We have a couple through truss bridges with overhead clearance beams in place prior to entering the truss portals.	Y
New Jersey	Signs just post the vertical underclearance restriction--i.e., Minimum Vertical Clearance 14'	No	N
New Mexcio			N
North Carolina	Low Clearance Ahead - 14 ft 2 in	chains, light beam/flashing lights if light beam is broken	N
Texas	Low Clearance Bridge Ahead	chains on tensioned wires	Y
D.C.			
South Carolina	Low Clearnce Ahead x'-x"		Y
Massachusetts	MUTCD W12-2	Chains	Y
Kansas	No Vehicle over xx ft xx in		N
Hawaii	None. Just posted sign with height of clearance.	No.	Y
North Dakota		No	N
NJTPK	___ clearance ahead	No.	N
Montana		No	Y
Wyoming			Y
Georgia	Low Clearance 14'-6"	No	N
Michigan	Underclearance warning		N
Louisiana	No special message	In isolated instances	N
Minnesota	Low clearance X'-xx" Z miles ahead	No	Y
Florida	Vertical Clearance X ft X in	No	N
Delaware	only underclearance dimension is given	No	N
Alabama	Clearence	None	N
NEBRASKA	w12-2, w12-2p		N
Oregon	The clearance limit only.	No	N
Missouri	Low Clearance X ft X in	No	Y
Idaho			N
Iowa	Low Clearance Ahead 14'-0"	We have used chains with unsatisfactory results. We have also used continuously flashing lights to warn of upcoming low clearance with limited success.	N
New Hampshire			N
Wisconsin		No	Y
Alaska	MUTCD W12-2 and W12-1	No	Y
Nevada		Headache bars used at a few non-state owned bridge loactions	N
Kentucky	'Low vertical clearance ahead 12ft 6in'	No	N
California	No messages are posted	No	N
Mississippi		No.	N
Rhode Island	xx ft xx in under clearance ahead	No	N

APPENDIX C: PHASE 2 SURVEY QUESTIONNAIRE

Bridge Vehicle Impact Assessment Survey Phase-II
New York State Department of Transportation

State: Person Preparing:
Date Prepared: Contact Telephone
No.:
E-mail:

During a recent survey on impacts of over-height trucks on low-clearance bridges, your state representative mentioned about using automated vehicle height detection system. New York State Department of Transportation is planning to carry out a pilot study of most-effective automatic height detection system for implementation near bridge that have been impacts by over-height trucks frequently. Your feedback will be important for us to identify most effective technologies, based on your experience, for further investigation and implementation. Outcome of our study will be available to all DOTs across the country. Your support and feedback in this regards will be appreciated very much.

1. Besides passive and automated over-height detection system, have you considered any other alternative? If yes, please describe below
2. Please provide information on "Automatic Vehicle Height Detection Systems" used by your state in the table below:

Type of Device	Manufacturer	Initial Cost	Maintenance and Operating Costs (Yearly)	Number of Years in Service

3. In regards to the installed automated systems noted in question above, please rate the following factors on a scale from 1 to 10. Please provide data for up to 4 system listed above.
   (a) Reduction in bridge hits after installation of automated systems (1 no reduction to 10 complete reduction): ☐ ☐ ☐ ☐
   (b) Reduction in number of trucks on unauthorized highways (with restriction on trucks) (1 no reduction to 10 complete reduction):
   (c) Satisfaction with Maintenance (1 least satisfied to 10 completely satisfied):
   (d) Issues with vandalism (1 least concerned to 10 most concerned):
   (e) Satisfaction with overall performance (1 completely dissatisfied to 10 completely satisfied):
   (f) Occurrence of false positives (1 low to 10 high):
   (g) If you have installed different types of automated vehicle height measuring devices (either by manufacturer / type of device), please list the devices in the order of decreasing overall performance (reduction in bridge hits).

4. Do your installations have any operational / maintenance issues? If yes, please describe below.
5. Have you observed any operational issues during snow? If yes, please describe below.
6. Do you also use advanced signing to supplement automated overheight detection devices (Y/N)?
7. What is the frequency of false positives? Do you use any mitigation approaches for false positives?
8. What is the local power source for the automated overheight detection system?
9. Is the environment around the device, such as high bird area, gusty winds, debris, etc., a problem in the detection of overheight vehicles? Please describe below.
10. How long do you expect the system to last (functionally and technologically)?
11. What is your overall opinion of the system and its cost effectiveness?
12. Please describe any specific notable approaches / factors (such as unique traffic laws) that have been effective in reducing the frequency of bridge hits.

We want to thank you very much for your feedback and participation in the survey. Upon completion of the study, it will be our pleasure to share the outcome of the study with you.

Please e-mail the completed survey to <Agrawal@ccny.cuny.edu>. Paper copies can be sent to:

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APPENDIX D: STAGE 2 SURVEY DATA

State:	Question 1	Question 3(a)				Question 3(b)				Question 3(c)			
		Sys1	Sys2	Sys3	Sys4	Sys1	Sys2	Sys3	Sys4	Sys1	Sys2	Sys3	Sys4
Missouri	No	8	9			NA	NA			10	10		
Maryland	We also have police enforcement.	8	8			NA	NA			5	5		
Texas	No		9								9		
HAWAII		10	10	10	10	10	10	10	10	9	7	8	9
Minnesota		9	NA	10		NA				8			
maine	No	8	8			8	8			9	9		
Alaska	bar/chains/plastic tubes	N/A 0 No counts, No followup, no photos				0 No restriction - bypass ramp avail				1 - System off. Fixing false calls.			
Virginia		10	10			NA	NA			9	9		
Wyoming	No	Too early to tell - new system				Too early to tell - new system				Too early to tell - new system			

State:	Question 3(d)				Question 3(e)				Question 3(f)				Question 3(g)			
	Sys1	Sys2	Sys3	Sys4	Sys1	Sys2	Sys3	Sys4	Sys1	Sys2	Sys3	Sys4	Sys1	Sys2	Sys3	Sys4
Missouri	1	1			9	9			1	1			NA			
Maryland	1	1			8	8			3	3						
Texas		2				8				1			Pipe on cable			
HAWAII	1	3	1	1	9	9	9	9	1	5	2	2				
Minnesota	1				8		8		unsure							
maine	1	1			9	9			2	2						
Alaska	1 - remote, few problems				1-Should have been design/build				10 - very high - snowfall issue, wind				NA			
Virginia	1	1			8	9			8	7						
Wyoming	Too early to tell - new system				Too early to tell - new system					1						

Note: Question 2 is on next page.

Question 2 (System 1)					
State:	Type of Device	Manufacturer	Initial Cost	Maintenance and Operating Costs (Yearly)	No. of Years in Service
Missouri	Z - Pattern System	Trigg	$7,700	Appr. $50 per year	8
Maryland	Optic	Sick	$50-100K	5-10K	>15
Texas					
HAWAII	Pulsed Infra-Red	Trigg	$13,000.00	$400.00	12
Minnesota	infrared light	Trigg Inc.	$45,231	N.A.	6
maine	Z-Pattern dual beam	Trigg	$200,000	$600	3
Alaska	Laser	Trigg	1.33 million	On Warranty	3
Virginia	Dual beam	Jo-Kell	1233.00 each		12
Wyoming	No				

Question 2 (System 2)					
State:	Type of Device	Manufacturer	Initial Cost	Maintenance and Operating Costs (Yearly)	No. of Years in Service
Missouri	Z - Pattern System	Trigg	$8,900	appr. $50 per year	4
Maryland	Optic	Sick	$50-100K	5-10K	>10
Texas	Pipes on cable	custom	10,000	1500	10+
HAWAII	Pulsed LED and IR	Trigg	$14,300.00	$400.00	4
Minnesota	infrared light	ASTI	tested only		zero - tested
maine	Z-Pattern dual beam	Trigg	$150,000	$600	1
Alaska					
Virginia	Dual beam	Trigg	2400.00 each		17
Wyoming					

Question 2 (System 3)					
State:	Type of Device	Manufacturer	Initial Cost	Maintenance and Operating Costs (Yearly)	No. of Years in Service
Missouri					
Maryland					
Texas					
HAWAII	Pulsed Infra-Red	Trigg	$13,000.00	$400.00	12
Minnesota	Unsure	Contractor	incl. in contract	N.A.	1 -during const. project
maine					
Alaska					
Virginia					
Wyoming					

Question 2 (System 4)					
State:	Type of Device	Manufacturer	Initial Cost	Maintenance and Operating Costs (Yearly)	No. of Years in Service
Missouri					
Maryland					
Texas					
HAWAII	Pulsed LED and IR	Trigg	$14,300.00	$400.00	6
Minnesota					
maine					
Alaska					
Virginia					
Wyoming					

State:	Question 4	Question 5	Question 6
Missouri	We had two problems. First lighting took out one of the units, but it was able to be repaired by Trigg within two weeks. The second is the IR units are directional which requires a pole on each side of the highway. One of the poles has been hit by a vehicile and had to be reinstalled.	No Problems during snow.	Yes
Maryland	There is insufficient space for the enforcement people to operate. This is due to fitting the system to an existing tunnel approach.	Snow, rain, birds, exhaust from trucks will cause false sensor trips. We use multiple sensors to reduce the impacts. e.g.: Two sensors a foot or so apart	Yes
Texas	The pipe on cable system is only for low speed/low volume roadways. We would not use it on a high speed facility.	NA	Yes
HAWAII	Difficult maintenance due to accessibility. OH located on side of a bridge.		Yes
Minnesota	Has requiured replacement of voltage regulator and detection components on one occasion. May have been the result of a severe lightning storm	No	Yes
maine	No	During cold weather false positives increase	Yes
Alaska	Significant - too complex for our single lighting electrician. No one division in DOT/PF will own it. Does not have good truck discrimination built in, or documentation devices when bridges are hit.	Significant - false calls constant. Snow plowing at truck speeds impact, bend, clog sign boards.	Yes
Virginia	The direction the receiver is critical with respect to the sun. Certain times of the year the early morning or late afternoon sun will cause false alarms. Also areas that are prone to a lot of bird activity causes false alarms.	During very heavy snow we sometimes have false alarms.	Yes
Wyoming		Too early to tell - new system	New System

State:	Question 7	Question 8	Question 9
Missouri	We don't experience flase positives becuase the unit has directional detection as well as speed indicator.	120 volt	No Problem
Maryland	There are individual false positive hits on sensors. We use multiple sensors to try and reduce the impact. Generally, it is more acceptable to falsly trigger the waraning signs than not to trigger the signs at all.	120V utility company feed	Birds will false trigger single devices. Poor pavement will cause trucks to bounce limiting accuracy also. Its an IR beam so anything that blocks it will cause a trigger.
Texas			Yes - leads to many of the flase positives
HAWAII	1 per month	Using freeway lighting 277V down to	no
Minnesota		120 VAC, +/-10%, 50/60 Hz	No
maine	One every 3 months	hard wired	High Pigeon area
Alaska	Constant during snowfall. Loop design poor, Research retrofit for improved truck verification and snowfall screening.	Freeway lighting load center.	Gusty area. Not enough room to set devices on stronger posts. Steep interchange embankments.
Virginia	Most of the false alarms are caused by environmental factors. The primary factor over the years has been sunlight where during certain times of the year the sun shines directly into the receivers. We have learned to try to avoid pointing the receivers due east or west.	Most of the overheight detectors are powered from our tunnel power systems that are backed up with either generators or dual power sources. Some of the outlying detectors are fed from standard "neighborhood" sources.	It is a minor problem. Most of our mainline overheight detectors have backup detectors. We also have some visual coverage with our tower mounted CCTV cameras.
Wyoming			

State:	Question 10	Question 11	Question 12
Missouri	15 years	this system has been very reliable for what we are using it for. Our Overheight system is used to detect vehiciles over 10 feet tall that are traveling faster than 20 MPH. If it detectssuch avehicle it activates advanced flashers for a sharp curve in the road.	NA
Maryland	It is PLC based with SICK optical sensors. Life cycle is 12-15 years.	It is effective at reducing damage in the tunnel from overhieght vehicles. It is effective enough that operations places a high demand on the system being functional.	Our issue is overheights getting into the tunnel. So our system is focussed on that. We have a pre-warning system that activates a sign prior to the last exit before the tunnel. If the truckers fail to get off, the second system alerts on-duty police and the truck is pulled over and ticketed. My understanding is that the fine is very high. The combination of warning systems, enforcement, and and high fines greatly reduce overhieghts in the tunnel. They do still occasionally get in though.
Texas			
HAWAII	20 years	Very good. After installation cost, the maintenance cost is minimal.	None
Minnesota		Has worked well so far	
maine	15 years	Satisfied with teh system	
Alaska	5years with research retrofit, otherwise, zero, will be dismantled.	Very poor - not all the manufacturer. Used less knowledgeable designer, builder. Need to use a turnkey Design/Build option instead.	Regionwide posting of low bridges based on hit frequency - all < 16'.
Virginia	The overheight detectors usually last about 15 years. The hardware usually will last longer but the manufacturers discontinue support.	Our overheight detectors are connected to our tunnel traffic control systems. With the aid of the traffic signs and signals overheights are detected and pulled out of traffic. The overheight systems are very effective and necessary to protect our tunnel ceilings. In the past, we have had one overheight vehicle cause over 1 million dollars in damages to a tunnel ceiling.	We have had the support of our local legislature to have laws implemented to issue severe fines and up to 3 points applied against the driver's CDL license.
Wyoming			

APPENDIX E: BRIDGES HIT MOST FREQUENTLY IN FOUR REGIONS OF NYSDOT VISITED BY THE PI (HIT FREQUENCIES AS PER VISIT DATES).

Number	BIN	HIT FREQUENCY
REGION 5		
1	**7046420**	**48**
2	7708450	32
3	**7708160**	**23**
4	7708100	14
5	7707940	11
6	7046410	10
7	**7708610**	**6**
8	5045752	4
9	7707720	3
10	7707770	3
11	7050634	3
12	1091841	3
13	7023130	2
14	1050620	2
15	7707520	2
REGION 8		
1	**1037390**	**95**
2	5500200	90
3	**5500100**	**40**
4	1037520	35
5	**5500050**	**32**
6	**5500160**	**30**
7	**3037170**	**28**
8	**1006160**	**23**
9	3348999	23
10	**1037570**	**23**
11	7000110	22
12	**5500150**	**21**
13	1054380	17
14	5500860	16
15	1037710	12
REGION 10		
1	**1059440**	**27**
2	**1036799**	**26**
3	**1018399**	**23**
4	**1058259**	**22**
5	1058210	21
6	**1058080**	**18**
7	**1037019**	**16**
8	**1058260**	**12**
9	**1049310**	**11**
10	1059909	11
11	**1058950**	**9**
12	1059169	9
13	1059289	7
14	1059509	7
15	1057730	6

REGION 11		
1	**2075837**	**37**
2	2232167	20
3	**2231300**	**12**
4	2240019	11
5	2240047	9
6	2230190	9
7	2229500	8
8	2266129	7
9	2233038	7
10	**2240059**	**6**
11	2231260	6
12	2230550	6
13	2230857	4
14	2230209	4
15	2240048	4

APPENDIX F: COMPARISONS OF DIFFERENT OVERHEIGHT DETECTION SYSTEMS

Company	Device	Principle	Direction Discern	Warning Sign	Alarm	Changeable Message Signs or VMS	Video Capable	States Using	Initial Costs	Maint. Costs	Maint. Issues (Owners)	Perform. (DOT Feedback)
Int. Road Dynamics Inc (IRD)	OHVDS	Receiver issues an alarm[1] if red beam[2] blocked by an object[3]	Yes[4]	Opt.	Yes	Opt.[5]	Opt.[6]					
SICK	HISIC 450	Parallel sub-systems[7]. Alarm and red light activated by an interruption of the light beam[8] by an overheight vehicle[9]	No[10]	Yes[11]	Yes	N.A.	N.A.	MD[12]	$4,300 (for a system)	Nearly Maint. Free	Insuff. space[13]	Good[14]
TRIGG IND.	Double Eye Z-Pattern	Detects Over-height vehicle, warning by alarm bell and sign[16]	Selection switch. No tools required	Yes	Yes[17]	Yes	N.A.	MO	$10142-$11892	Depend on the Environment	Systems hit by lightening and by a vehicle[18]	Good[19]
TRIGG IND.	Model # 3400-Z[20]	Detects Over-height vehicle, warning by alarm bell and sign[16]	Selection switch. No tools required	Yes	Yes[21]	Yes	N.A.	-	$10142	Depend on the Environment	-	-
TRIGG IND.	Model # 3401-Z[22]	Detects Over-height vehicle, warning by alarm bell and sign[16]	Selection switch. No tools required	Yes	Yes[21]	Yes	N.A.	-	$11892	Depend on the Environment	-	-
TRIGG IND.	Model # 3402-Z[22]	Detects Over-height vehicle, warning by alarm bell and sign[16]	Selection switch. No tools required	Yes	Yes[21]	Yes	N.A.	-	$11892	Depend on the Environment	-	-

TRIGG IND.	Model # DE-IR/3111[23]	Detects Over-height vehicle, warning by alarm bell and sign[16]	Selection switch. No tools required	Yes	Yes[24]	Yes	N.A.	-	$5434	Depend on the Environm ent	-	-
TRIGG IND.	Model # DB-R/IR-3200[25]	Detects Over-height vehicle, warning by alarm bell and sign[16]	Selection switch. No tools required	Yes	Yes[26]	Yes	N.A.	-	$7634	Depend on the Environm ent	-	-
TRIGG IND.	Single Eye without fault	Detects Over-height vehicle, warning by alarm bell and sign[16]	Selection switch. No tools required	Yes	Yes	Yes	N.A.	-	$3404	Depend on the Environm ent	-	-
TRIGG IND.	Single Eye with fault	Detects Over-height vehicle, warning by alarm bell and sign[16]	Selection switch. No tools required	Yes	Yes	Yes	N.A.	-	$3652	Depend on the Environm ent	-	-
Han-D-Man & Co	Vehicle Height Clearance Detectors	Pile mounted on a pillar, the arm[15] hits the vehicle exceeding clearance.	Yes	Yes (Sign post on arm)	No	No	No	Long Beach harbor Dept (In Progress)	$875	About $25 per Year	N.A.	N.A.

[1]The alarm activates a warning sign with alternating flashers and/or an audible alarm
[2]The red beam can be Infrared Light and Visible Red Light.
[3]The object must be at least 5cm (2'') in diameter, 2.5 cm (1'') above the line of detection and moving between 1km/h (1 MPH) and 120 km/h (75 MPH).
[4]The transmitter and receiver may be direction discerning, which triggers the alarm only when vehicles traveling in a certain direction are considered overheight.
[5]Changeable message signs have two or three predetermined messages that become visible when activated. Variable message signs are fully variable and when activated will display a predetermined message (e.g. "WARNING-HEIGHT RESTRICTION").
[6]A video component can be added to the system to capture and store video images of vehicles which trigger the overheight detector.
[7]Each are fitted with a sender and a receiver.
[8]The light beams across the road at required monitoring height.
[9]The vehicle with a minimum diameter of 100mm, travelling at a speed of up to 100km/h can be reliably detected.

[10] Usually they can discern the direction via intelligent PLC programming.
[11] Traffic lights switch to red
[12]They installed this system in front of a Tunnel
[13]Because of fitting to existing tunnel approach
[14]It is effective at reducing damage in the tunnel from overheight vehicles. It is effective enough that operations place a high demand on the system being functional.
[15]The arm will swing back very soon, and it will cause some legal issues.
[16]A. Overheight vehicle is detected by OVDS
B. First Alarm Bell activated
C. Warning Sign activated
D. Vehicle driver is alerted-first by sound, then by sight
E. Second Alarm Bell activated
[17]Alarm time can be adjusted by customer:
DE-Z/3400 from 2 to 30 seconds
DE-Z/3401, 3402, 3403 from 5 to 60 seconds
[18]Response from Missouri Department of Transportation.
[19]Response from Missouri: Before this system come into use there are 78 hits for 3 years.
After they installed this system, they only have a couple of hits in the first 3 years.
[20]Double Eye Z-Pattern (Visible Red/Infrared)
[21]Adjustable by customer from 1 to 30 seconds
[22]Double Eye Z-Pattern (Infrared/Infrared)
[23]Double Eye Infrared
[24]Adjustable by customer from 1 to 30 seconds. Custom alarm times available.
[25]Dual beam
[26]Adjustable by customer from 1 to 30 seconds. Other options available.

APPENDIX G: INFORMATION ON DIFFERENT OVERHEIGHT DETECTION SYSTEMS

International Road Dynamics System

INTERNATIONAL ROAD DYNAMICS INC.

www.irdinc.com

We make highways talk™

- ***MANAGEMENT***
- ***SAFETY***
- ***PRESERVATION***

International Road Dynamics Inc. develops and maintains traffic management products and systems technology that make highways talk. What are they saying? They are providing information that roadway administrators need to manage traffic, preserve infrastructure and provide safety warnings to drivers.

IRD's multi-discipline, innovative and customer-focused team is expert in advanced technologies, advanced traffic solutions and custom-designed systems.

CUSTOMER DRIVEN™

JUNE, 2006 REV. C
PRINTED IN CANADA

Overheight Vehicle Detection System (OHVDS)

Are your overhead structures being damaged by overheight vehicle collisions? We can help you!

OVERVIEW

IRD is an integrator and supplier of an Overheight Vehicle Detection System (OHVDS) that reduces collisions between motorists and overhead structures. An Overheight Vehicle Detection System detects overheight vehicles moving toward overhead obstacles, such as bridges, tunnels and other structures, and individually warns drivers. The system provides the driver with the opportunity to actively avoid a collision with an overhead structure.

The OHVDS is comprised of a transmitter and receiver. The transmitter contains either an infrared or high intensity, visible red light source that is pulsed across the highway from the transmitter to the receiver. The receiver is designed to issue an alarm if the red beam is blocked by an object at least 5 cm (2") in diameter, 2.5 cm (1") above the line of detection and moving between 1 km/h (1 MPH) and 120 km/h (75 MPH). The transmitter and receiver may be direction discerning, which triggers the alarm only when vehicles traveling in a certain direction are considered overheight.

The alarm activates a warning sign with alternating flashers and/or an audible alarm. In the event of a failure, the system will not activate the flashers on the sign, but will display a constant message, such as "WARNING - HEIGHT RESTRICTION".

This system reduces damage to structures by overheight vehicles. The driver is made aware of the danger ahead and is provided with the opportunity to take alternate action or an alternate route.

APPLICATIONS

To provide overheight warning detection for:

- Overpasses
- Traffic tunnels
- Bridges
- Warehouse entrances

BENEFITS

Driver:	Reduces damage to trucks/trailers and occupant injuries
Government/Owner:	Decreases damage to public structures
Public:	Decreases traffic backups due to a reduction of vehicle collisions with overhead structures
Insurance Companies:	Reduces accident claims due to a reduction of truck - overhead structure accidents

OVERHEIGHT VEHICLE DETECTION SYSTEM

SENSOR TECHNOLOGY AVAILABLE

- Infrared Light
- Visible Red Light

OPTIONAL SIGNS

As an alternative to flashing warning signs, changeable message signs (CMS) or variable message signs (VMS) may be incorporated into the system. Changeable message signs have two (2) or three (3) predetermined messages that become visible when activated. Variable message signs are fully variable and when activated will display a predetermined message (e.g. "WARNING - HEIGHT RESTRICTION"). During times when the message sign is not activated, the sign may display any operator-defined message or image.

OPTIONAL VIDEO

As an option, a video component can be added to the system to capture and store video images of vehicles which trigger the overheight detector.

SPECIFICATIONS

Power	115 VAC +/- 10%, 50/60 Hz Other options include 24 VDC solar power on 230 VAC on special order for certain models of transmitter and receiver
Output	Form C, dry relay contact closure Contacts rated 115 VAC 10A, protected by an 8A circuit breaker
Climatic Operating Range	-40 to + 58°C (-40 to +135°F)
Environmental Control	Internal thermostat controls air flow which reduces moisture and maintains internal temperatures during cold weather (on some models)
Alarm Time	Adjustable between 2 and 30 seconds
Maximum Range*	Suggested maximum range 60 meters (200 feet) to allow for bad weather and lens contamination. Absolute maximum range of 215 meters (700 feet)
Reaction Speed	1 to 120 km/h (1 to 75 MPH) for a 5 cm (2") diameter object 2.5 cm (1") above the established height of detection
Housing	External housing is heavy ALMAG casting and sheet aluminum (not less than 1/3cm (1/8") thickness) to minimize vandalism and provide for rigid mounting
Shipping Weight	14 to 23 kg (30 to 50 lbs)

*** Maximum range refers to maximum distance the detector eyes will perform**

International Road Dynamics Inc.

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Publicly Traded on the TSX (Symbol IRD)
Find out more about IRD on our website: www.irdinc.com

SICK MAIHAK GmbH

PRODUCT INFORMATION

HISIC450

Overheight Vehicle Detection in front of Bridges and Tunnels

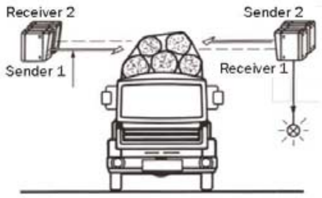
Detection of vehicles with overheight

The HISIC450 detects vehicles which are too high – at tunnel entrances, low underpasses or bridges, for example. Stop and alarm signals are immediately activated when a vehicle infringes the light beam.
The HISIC system is typically of a redundant design consisting of two subsystems, installed parallel to each other. Each are fitted with a sender and a receiver. The light beams across the road at required monitoring height. Any interruption of the light beam by an overheight vehicle sets off an alarm signal, and traffic lights switch to red for instance.
Response- and OFF-delay times are selectable across a wide range allowing moving obstructions with a minimum diameter of 100 mm, travelling at a speed of up to 100 km/h to be reliably detected.
The usual operating distance of the HISIC450 is 100 m (330 ft) with a scanning range of 300 m (980 ft). As a rule, the width of carriageways is less than 25 m (80 ft), so the received signal strength is enhanced and there is sufficient light in reserve to cope with difficult weather conditions, i.e. rain, snow or dust clouds. However, these atmospheric influences can not cause a false alarm.

Complete systems from one source

Our measurement systems for use in traffic, road or tunnel control are based on the perfect combination of precise optics and high speed intelligent electronics.
The systems are characterized by:

- high reliablity
- robust and weather proof construction,
- easy to operate and low maintenance requirements
- modular and extendable design



Key Features

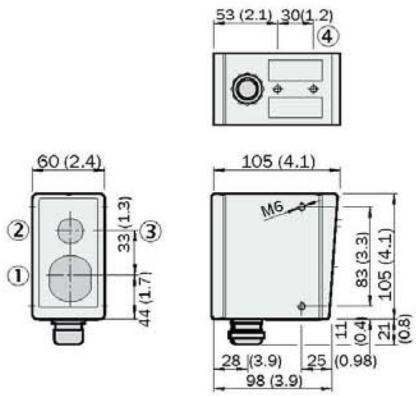
- Robust cast aluminium housing, sealed to IP 67
- Built-in lens heaters to prevent condensation or icing (option)
- Weather protection against snow, rain and dust clouds
- Optical alignment equipment
- Sensitivity adjustment
- Ambient light insensitivity
- Wide power supply range from 24 up to 240 V UC (universal)

SICK|MAIHAK
Analyzers and Process Instrumentation

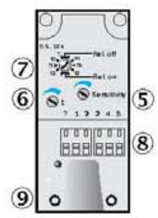
8006248/2006-01 • DIVO3/BW • Printed in Germany (2006-02) · Subject to change without prior notice

HISIC450 components

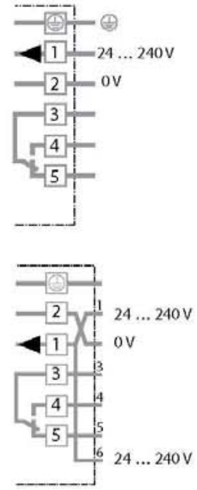
Dimensions HISIC450 in mm (in)



Possible adjustments

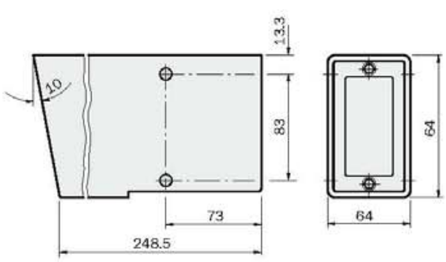


Connection diagramm

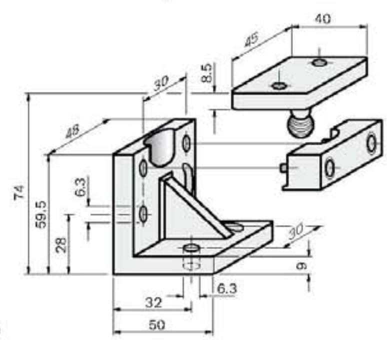


① Center of optical axis, sender, center of optical axis, receiver
② View finder
③ LED signal strength indicator
④ Threaded mounting hole M6 x 8
⑤ Sensitivity adjustment
⑥ Time adjustment
⑦ Time delay selector switch; left light-switching, right: dark-switching
⑧ Terminal strip
⑨ Status indicator

Dimensions Dust protection



Dimensions Ball joint bracket



Dimension in mm

Technical data	HISIC450 (WS/WE45)	HISIC450 (WS/WE Transistor)
Scanning range	300 m (980 ft)	300 m (984 ft)
Supply voltage	24 ... 240 V UC (universal)	10 ... 60 V DC
Current/power consumption	250 mA/6 VA	≤ 500 mA
Light transmitter	LED, infrared, pulsed	LED, infrared, pulsed
Average life time	100,000 h	100,000 h
Switching outputs	SPDT, electrically isolated	PNP, Q and $\overline{Q}$
Max. switching voltage	120/250 V AC/DC	
Max. switching current	2/4 A AC/DC	200 mA
Max. braking capacity	120 W/750 VA AC/UC	
Max. response time	≤ 10 ms; max. switching frequency 10/s	≤ 500 μs, max. switching frequency 1000/s
Protection class	IP 67	IP 67
Weight	approx. 800 g (1.7 lb)	approx. 800 g (1.7 lb)
Contamination signal		100 mA, open collector

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SICK | MAIHAK
Analyzers and Process Instrumentation

Trigg Industries

TRIGG international

OVDS

Overheight Vehicle Detection and Warning Systems [OVDS]

What Does Trigg Industries OVDS Do?

- Detects overheight vehicles and warns drivers of an impending problem.
- Directs the driver via warning signs and warning bells to take corrective action.
- Provides secondary warning beyond existing signage in the interest of public safety.
- Reduces exposure to costs associated with incidents or accidents.
- Proven to minimize or eliminate the occurrence of accidents and incidents caused by overheight vehicles.

Industry Standard

- The standard for quality and performance in all environments for thirty-five years.
- Integral to hundreds of state, county and municipal infrastructures coast to coast.
- System of choice for Boston Central Artery Tunnel Project, Cumberland Gap Tunnels, Queens Tunnel and 25 DOTs.
- We provide technical support and documentation from the planning stage through installation.

Applications

- Bridges
- Tunnels
- Overpasses
- Airport Overhangs/Walkways
- Temporary Falsework
- Parking Structures
- Equipment Yards
- Railroads
- Car Carriers
- Logging Trucks

Cost Benefit

One accident usually exceeds the cost of a complete detection and warning system. Trigg Industries OVDS adds an additional layer of protection and helps to minimize or eliminate costs associated with:

- Injury or loss of life
- Emergency Response
- Traffic Delays
- Administrative costs
- Structural Repair
- Insurance Premiums
- Dispute or Litigation
- Media Publicity

Highest Reliability and Quality Control Standards

Installed in some of the most adverse conditions worldwide. Proprietary cabinet design and internal environmental control allows continuous operation in fog, ice, snow, dust and heat. Systems meet ISO/IEC Guide 22 Compliance, CE Mark, NEMA 3R Cabinet Enclosure Rating, CALTRANS lightning and hi/lo voltage parameters. We provide extensive documentation and Factory Acceptance Testing protocols.

Innovation

The Trigg Industries Patented Z-Pattern™ Red/Infrared dual beam array provides the most advanced ability to reject ambient light and virtually eliminates false overheight alarms. Fault Detection and Alert Function notifies Central Control Facility when system is operating in Single Eye Mode [temporary condition] or has experienced a line power failure. Double and Single Eye systems also offer Fault Detection and Alert Function.

Ease of Use

Trigg Industries provides specialized mounting brackets for all systems and all elements of the system that allow it to be attached to any sturdy structure. Installation instructions are direct and easy to follow.

Descriptions

Device	Description
OVDS	Point of detection and direction discernment. Four categories of systems, encompassing ten different models for a wide range of applications.
Audible Alarm	Sweep of sight is attracted by alarm. First alarm after detection and second above message sign.
Warning Signs	Standard Warning Sign with alternating flashers includes custom message providing directions to drivers of overheight vehicles.
Extras	Variable LED Message Signs (VMS) available in two, three and four line formats. PC programmable.
	Poles, sirens, bells, strobes, solar power, loop detector, radio frequency link and alternate mounts available.

Concept

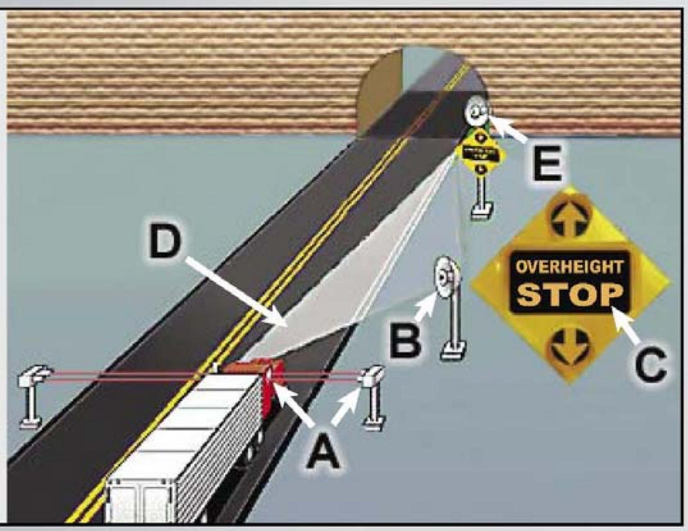
A. Overheight vehicle is detected by OVDS

B. First Alarm Bell activated

C. Warning Sign activated

D. Vehicle driver is alerted - first by sound, then by sight

E. Second Alarm Bell activated



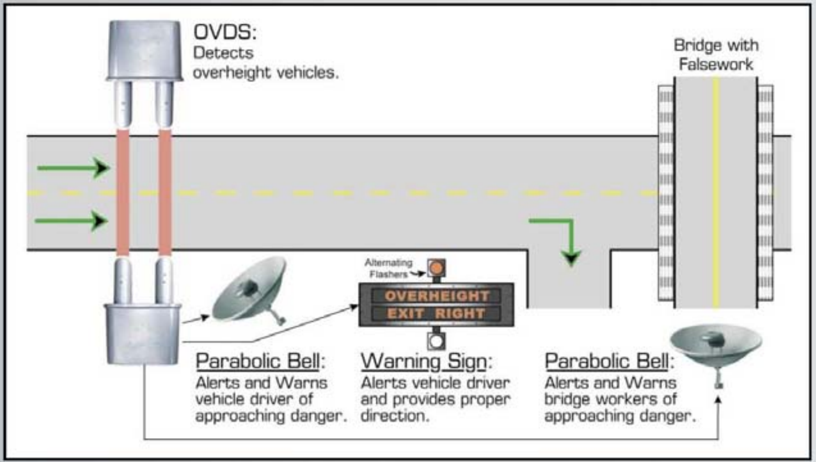
OVDS

Applications

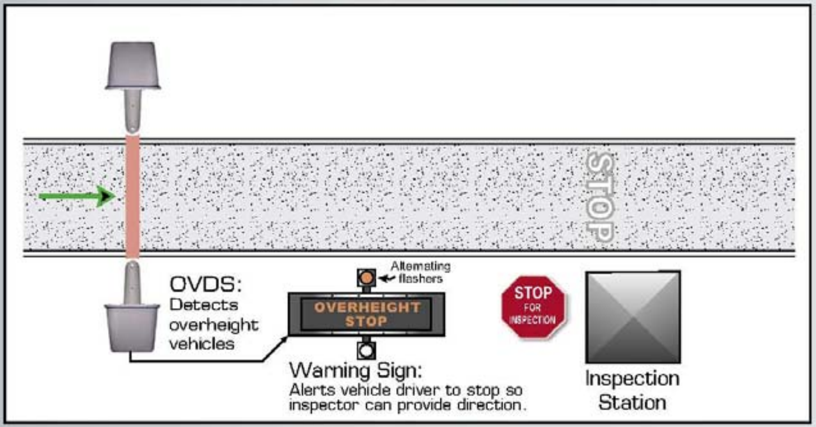
Trigg Industries manufactures complete systems, including detectors, warning signs, alarms, mounting poles and all needed accessories. We build to meet US and International power requirements, as well as AC and solar (DC) configurations.

Trigg Industries offers technical options to meet varying requirements and can provide cost effective solutions for virtually any overheight warning requirement. Custom systems can be provided as required.

- Bridges
- Tunnels
- Overpasses
- Temporary Falsework
- Railroad Tunnels
- Airport passenger drop-off overhangs and pedestrian walkways



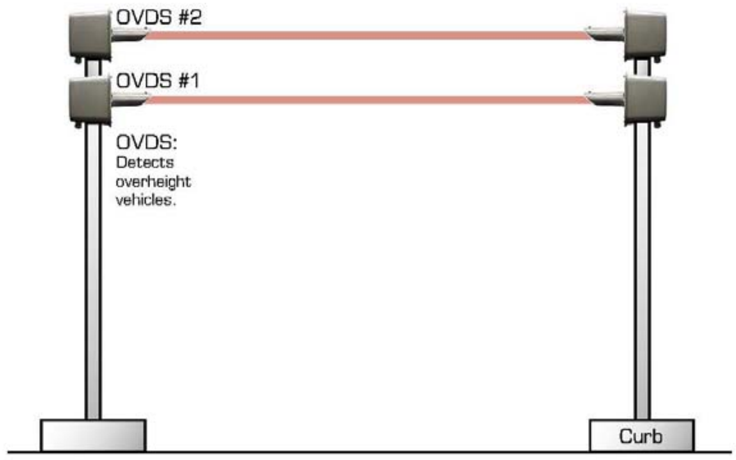
- Weigh Stations
- Load Height Verification for:
  - Equipment Yards
  - Car Carriers



Metro Economy OVDS installed inside parking structure detecting a single height.

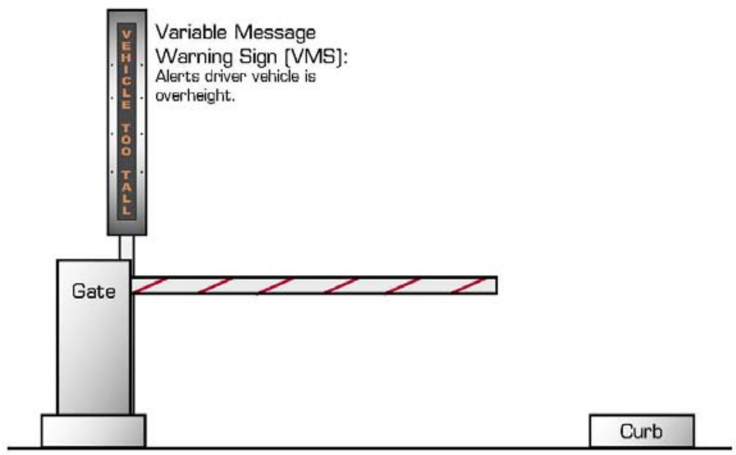
Dual Single Eye OVDS installed outside parking structure detecting two different heights.

EXAMPLE:
- If vehicle is detected by OVDS #1, driver is instructed by VMS to park where clearance is adequate.
- If vehicle is detected by OVDS #2, driver is instructed by VMS to stop and await further direction.



If a vehicle is overheight, the Variable Message Sign (VMS) displays a sequence of messages instructing driver where or where not to park. The gate can be delayed from opening while messages are displayed.

EXAMPLE:
- Message 1: "STOP"
- Message 2: "VEHICLE TOO TALL"
- Message 3: "PARK LEVEL 1 ONLY" or "DO NOT ENTER"



Double Eye Z-Pattern™ *

Visible Red and Infrared

Model #: 3400-Z, 3401-Z, 3402-Z, 3403-Z


Remote


Master

- *Patented Visible Red / Infrared Mixed
- Environmental control
- Enhanced rejection of ambient light
- Fault detection and reporting
- Nema 3R cabinet rating
- Direction discerning
- Proprietary ALMAG cabinet design

Z-Pattern™

INPUT POWER	115VAC, +/- 10%, 50/60HZ. Other options include 24VDC solar or 230VAC, +/-10%, 50/60HZ operation.
OUTPUT	Two Form C, dry relay contact closures for Overheight Alarm Functions. One Form C, dry relay contact closure for Fault Reporting. Contacts rated 115VAC 10A, protected by 8A circuit breakers.
FAULT REPORTING	**DE-Z/3400** - Fault reporting output upon loss of source/detector power or total failure. **DE-Z/3401, 3402, 3403** - Fault reporting output upon loss of source/detector power or total failure. Fault Relay toggles at one-second intervals during Single Eye Mode of operation.
ALARM TIME	**DE-Z/3400** - Adjustable by customer from 2 to 30 seconds. **DE-Z/3401, 3402, 3403** - Adjustable by customer from 5 to 60 seconds.
ELECTRONICS	Sensors are NEMA 6P enclosure rated.
EFFECT OF AMBIENT LIGHT	Use of Dual Beam "Z" Pattern provides automatic switch to Single Beam Detection Mode of Overheight Protection if the sun or other interference saturates one detector.
MAXIMUM RANGE	700 feet (213 m). Suggested maximum range 200 (61 m) feet to allow for bad weather and lens contamination.
DIRECTION SELECTION	Selection switch. No tools or adjustment required.
ALIGNMENT	Four LEDs and meter (GO-NOGO functions) provided for ease of alignment and testing.
REACTION SPEED	1 to 75 MPH (1 to 121 km/h) for a 2 inch (50 cm) diameter object 1 inch (3 cm) above the detection height. Custom speed/size available.
TEMPERATURE RANGE	-40° to +135° F (-40° to +57° C).
ENVIRONMENTAL CONTROL	Internal thermostat controls air flow which reduces moisture and maintains internal temperature during cold weather.
HOUSINGS	External housing is heavy ALMAG casting and sheet aluminum (not less than 1/8 inch or .318 cm thickness) for rugged durability and extended life. Cabinet design minimizes effects of vandalism and provides rigid mounting. The pole cap serves as a mounting bracket and sighting base with our poles. NEMA 3R Certified.
DIMENSIONS	Remote Cabinet: 12¾ x 16½ x 8½ inches (32 x 42 x 22 cm). Master Cabinet: 12¾ x 18¾ x 8½ inches (32 x 48 x 22 cm).
SHIPPING WEIGHT	60 lbs (27 kg).

Double Eye

Visible Red or Infrared

Model #: DE-R/3110 or DE-IR/3111

- Visible Red or Infrared systems
- Fault detection and reporting
- Environmental control
- Meets Nema 3R Intent
- Direction discerning
- Proprietary ALMAG cabinet design


Transmitter


Receiver

INPUT POWER	115VAC, +/- 10%, 50/60HZ. Other options include 24VDC solar or 230VAC, +/-10%, 50/60HZ operation.
OUTPUT	Form C, dry relay contact closure, contacts rated 115VAC 10A, protected by an 8A circuit breaker. System switches to Single Eye Mode of operation upon loss of either detector.
FAULT REPORTING	Optional fault reporting output upon loss of power, transmitter failure or either eye blocked for more than 13 seconds. Single Eye mode of operation implemented.
ALARM TIME	Adjustable by customer from 1 to 30 seconds. Custom alarm times available.
ELECTRONICS	Sensors are NEMA 6P enclosure rated. Electronic printed circuits for years of reliable operation.
EFFECT OF AMBIENT LIGHT	**DE-R/3110** - Sunlight immunity of 10,000 foot-candles. **DE-IR/3111** - Very high noise immunity.
MINIMUM RANGE	10 feet (3 m).
MAXIMUM RANGE	**DE-R/3110** - 800 feet (244 m). Suggested maximum range 200 feet (61 m) to allow for bad weather and lens contamination. **DE-IR/3111** - 700 feet (213 m). Suggested maximum range 200 feet (61 m) to allow for bad weather and lens contamination.
DIRECTION SELECTION	Selection switch. No tools or adjustment required.
ALIGNMENT	Two LEDs and meter (GO-NOGO functions) provided for alignment. No special tools required.
REACTION SPEED	1 to 75 MPH (1 to 121 km) for a 2 inch (5 cm) diameter object 1 inch (3 cm) above the detection height. Custom speed/size available.
COUNTER	Records the number of activations.
TEMPERATURE RANGE	-40° to +135° F (-40° to +57° C).
ENVIRONMENTAL CONTROL	Internal thermostat controls air flow which reduces moisture and maintains internal temperature during cold weather.
HOUSINGS	External housing is heavy ALMAG casting and sheet aluminum (not less than 1/8 inch or .318 cm thickness) for rugged durability and extended life. Cabinet design minimizes effects of vandalism and provides rigid mounting. The pole cap serves as a mounting bracket and sighting base with our poles. Meets NEMA 3R intent.
DIMENSIONS	Transmitter: 15½ x 10 x 8¾ inches (39 x 2 x 22 cm). Receiver: 12¾ x 16½ x 8½ inches (32 x 42 x 21.59 cm).
SHIPPING WEIGHT	45 lbs (20 kg).

Single Eye

Visible Red or Infrared

Model #: SE-R/3310 or SE-IR/3311

OVDS

- Visible Red or Infrared systems
- Environmental control
- Fault protection and reporting
- Non-direction discerning
- Meets Nema 3R Intent
- Proprietary ALMAG cabinet design

Transmitter

Receiver

INPUT POWER	115VAC, +/- 10%, 50/60HZ. Other options include 24VDC solar or 230VAC, +/-10%, 50/60HZ operation.
OUTPUT	Form C, dry relay contact closure, contacts rated 115VAC 10A, protected by an 8A circuit breaker.
FAULT REPORTING	Optional fault reporting output upon loss of power, transmitter failure or either eye blocked for more than 13 seconds.
ALARM TIME	Adjustable by customer from 1 to 30 seconds. Custom alarm times available.
ELECTRONICS	Sensors are NEMA 6P enclosure rated. Electronic printed circuits for years of reliable operation.
EFFECT OF AMBIENT LIGHT	**SE-R/3110** - Sunlight immunity of 10,000 foot-candles. **SE-IR/3111** - Very high noise immunity.
MINIMUM RANGE	6 feet (2 m).
MAXIMUM RANGE	**SE-R/3110** - 800 feet (244 m). Suggested maximum range 200 feet (61 m) to allow for bad weather and lens contamination. **SE-IR/3111** - 700 feet (213 m). Suggested maximum range 200 feet (61 m) to allow for bad weather and lens contamination.
ALIGNMENT	One LED and meter (GO-NOGO functions) provided for alignment. No special tools required.
REACTION SPEED	1 to 75 MPH (1 to 121 km) for a 2 inch (5 cm) diameter object 1 inch (3 cm) above the detection height. Custom speed/size available.
COUNTER	Records the number of activations.
TEMPERATURE RANGE	-40° to +135° F (-40° to +57° C).
ENVIRONMENTAL CONTROL	Internal thermostat controls air flow which reduces moisture and maintains internal temperature during cold weather.
HOUSINGS	External housing is heavy ALMAG casting and sheet aluminum (not less than 1/8 inch or .318 cm thickness) for rugged durability and extended life. Cabinet design minimizes effects of vandalism and provides rigid mounting. The pole cap serves as a mounting bracket and sighting base with our poles. Meets NEMA 3R intent.
DIMENSIONS	Transmitter: 15½ x 10 x 8¾ inches (39 x 25 x 22 cm). Receiver: 12¾ x 16½ x 8½ inches (32 x 42 x 22 cm).
SHIPPING WEIGHT	40 lbs (18 kg).

Metro Economy

Visible Red

Model #: ME-R/301

Model #: ME-R/305 or ME-R/310

- Visible Red system
- Nema 6P rating
- Light weight PVC cabinet

Transmitter

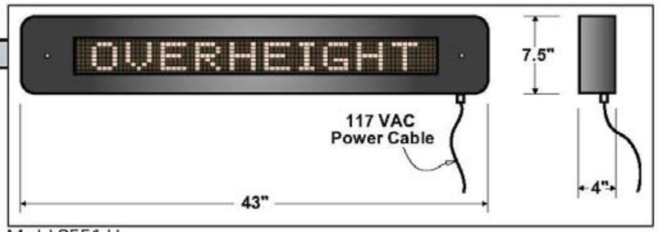
Receiver

INPUT POWER	115VAC, +/- 10%, 50/60HZ. Other options include 12/24VDC solar or 230VAC, +/-10%, 50/60HZ operation.
OUTPUT	Two form C dry relay contact closures. Contacts rated 115VAC 5A, protected by 5A fuses.
ALARM TIME	**ME-R/301 & ME-R/305** - Adjustable by customer from 2 to 30 seconds. Other times available on request. **ME-R/310** - Duration equal to time beam is broken.
ELECTRONICS	**ME-R/301 & ME-R/305** - Sensors are NEMA 6P enclosure rated. Electronics use printed circuit board for reliable operation. **ME-R/310** - Sensors are NEMA 6 enclosure rated.
EFFECT OF AMBIENT LIGHT	Sunlight immunity of 10,000 foot candles.
MINIMUM RANGE	**ME-R/301** - 6 feet (2 m). **ME-R/305 & ME-R/310** - 1 foot (.3 m).
MAXIMUM RANGE	**ME-R/301** - 800 feet (244 m). Suggested maximum range 200 (61 m) feet to allow for bad weather and lens contamination. **ME-R/305 & ME-R/310** - 80 feet (24 m). Suggested maximum range 40 (13 m) feet to allow for bad weather and lens contamination.
ALIGNMENT	GO-NOGO green LED indicator provided for alignment. No special tools required.
REACTION SPEED	**ME-R/301** - 1 to 75 MPH (1 to 121 km) for a 2 inch (5 cm) diameter object 1 inch (3 cm) above the established height of detection. **ME-R/305 & ME-R/310** - 1 to 11 MPH (1 to 121 km) for a 2 inch (5 cm) diameter object 1 inch (3 cm) above the established height of detection.
HOUSINGS	Schedule 40 PVC shell and NEMA 6P eye enclosure.
SHIPPING WEIGHT	20 lbs (9 kg).

One Line or Two Line Half Scale VMS Sign

Model #: 3551 & 3552*

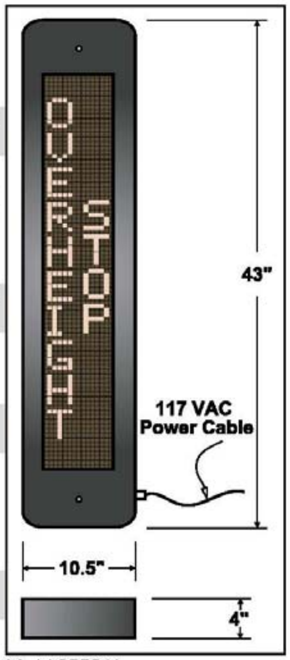
- Programmable messages
- Bright LED display
- Custom sizes available
- Available in Horizontal (H) or Vertical (V) Configurations
- *V2 available in 3552-H Only



Model 3551-H

V1 Format - Message lines cannot be merged for larger characters.
V2 Format - Message lines can be merged for larger characters.

INPUT POWER	117VAC, +/- 10%, 50/60HZ at 1A. Other options include 24VDC solar or 230VAC, +/- 10%, 50/60HZ operation.
DISPLAY	16-Character lines with 2 inch (50 mm) high brightness, Red or Amber LED characters, message input provided by RS232 port. Up to 32,000 characters can be stored. Customer choice of 1200 mcd up to 2000 mcd brightness LEDs.
INPUT	Isolated LED on control from contact closure. Rapid turn-on of LED display.
EFFECT OF AMBIENT LIGHT	Acrylic non-glare face for greater readability.
TEMPERATURE RANGE	-30° to +130°F (-34° to 54° C)(with heater).
ENVIRONMENTAL CONTROL	Optional internal thermostat and heater maintains internal temperature during cold weather. Add 2A (200W) at 117VAC for heater power.
HOUSINGS	Weather proof epoxy powder coat painted steel enclosure. IP65 rating.
MOUNTING	Wall mount standard. Pole mounting or other styles available.
DIMENSIONS	**3551** - 43 x 7.5 x 4 inch (108 x 19 x 10 cm). **3552** - 43 x 10.5 x 4 inch (109 x 27 x 10 cm).
SHIPPING WEIGHT	**3551** - 25 lbs (11 kg). **3552** - 30 lbs (14 kg).

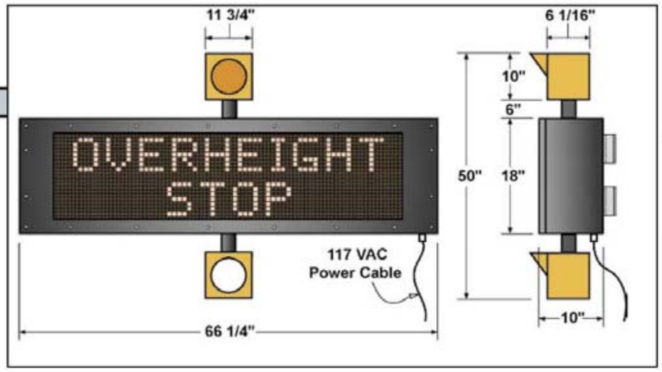


Model 3552-V

Two Line VMS Sign

Model #: 3505

- Programmable messages
- Bright LED display
- Custom sizes available
- Available in Horizontal (H) or Vertical (V) Configurations
- V2 Format for H models only



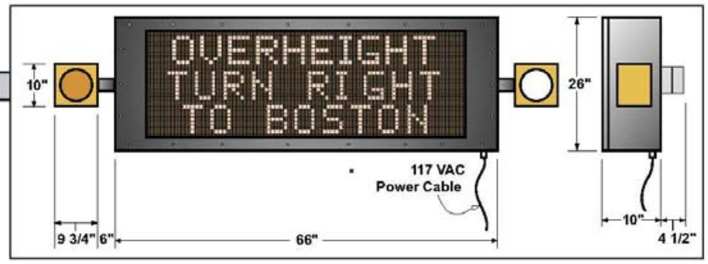
V1 Format - Message lines cannot be merged for larger characters.
V2 Format - Message lines can be merged for larger characters.

INPUT POWER	117VAC, +/- 10%, 50/60HZ at 2A. Other options include 24VDC solar or 230VAC, +/- 10%, 50/60HZ operation.
DISPLAY	12-character line with 4.92 inch (125 mm) high brightness Red or Amber LED characters, message input provided by RS232 port. Up to three messages can be stored for user selection. Customer choice of 1000 mcd brightness LEDs with 30 degree viewing angle or 2000 mcd brightness LEDs with 15 degree viewing angle. The 2000 mcd sign should be mounted so it faces about 15 degrees to the on-going traffic.
INPUT	Isolated LED On control from contact closure. Rapid turn-on of LED display.
FLASHERS	Optional 8 inch (20 cm) LED Yellow Ball with weatherproof enclosure mounted on each side of enclosure. Alternating flasher provides one second On-Off cycle. 8 inch (20 cm) LED Yellow Balls can also be mounted on the top and bottom of the sign if desired.
EFFECT OF AMBIENT LIGHT	Acrylic non-glare face for greater readability.
TEMPERATURE RANGE	-30° to +130°F (-34° to 54° C) (with heater).
ENVIRONMENTAL CONTROL	Optional internal thermostat and heater maintains internal temperature during cold weather. Add 2A (200W) or 8A (800W) at117VAC for heater power.
HOUSINGS	Weatherproof epoxy powder coat painted steel enclosure. IP65 rating.
MOUNTING	Wall mount standard. Pole mounting or other styles available.
DIMENSIONS	**3505** - 66¼ x 18 x 10 inch (168 x 46 x 25 cm) for enclosure. Add 16 inches (41 cm) to each side (or top/bottom) for the alternating flasher LEDs. **3520** - 126 x 64 x 10 inch (320 x 163 x 25 cm) for enclosure. Add 16 inches (41 cm) to each side (or top/bottom) for the alternating flasher LEDs.
SHIPPING WEIGHT	**3505** - 125 lbs (57 kg). **3520** - 250 lbs (113 kg).

Three Line VMS Sign

Model #: 3510

- Programmable messages
- Bright LED display
- Custom sizes available
- Available in Horizontal (H) or Vertical (V) Configurations
- V1 Format



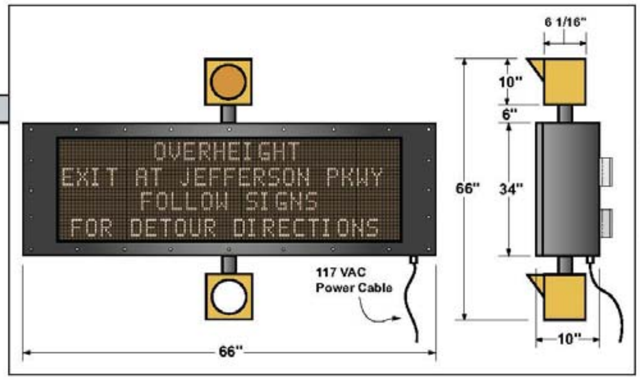
V1 Format - Message lines cannot be merged for larger characters.
V2 Format - Message lines can be merged for larger characters.

INPUT POWER	117VAC, +/- 10%, 50/60HZ at 3A. Other options include 24VDC solar or 230VAC, +/- 10%, 50/60HZ operation.
DISPLAY	12-character line with 4.92 inch (125 mm) high brightness, Red or Amber LED characters, all lines with V1 format, message input provided by RS232 port. Up to three messages can be stored for user selection. Customer choice of 1000 mcd brightness LEDs with 30 degree viewing angle or 2000 mcd brightness LEDs with 15 degree viewing angle. The 2000 mcd sign should be mounted so it faces about 15 degrees to the on-going traffic.
INPUT	Isolated LED On control from contact closure. Rapid turn-on of LED display.
FLASHERS	Optional 8 inch (20 cm) LED Yellow Ball with weatherproof enclosure mounted on each side of enclosure. Alternating flashers provides one second On-Off cycle. 8 inch (20 cm) LED Yellow Balls can also be mounted on the top and bottom of the sign (or omitted) if desired.
EFFECT OF AMBIENT LIGHT	Acrylic non-glare face for greater readability.
TEMPERATURE RANGE	-30° to +130°F (-34° C to 54° C) (with heater).
ENVIRONMENTAL CONTROL	Optional internal thermostat and heater maintains internal temperature during cold weather. Add 2A (200W) or 8A (800W) at 117VAC for heater power.
HOUSINGS	Weatherproof epoxy powder coat painted steel enclosure. IP65 rating.
MOUNTING	Wall mount standard. Pole mounting or other styles available.
DIMENSIONS	66 x 26 x 10 inch (168 x 66 x 25 cm) for enclosure. Add 16 inch (41 cm) to each side (or top/bottom) for the alternating flasher LEDs.
SHIPPING WEIGHT	150 lbs (68 kg).

Four Line VMS Sign

Model #: 3515 & 3520

- Programmable messages
- Bright LED display
- Custom sizes available
- 3515 in V1 Format
- 3520 in V2 Format



V1 Format - Message lines cannot be merged for larger characters.
V2 Format - Message lines can be merged for larger characters.

INPUT POWER	117VAC, +/- 10%, 50/60HZ at 3A. Other options include 24VDC solar or 230VAC, +/- 10%, 50/60HZ operation.
DISPLAY	12-character line with 4.92 inch (125 mm) high brightness, Red or Amber LED characters, all lines, message input provided by RS232 port. Up to three messages can be stored for user selection. Customer choice of 1000 mcd brightness LEDs with 30 degree viewing angle or 2000 mcd brightness LEDs with 15 degree viewing angle. The 2000 mcd sign should be mounted so it faces about 15 degrees to the on-going traffic.
INPUT	Isolated LED On control from contact closure. Rapid turn-on of LED display.
FLASHERS	Optional 8 inch (20 cm) LED Yellow Ball with weatherproof enclosure mounted on each side of enclosure. Alternating flashers provides one second On-Off cycle. 8 inch (20 cm) LED Yellow Balls can also be mounted on the top and bottom of the sign (or omitted) if desired.
EFFECT OF AMBIENT LIGHT	Acrylic non-glare face for greater readability.
TEMPERATURE RANGE	-30° to +130°F (-34° to 54° C) (with heater).
ENVIRONMENTAL CONTROL	Optional internal thermostat and heater maintains internal temperature during cold weather. Add 2A (200W) or 8A (800W) at 117VAC for heater power.
HOUSINGS	Weatherproof epoxy powder coat painted steel enclosure. IP65 rating.
MOUNTING	Wall mount standard. Pole mounting or other styles available.
DIMENSIONS	**3515** - 66 x 34 x 10 inch (168 x 86 x 25 cm) for enclosure. Add 16 inch (41 cm) to each side (or top/bottom) for the alternating flasher LEDs. **3520** - 126 x 64 x 10 inch (320 x 163 x 25 cm) for enclosure. Add 16 inch (41 cm) to each side (or top/bottom) for the alternating flasher LEDs.
SHIPPING WEIGHT	**3515** - 175 lbs (79 kg). **3520** - 250 lbs (113 kg).

Blank Out Signs

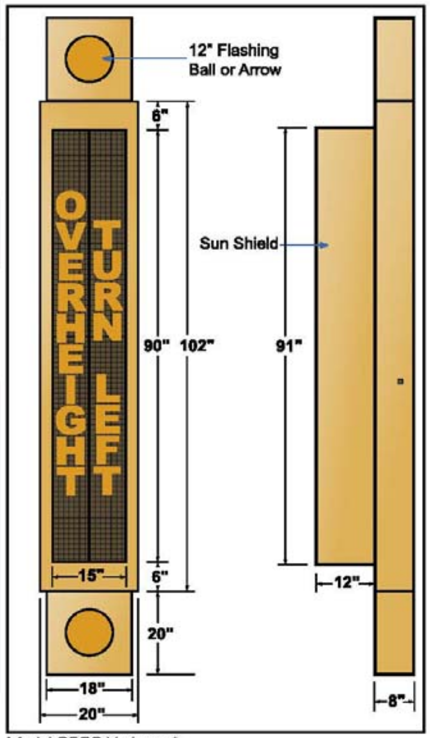
Model #'s: 3500, 3501, 3502 & 3503

OVDS

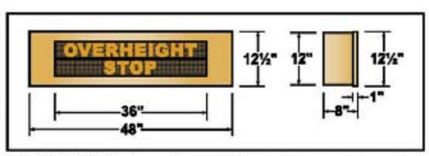
- Easy Installation
- H = Horizontal configuration
- V = Vertical configuration
- Cost Effective
- Rugged Construction

HOUSING	**3500** - 63 x 63 inch (160 x 160 cm) reinforced sheet aluminum (NLT .09) (2 cm). All aluminum and stainless steel with neoprene seats. **3501** - 43 X 43 inch (109 X 109 cm) reinforced sheet aluminum (NLT .09) (2 cm). All aluminum and stainless steel with neoprene seats. **3502** - 20 X 102 inch (51 X 259 cm) reinforced sheet aluminum (NLT .09) (2 cm). All aluminum and stainless steel with neoprene seats. **3503** - 12½ X 48 inch (32 cm X 122 cm) reinforced sheet aluminum (NLT .09) (2 cm). All aluminum and stainless steel with neoprene seats.
SUN SHIELD	**3500 & 3502** - Sheet aluminum (NLT .06) (.15 cm) projects 14 inch (36cm) to shield each element individually. **3501 & 3503** - Sheet aluminum (NLT.06) (.15 cm) projects 10 inch (25 cm) to shield each element individually.
FACING	Blank out with desired message "OVERHEIGHT" plus "STOP" or "TURN RIGHT", etc. Alternating amber arrows at top and bottom.
FLASHERS	Optional flashers with weather proof enclosure (3502 & 3503 ONLY) mounted on either side/top and bottom of enclosure. Alternating flashers provides one second On-Off cycle.
ELECTRONICS	**3500** - 120VAC 50/60 Hz operating four to eight rapid start fluorescent CWHO (high output) bulbs for message area and two 12 inch (30 cm) alternately flashing amber arrows. **3501** - 120VAC 50/60 HZ operating four rapid start fluorescent CWHO (high output) bulbs for message area and two 8 inch (20 cm) alternately flashing amber arrows. **3502** - 120VAC 50/60 Hz operating four to eight rapid start fluorescent CWHO (high output) bulbs for message area. **3503** - 120VAC 50/60 HZ operating four rapid start fluorescent CWHO (high output) bulbs for message area.
MOUNTING	V protections affixed to the back of the sign match upright supports. Heavy duty stainless steel straps provide horizontal stability.
SHIPPING WEIGHT	**3500** - 280 lbs (127 kg). **3501** - 160 lbs (73 kg). **3502** - 250 lbs (113 kg). **3503** - 150 lbs (68 kg).

Model 3500 shown*



Model 3502-V shown*



Model 3503-H shown* *Illustrations not to scale.

Parabolic Bell

Model #: 3600

- Directional
- Light Weight
- Easy Installation

INPUT	120VAC, 50/60Hz.
OUTPUT	Bells 101 db at 10 feet (3 m) directed by parabolic shield. Sound reduced to 50 - 60% at sides and rear of bell by the parabolic shield, shield diameter: 38 inch (97 cm).
ADJUSTMENT	Adjustable mounting bracket provided. Other brackets provided as needed.
PARABOLA DIMENSIONS	38 inch (97 cm) diameter.
SHIPPING WEIGHT	50 lbs (23 kg).

DECIBLE TEST RESULTS

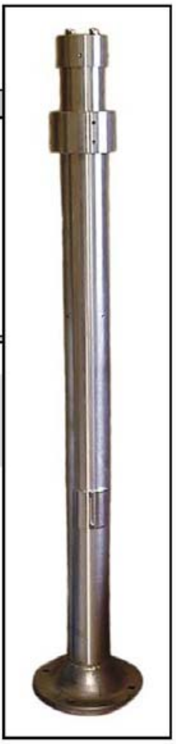
Distance From Parabolic Shield	Reading
10 feet	101 db
20 feet	93 db
30 feet	90 db
40 feet	87 db
50 feet	83 db
60 feet	82 db
70 feet	82 db
80 feet	81 db
90 feet	79 db
100 feet	76 db

TRIGG industries international

OVDS

Mounting Poles

Model #: 3701 & 3702



- For Detectors, Signs and Bells
- Strong, light-weight aluminum

One piece, seamless round aluminum tube. Hand-hole is centered 18 inch (46 cm) above the bottom of the shaft and the cover is secured by stainless steel screws. Base flange is one piece cast aluminum socket with 8¼ inch (21cm) bolt center. Poles are complete with all hardware, brackets, except base mounting bolts and nuts.

DIMENSIONS	**3701** - 10 - 16½ feet (3 - 5 m) Pole, Telescoping. Two poles are required for each system. **3702** - 10 feet (3 m) Pole, One Piece (for Warning Bell and/or Warning Sign).
SHIPPING WEIGHT	**3701** - 90 lbs (41 kg). **3702** - 60 lbs (27 kg).

Three Axis Mount

Model #: TGZ-M017

- Designed for the DE-Z Series
- Heavy Duty
- Adjustment in 3 independent axes

Enables independent axis adjustments to match difficult crowns and contours of the roadway.

CONSTRUCTION	Three-piece mount of 9mm 5052 aluminum, with stainless steel hardware.
ADJUSTMENT	Enables independent adjustment in Pitch +/- 40°, Roll +/- 40° and Heading +/- 60°.
ATTACHMENT	Designed for pole-top or pole-mount bracket installations via 5/8 inch (2 cm) stainless steel bolt.
DIMENSIONS	9 X 8½ X 3½ inch (23 x 22 x 9 cm).
SHIPPING WEIGHT	4 lbs (2 kg).

Pole Mount Bracket

Model PMB-406

- Adapts to any size pole or post
- Heavy Duty
- Easy Installation
- Ideal for OVDS and Warning Bell

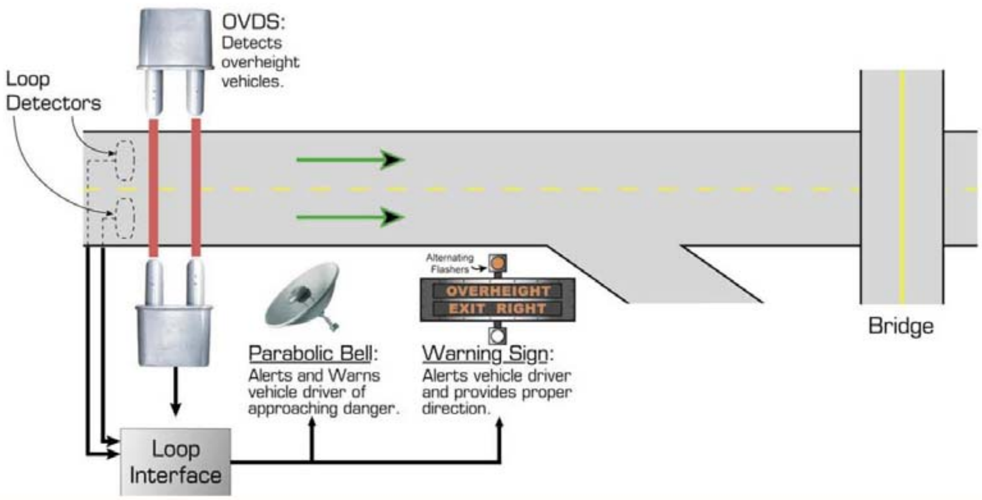
SHIPPING WEIGHT	4 lbs (2 kg).

Loop Detector Interface

Model #: TGL-2001

- Eliminates False Alarms
- Accepts most loop detector outputs
- Internal loop hold adjustments
- Internal Alarm time adjustment
- Easy installation

The Trigg Industries Loop Detector Interface insures that non-vehicular causes do not false-trigger overheight vehicle alarms. A loop detector (or detectors) in the roadway makes it possible to identify passage so that an overheight alarm is issued only when a vehicle is present. The interface is designed to accept a relay contact opening from a loop detector (or detectors) and a Trigg OVDS relay contact closure. The Model TGL-2001 includes a "Loop Hold" adjustment that allows for slower moving vehicles to be detected.

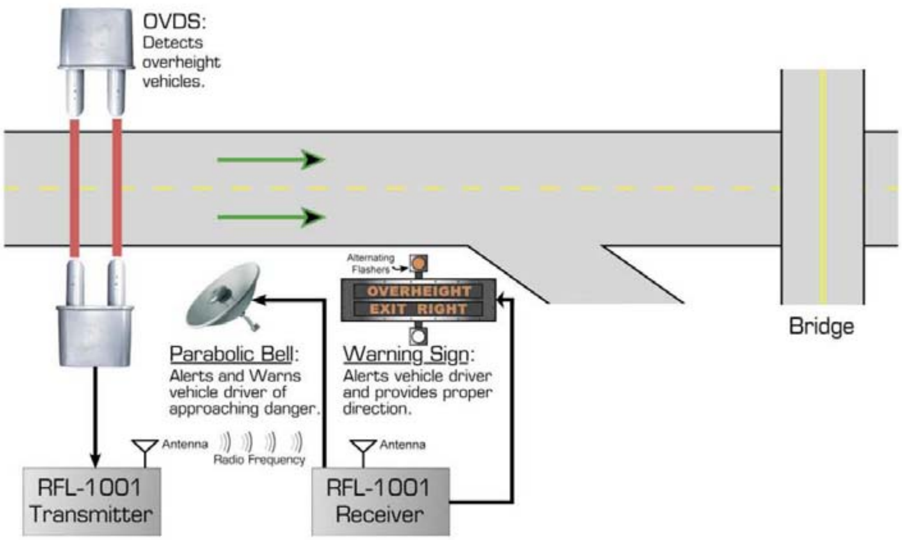


INPUT POWER	115 VAC +/- 10% Hz. Options include 24 VDC solar or 230 VAC +/- 10%, 50/60 Hz.
OUTPUT	Two Form C Dry relay contacts rated at 10A, protected bt 8A fuses.
ALARM TIME	An Alarm Time adjustment is incorporated that allows a double-pole-throw relay to be energized from 1 to 30 seconds upon receiving a valid alarm. This feature enables the OVDS Alarm Time to be set for a short time (1 - 2 seconds), which in turn, allows the TGL-2001 control over alarm time.
ELECTRONICS	Heavy duty printed circuit board, terminal strips with Phillips screw connections.
TEMPERATURE RANGE	-40° to +135°F (-40° to +57° C).
HOUSING	All electronics are enclosed in PVC NEMA rated cabinet. Cord grips/strain relief connectors are included for cable access. The enclosure need not be mounted near either the loop relay(s) or OVDS but we do not suggest more than 500 feet (152 m) of separation due to the possibility of noise pickup in the cabling. Use of shielded cable may be required in some applications.
SHIPPING WEIGHT	20 lbs (9 kg).

Radio Frequency Link

Model #: RFL-1001

- Wireless cost effective alternative to cable installation
- Mobility - System can be portable
- Antenna options for custom applications
- License-free 900 Mhz transmission



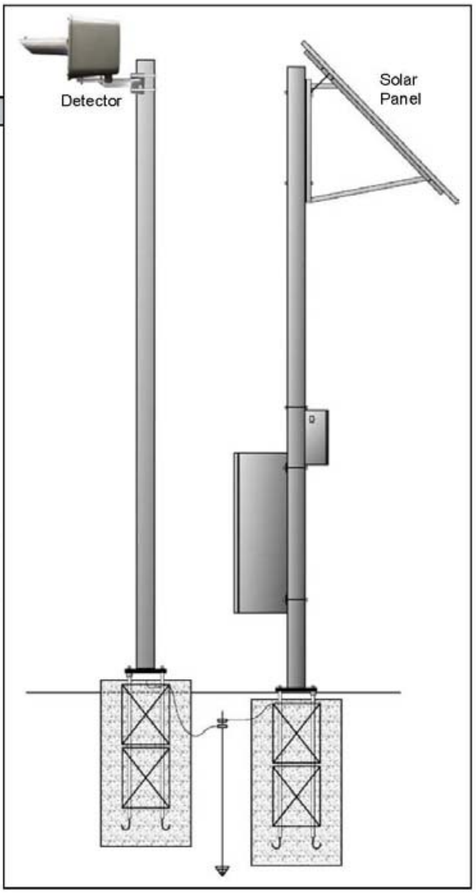
INPUT POWER	115 VAC +/- 10% Hz. Options include 24 VDC solar or 230 VAC +/- 10%, 50/60 Hz.
OUTPUT	Two Form C Dry relay contacts rated at 5A, protected by 5A fuses.
THROUGH-PUT	Approximately 1 second.
ELECTRONICS	Heavy duty printed circuit board for years of reliable operation.
TEMPERATURE RANGE	-40° to +135°F (-40° to +57° C).
HOUSING	Heavy duty PVC NEMA rated cabinet.
RANGE	OMNI Antenna - 1 mile (1.6 km). YAGI Antenna - 7 miles (11 km).
SHIPPING WEIGHT	20 lbs (9 kg).

OVDS

Solar Power Source

Model #: SELS-2XX

- Cost effective alternative to cable installation
- Can mix AC/DC in installation
- 21 consecutive sunless days capacity standard
- Rechargeable by generator



All Trigg Industries International, Inc., Overheight Vehicle Detection Systems (OVDS) can be operated with solar power. The operating voltage is 24 Volts DC for both the Transmitter and Receiver units. Solar Electric Power Company (SEPCO) is the provider of the solar power system, which is custom configured for each geographic location (at least 7 times US Department of Energy requirements).

The solar power system consists of a solar panel assembly, batteries and solar control electronics. A 24VDC to 115VAC inverter can be included to supply 115VAC power for the Trigg Industries Warning Sign, Bell or other warning devices. The batteries, solar control electronics and inverter are mounted in vandal proof aluminum enclosures with inside the pole wiring. Mounting poles can be supplied or the customer can supply their own or use existing structures. Proper orientation of the solar panel assembly is necessary.

Solar power is a consideration where costs and/or substantial difficulties (trenching, right-of-way, etc.) are encountered in providing 115VAC power to one or both sides of the roadway. The Trigg Industries OVDS can be operated by a combination of solar power and 115VAC without system degradation.

OUTPUT	24 VDC.
ELECTRONICS	Enclosed in DOT grade stainless steel cabinet.
TEMPERATURE RANGE	-40° to +135°F (-40° to +57° C).
SHIPPING WEIGHT	Varies with system requirements.

Han-D-Man & Company

Height Detectors - Products

Vehicle Height Clearance Detectors

A Division of Han-D-Man & Co.

CLEARANCE 9'

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