Boston Blind Zone Safety Initiative

Current Fleet Analysis, Market Scan, and Proposed Direct Vision Rating Framework

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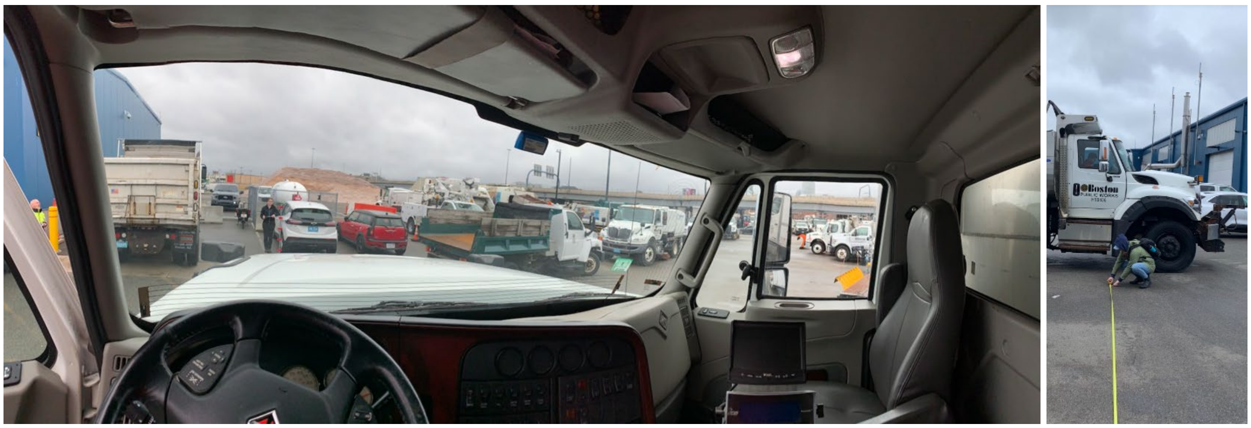

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14. ABSTRACT
Direct vision is the ability of a driver to see firsthand outside their vehicle without the aid of an indirect vision device, such as mirrors or camera displays. The Boston Public Health Commission and Boston Transportation Department, recognizing that poor direct vision of certain vehicles has contributed to VRU fatalities that the City's Vision Zero Task Force regularly reviews, approached Volpe in 2022 to assess the blind zone sizes of its own fleet vehicles as well as the blind zones of alternative vehicle models outside of its fleet. Volpe measured 21 vehicles across the three City of Boston Departments using two methodologies, and framing resulting blind zone size relative to child or adult visibility in a crosswalk or bicycle lane in accordance with Manual on Uniform Traffic Control Devices as well as Boston Transportation Department geometric standards. The technical approach and potential direct vision rating framework, developed in consultation with the City as well as nonprofit and industry stakeholders, are intended to support the City of Boston in measuring and managing blind zone risk and could be adapted by other public and private organizations.

15. SUBJECT TERMS
Direct vision, blind zone, vulnerable road user, pedestrian, bicyclist, vehicle design, large truck, geometric design, and safety.

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1 Introduction and Context

1.1 What is direct vision?

Direct vision is the ability of a driver to see firsthand outside their vehicle without the aid of an indirect vision device, such as mirrors or camera displays. In contrast, indirect vision is the ability of a driver to see outside their vehicle through mirrors or camera displays. Direct vision enables eye contact between a driver and a vulnerable road user near the vehicle; indirect vision generally does not.

Figure 1: View from the driver's seat of an International HV 513. Direct vision of the environment is shaded green (unobstructed view through the windows) and indirect vision areas are shaded purple (mirrors and camera display unit).

Blind zones around a vehicle can be made visible through indirect vision, however drivers' reaction time is significantly faster through direct vision. According to published research, when drivers have direct vision of a pedestrian, they can react 0.7 seconds, or 50% faster, than when they can see the same pedestrian through indirect vision.[1]

Blind zones have been identified as the second leading cause of truck-pedestrian crashes in the UK,[2] and in the United States about one-fourth of truck-involved VRU fatalities consist of vision-related low-speed

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[1] https://content.tfl.gov.uk/road-safety-benefits-of-direct-vs-indirect-vision-in-hgv-cabs-technical.pdf "Exploring the Road Safety Benefits of Direct vs Indirect Vision in HGV Cabs: Direct Vision vs Indirect Vision: A study exploring the potential improvements to road safety through expanding the HGV cab field of vision"

[2] https://link.springer.com/chapter/10.1007/978-3-030-20503-4_39

maneuvers[3]. Additionally, NHTSA data for non-traffic crashes indicate an increase from 225 apparent VRU frontover fatalities in 2012 to 526 apparent VRU frontover fatalities in 2020, in which front blind zones may be expected to be a contributing factor.[4]

1.2 Existing global direct vision standards and regulations

Multiple standards and regulations have been developed globally to address visibility in varying vehicle classes.

Originally published in 2006 and revised in 2017, ISO Standard 5006:2017 applies to earth-moving machines with seated operators and provides visibility performance criteria and a test method to determine acceptability.[5] The ISO standard details indirect visibility devices that may be used to meet the visibility criteria if the measured direct visibility is inadequate for proper, effective, and safe operation of the machine.

Starting in 2017, Volpe researchers held technical exchanges with Transport for London and their researchers at Loughborough University and the University of Leeds on direct and indirect vision. The exchanges included discussion of the findings in Transport for London's reports Understanding Direct and Indirect Driver Vision in Heavy Goods Vehicle (HGVs)[6] and Exploring the Road Safety Benefits of Direct vs Indirect Vision in HGV Cabs.[7]

In 2021, in a first of its kind scheme, Transport for London (TfL) and the Mayor of London implemented a Direct Vision Standard (DVS) as part of the city's Vision Zero approach.[8] This standard applies to all vehicles over 12 tons (26,455lbs) entering London and assigns a star rating from zero to five to all HGVs. The star rating is based on measurements of a driver's direct vision through the HGV windows.

All vehicles entering London are required to obtain a free HGV safety permit. Vehicles that are rated zero stars must be retrofitted with additional safety equipment to be able to obtain their safety permit. These retrofit requirements include equipment to improve indirect vision such as mirrors, cameras or sensors, warnings for VRUs of vehicle maneuvers, and systems to minimize the physical risks of an HGV-VRU crash (see Section 0). According to the program, additional retrofitting options will be added for zero star rated vehicles to obtain a safety permit after periodic review of additional technology and

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[3] https://rosap.ntl.bts.gov/view/dot/20427/Share "Prioritizing improvements to truck driver vision"

[4] Based on "forward moving vehicles" in "non-traffic crashes," i.e., crashes in parking lots, driveways, and other locations not on public roadways. https://crashstats.nhtsa.dot.gov/Api/Public/Publication/812311, https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813363

[5] https://www.iso.org/standard/45609.html

[6] https://content.tfl.gov.uk/understanding-direct-and-indirect-vision-in-hgvs-full-technical-report.pdf

[7] https://content.tfl.gov.uk/road-safety-benefits-of-direct-vs-indirect-vision-in-hgv-cabs-technical.pdf

[8] https://tfl.gov.uk/info-for/deliveries-in-london/delivering-safely/direct-vision-in-heavy-goods-vehicles

safety equipment options on the market for HGVs. According to TfL, "the first year of enforcement of the DVS and the HGV safety permit scheme has seen a reduction in fatal collisions where vision is cited as a contributing factor. In 2021, there were a total of 11 fatal collisions involving HGVs and people walking or cycling. Of these, six fatal collisions occurred where vision was cited as a contributing factor, compared to eight in 2020 and nine in 2019. The majority (four of the six) of fatal collisions in 2021 involved 0-star rated vehicles demonstrating the enhanced value of direct vision over other safe system equipment."[9] While this trend is based on a small number of years and crash sample size, it is directionally correct and encouraging and appears to have continued in 2022.[10]

At the international level, two UN regulations have been adopted by UNECE's World Forum for the Harmonization of Vehicle Regulations (WP.29), one for light-duty[11] and one for heavy-duty[12] vehicle direct vision. UN R125 for light-duty vehicles has provisions for enhancing driver's awareness of VRUs at the front and sides of vehicles by requiring "an adequate field of vision when the windscreen and other glazed surfaces are dry and clean," and it applies to Category M1 vehicles (passenger cars and SUVs carrying up to eight passengers). Largely resembling and based on the TfL Direct Vision Standard, UN R167 aims to reduce blind zones around commercial vehicles to the greatest extent possible to improve direct vision, setting minimums for visible volumetric space around the front and sides of vehicles. Japan and Europe have indicated they will apply UN R167 following its adoption in November 2022.[13]

According to a 2006 study of commercial truck visibility, U.S. "regulatory requirements for truck driver vision are minimal. The only standard that bears directly on driver fields of view is Federal Motor Vehicle Safety Standard (FMVSS) 111, which regulates mirror systems. Trucks over 10,000 lb are required to have planar mirrors with an area of at least 323 cm2 on each side of the cab. Direct vision is unregulated."[14] The TfL and UN regulations discussed above are not applied to vehicles sold in the U.S. and thus offer no means of blind zone comparison between vehicle makes and models in this market.

1.3 Project context

The Boston Public Health Commission and Boston Transportation Department, recognizing that poor direct vision of certain vehicles has contributed to VRU fatalities that the City's Vision Zero Task Force

[9] https://tfl.gov.uk/info-for/media/press-releases/2022/june/01-base-page-51729

[10] Email correspondence with TfL, May 10, 2023.

[11] UN R125: https://unece.org/sites/default/files/2022-09/ECE_TRANS_WP.29_2022_139E.pdf

[12] UN R167: https://unece.org/sites/default/files/2022-10/ECE_TRANS_WP.29_2022_140r1e.pdf

[13] https://unece.org/sustainable-development/press/unece-adopts-two-new-regulations-improve-safety-vulnerable-road-users

[14] https://rosap.ntl.bts.gov/view/dot/20427/Share "Prioritizing improvements to truck driver vision"

regularly reviews,[15] approached Volpe in 2022 to assess the blind zone sizes of its own fleet vehicles as well as the blind zones of alternative vehicle models outside of its fleet. To fund this work, they used grant funding from the Partnership for Healthy Cities network to which Boston belongs. An initiative of Bloomberg Philanthropies, in partnership with the World Health Organization and Vital Strategies, the network supports 70 cities across the world to deliver high-impact policies and program interventions to reduce noncommunicable disease and injury in their communities.

This baselining and best practice development effort is intended as an initial step to contemplate how specifications on direct vision could be developed and applied in a U.S. city context. The potential ratings that emerge from the vehicle blind zone measurements are intended to be meaningful and rigorous, yet simple and streamlined enough to be actionable for potential near-term City of Boston policy outcomes.

Concurrent to this effort, the safety nonprofit Together for Safer Roads convened a private-sector fleet-focused direct vison workshop in February 2023. The workshop sought to develop among fleet industry participants the requirements for and design of a prototype direct vision rating system. At the workshop, participants identified the requirements for a rating system as trust, interpretability, ability to communicate to a wide audience (including the general public), and a standardized approach across states or cities. The participants generally agreed that a star-rating system, similar to the TfL DVS, would be an intuitive rating system. Volpe and the City of Boston attended, documented, and considered the results of this workshop in the development of this memo.

This applied research effort also builds on the foundational direct vision and human factors research of a Volpe project sponsored by the Santos Family Foundation since 2019. As part of both that and the current effort, the VIEW app and driver simulation research has been produced, and a stakeholder group of national and international SMEs as well as USDOT modal agencies have been engaged for awareness, feedback, and coordination.

The technical approach and potential direct vision rating framework described in this memo are intended to support the City of Boston in measuring and managing blind zone risk. The City has various policy pathways that it may consider leveraging to do so, for example vehicle procurement and any contracts or permitting involving the use of vehicles.

This report may also be of use for other cities or municipalities who are interested in direct vision best practices for VRU safety. The procurement process varies by city so the implementation will vary as well, but the practices outlined in this report can be used to inform the development of procurement practices for other localities.

[15] For example: https://www.wcvb.com/article/pedestrian-struck-killed-by-vehicle-in-boston-on-wednesday/14472785#

2 Boston Fleet Analysis

2.1 Overview of the Boston fleet

The City of Boston has over 2,000 vehicles in their fleet, including approximately 800 school buses and 450 public works vehicles. This includes almost 500 unique make-model-year combinations. This work focused on vehicles used for Boston's Schools, Fire Department, and Public Works departments. School and Fire Department vehicles tend to be highly homogenous. Public Works, in contrast, had a varied fleet due to the diverse functions performed by the vehicles.

2.2 Vehicle selection measurement

Volpe measured 21 vehicles across the three City of Boston Departments. Table 1. Total vehicles measured by Department describes how representative these data are for the City's fleets. The Volpe team worked with the City of Boston to prioritize the vehicle measurements to prioritize the most common makes and models of vehicles. In all, the measured vehicles represent all but one type of Boston Public Schools vehicle, all types of BFD fire apparatus, and a significant percentage of the Public Works vehicles.

Table 1. Total vehicles measured by Department

Agency	Number of Vehicles Measured	Number of similar vehicles in fleet	Total vehicles in fleet	Similar vehicles measured % of fleet
Boston Fire Department	3	53	53	100%
Boston Public Schools	5	728	742	98.1%
Boston Public Works	11	138 46 additional vehicles with VIEW app	456	30.3% 40.4% with additional VIEW app vehicles
Boston Transportation Department	2	32	182	17.6%

This table aggregates vehicles across years, so this analysis assumes that vehicles of the same make and model are going to remain generally similar regardless of year. Vehicle redesigns do happen and can result in significant changes in direct vision, so this is a limitation of the study.

2.3 Methods

The Volpe team used the prioritized vehicle list to coordinate several site visits to measure vehicles and take pictures. The site visits included: Central Fleet at 400 Frontage Rd, BPS Freeport Yard, BFD headquarters, BPS Washington Yard, and Concord Public Schools yard in Acton, MA. Volpe collected field measurements based on direct observation using a consistent driver,[16] including the distance to the nearest visible point (NVP) on the ground directly in front of the driver and the distance to the NVP on the ground directly to the right of the driver through the passenger window.

Once completing the measurements, the Volpe team recorded NVP distances from the field measurements as well as input the vehicles into the VIEW app. All VIEW output data are available online by searching for the vehicle make and model.

Both Volpe and third parties have entered vehicle makes and models in the VIEW database (over 400 rows) that are not in Boston's fleet. Since VIEW eyepoint location is not currently standardized across crowdsourced entries and these entries do not include field measurements, further standardization and validation would be needed for confidence in any comparison between Volpe-measured Boston fleet vehicles and those only present in the VIEW database.

2.4 Boston Fleet Results

The following figures are presented in decreasing order of visibility, with the vehicles having the lowest direct vision being at the top and highest at the bottom for the crosswalk graphic, and for the bike lane graphic, the lowest amount of direct vision to the left and highest to the right. A standardized crosswalk and buffered bike lane were selected in consultation with the City to provide VRU safety context for these direct vision measurement results.

Summary bar charts based on **child and adult VRU distances follow** in Figure 2. Nearest Point at Which an Adult and Child are Visible to a Driver in a Standard Crosswalk and Figure 3. Nearest Point at Which an Adult and Child are Visible to a Driver in a Buffered Bike Lane.

[16] Of 6' 0" stature.

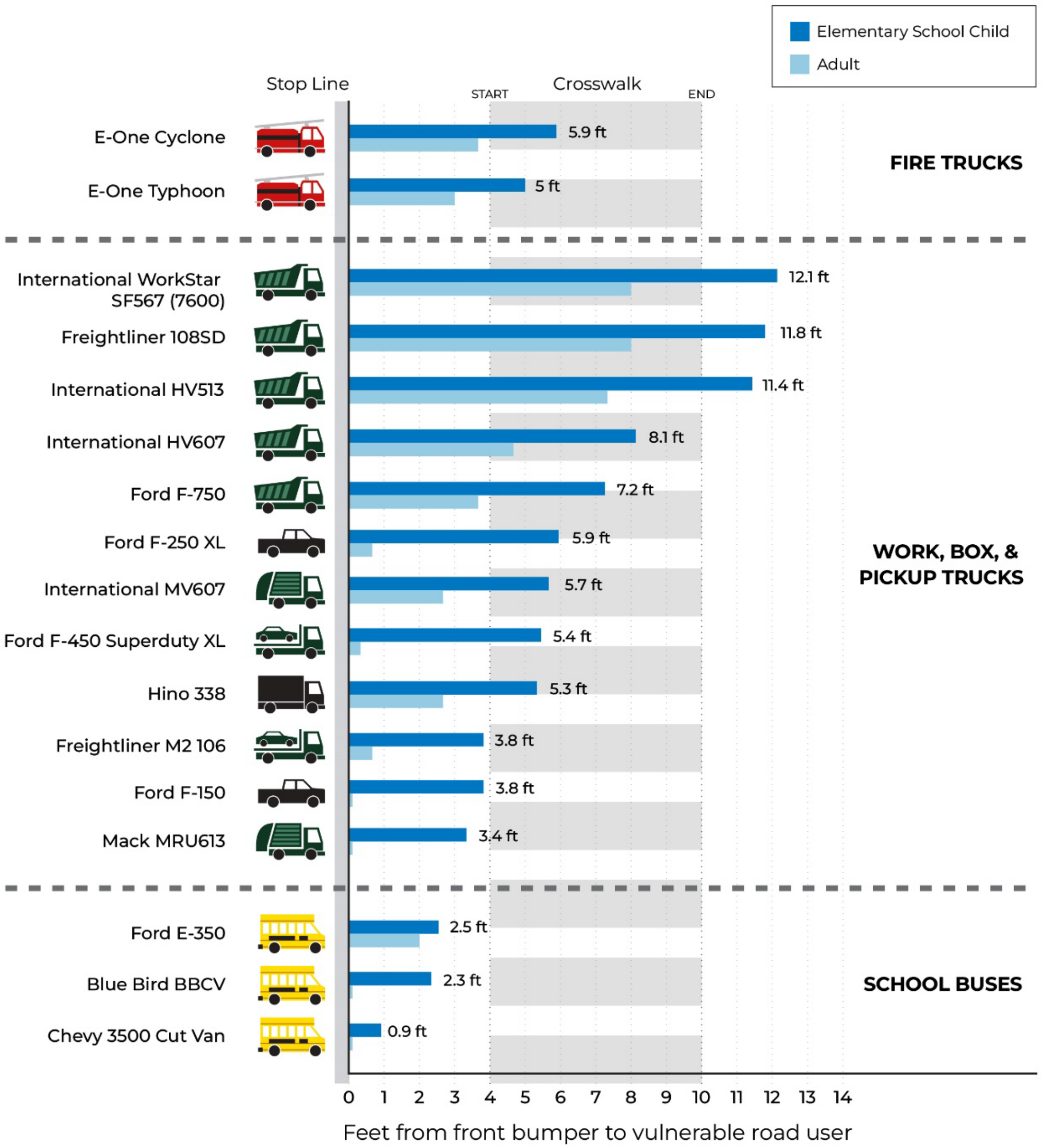


Figure 2. Nearest point at which an adult and child are visible to a driver in a standard crosswalk. The number listed in feet corresponds to the distance from the vehicle bumper to a child in the crosswalk.

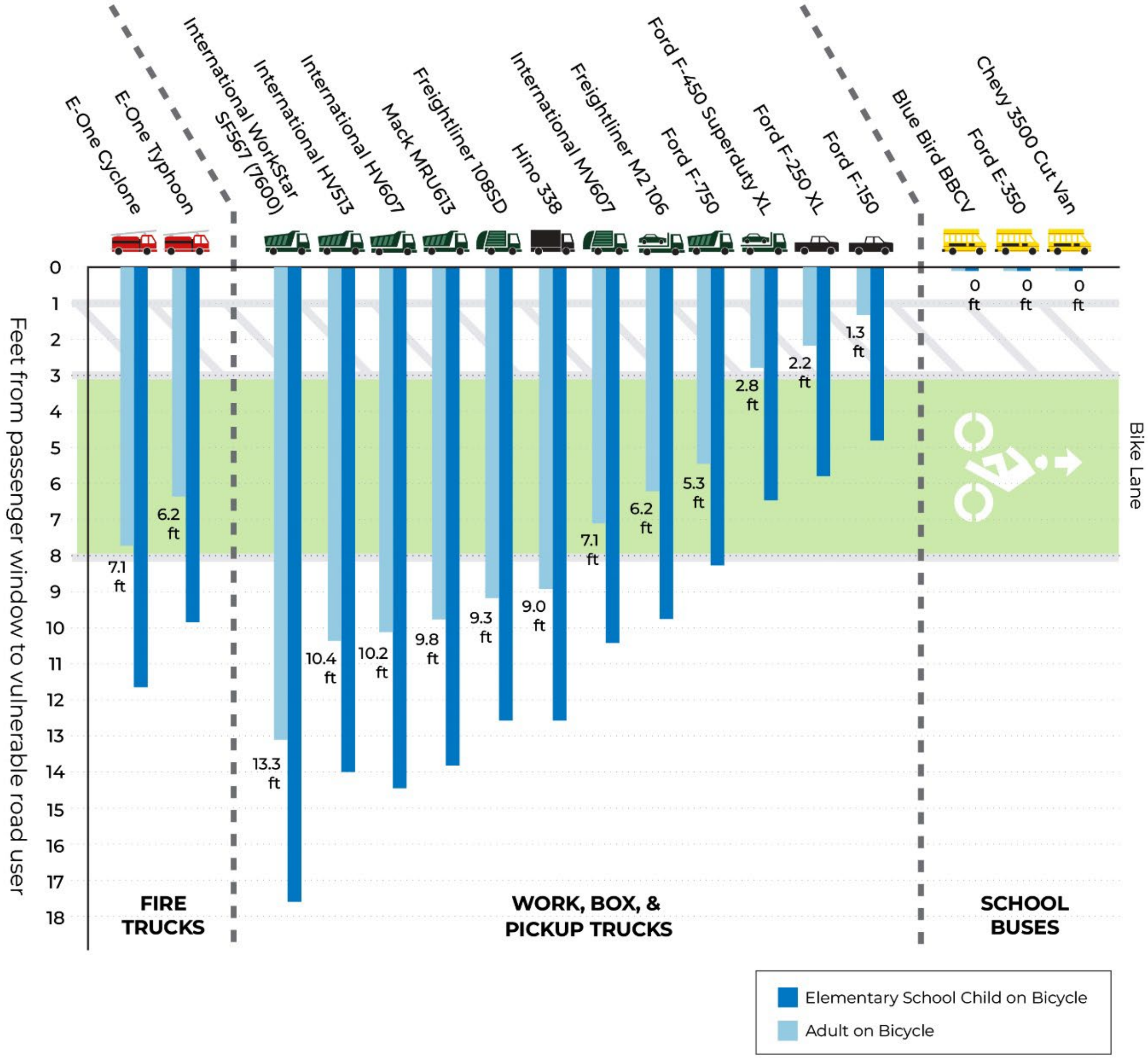


Figure 3. Nearest point at which an adult and child are visible to a driver in a buffered bike lane. The number in feet corresponds to the distance from the bumper to an adult on a bicycle.

Figure 4 through Figure 6 provide example views from the driver's perspective in three different City of Boston vehicles that Volpe measured.

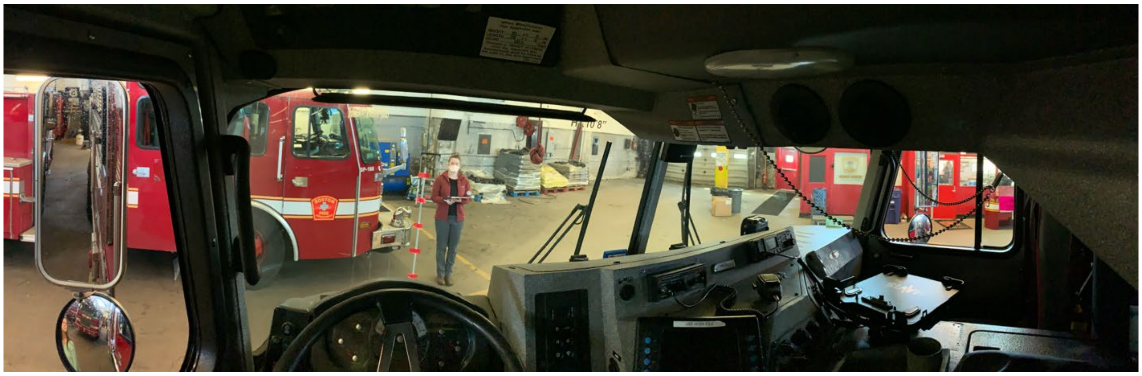


Figure 4. Example driver's view from measured E-One Typhoon fire truck.

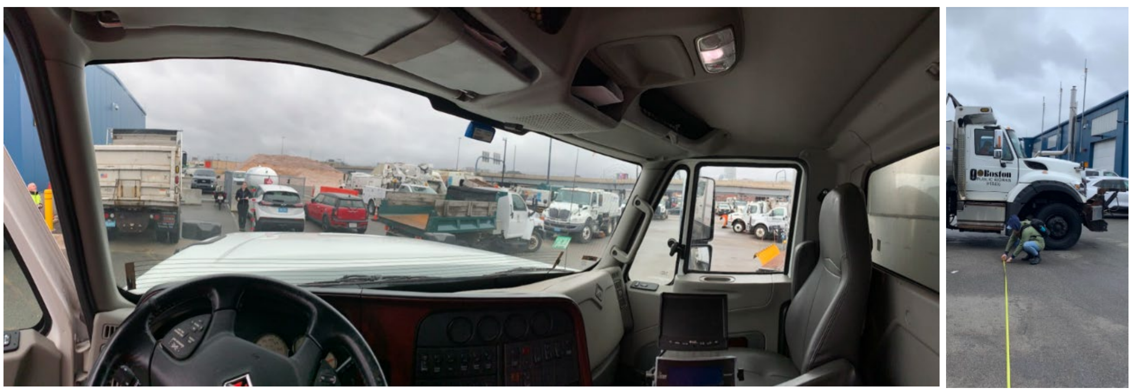


Figure 5. Left: Driver's view from measured International Workstar. Right: View toward driver from the nearest point at which the driver can see the road.

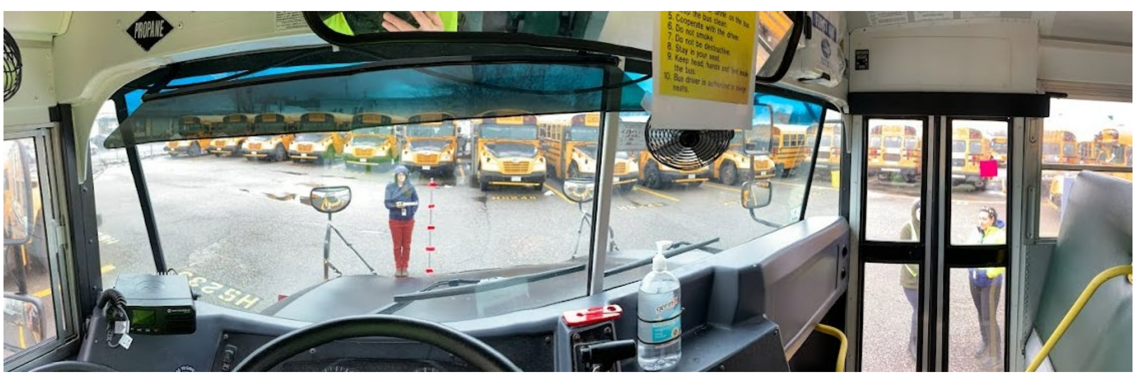


Figure 6. Driver's view from measured Bluebird BBCV school bus.

3 Proposed Minimum Direct Vision Criteria

Based on the Boston fleet analysis results and consultation with Boston, the project team developed an approach that can be used to assess the current vehicles in the City of Boston fleet. The approach can be generalized to assess all passenger and commercial vehicles.

3.1 Direct Vision Rating Framework for City of Boston Vehicles

3.1.1 Inputs and options

The project team used the Federal Highway Administration's Manual on Uniform Traffic Control Devices (MUTCD) to inform dimensions for the minimum crosswalk and stop bar geometry, providing a nationally consistent reference for an intersection context determined through consultation with the City of Boston to be both relevant and interpretable for rating direct vision. The MUTCD states that stop lines should be placed a minimum of 4 feet in advance of the nearest crosswalk line.[17] Additionally, the MUTCD provides guidance that a crosswalk that uses diagonal or longitudinal lines should be not less than 6 feet wide.[18] The standard crosswalk measurements for the analysis uses the minimum guidelines and assumes that a driver stops such that the vehicle's front bumper is directly above the stop line.

The MUTCD offers more limited guidance on bicycle lane dimensions. The project team therefore acquired typical design standards from the Boston Transportation Department to inform the typical buffered bike lane dimensions, in which the painted buffer is 2 feet wide, and the bike lane is 5 feet wide.

The project team incorporated VRU heights from U.S. anthropometric data tables.[19] The dimensions of VRUs are summarized in

Table 2. Vulnerable Road User dimensions based on anthropometric source

[17] Federal Highway Administration. *Manual on Uniform Traffic Control Devices*. 2009. https://mutcd.fhwa.dot.gov/htm/2009/part3/part3b.htm

[18] Federal Highway Administration. *Manual on Uniform Traffic Control Devices*. 2009. https://mutcd.fhwa.dot.gov/htm/2009/part3/part3b.htm

[19] Anthropometric Survey of U.S. Personnel: Summary Statistics Interim Report. March 1989. https://multisite.eos.ncsu.edu/www-ergocenter-ncsu-edu/wp-content/uploads/sites/18/2016/06/Anthropometric-Detailed-Data-Tables.pdf

Table 2. Vulnerable road user dimensions based on anthropometric sources

Vulnerable road user type	Anthropometric source	Stature	Shoulder Height	Width
Adult	5th percentile adult female shoulder height	60 inches	49 inches	16 inches
Wheelchair user	5th percentile adult female shoulder height, sitting + standard wheelchair seat height	49 inches	39 inches	26 inches
Elementary school child	5th percentile 7yo female shoulder height	45 inches	37 inches	12 inches
Preschool child	5th percentile 3yo female shoulder height	34 inches	28 inches	9 inches
Adult on bicycle	5th percentile adult female shoulder height, sitting * cos(30 deg torso angle) + buttock height = shoulder height	~58 inches	47 inches	16 inches (assume staggered row)
Elementary school child on bicycle	5th percentile 7yo female shoulder height, sitting * cos(30 deg torso angle) + buttock height = shoulder height	~45 inches	35 inches	12 inches (assume staggered row)

3.1.2 Proposal and results

The TSR workshop identified the need, and the City concurred, for direct vision criteria to be easy to understand and communicate to a wide audience, as well as sensitive enough to segment vehicles already in the City of Boston fleet. Given these goals, the project team proposes a five-star scoring framework. Stakeholders, including the public, are widely familiar with this type of rating system and would intuitively understand that one star is low and five stars is high. Additionally, the project team proposes aligning the star ratings based on infrastructure because these related blind zones to the potential safety risks for vulnerable road users who rely on that infrastructure.

The project team also proposes creating separate scores for forward and passenger side visibility. Each score would align with vulnerable road user infrastructure – crosswalks for forward visibility and buffered bike lanes for passenger side visibility.

Table 3. Proposed direct vision rating system based on standard crosswalks and buffered bike lanes

Star rating	Forward	Passenger Side
5	**Elementary school children and adults are visible less than 4 feet from the front of vehicle.**	**Elementary school children and adults are visible less than 3 feet from the passenger side of vehicle.**
4	**Elementary school children are visible 4-6 feet from the front of vehicle.**	**Adults are visible less than 3 feet from the passenger side of vehicle.**
3	**Elementary school children are visible 6-8 feet from the front of vehicle.**	**Adults are visible 3-6 feet from the passenger side of vehicle.**
2	**Elementary school children are visible 8-10 feet from the front of vehicle.**	**Adults are visible 6-8 feet from the passenger side of vehicle.**
1	**Elementary school children are visible more than 10 feet from the front of vehicle.**	**Adults are visible more than 8 feet from the passenger side of vehicle.**

Figure 7 and Figure 8 summarize the City of Boston fleet with overlays showing how vehicles score according to the proposed 5-star rating system. Colored boxes reflect which vehicles can allow the driver to view a child at any point in either a crosswalk or buffered bike lane, at some but not all points, and at no point in a crosswalk.

Key takeaways and observations about the range of ratings include:

- School buses show up as the highest visibility vehicles in Boston's fleet. The high passenger visibility is due to full-height door windows rather than conventional hinged doors.
- Due to generally lower visibility on the passenger side as compared to in front, the passenger visibility ratings are proposed to consider adults as the vulnerable road user to not limit all work truck vehicles.
- Ford F-150, the smallest vehicle measured in this effort, was the highest rated non-school bus vehicle for passenger visibility and the second highest rated non-school bus vehicle on forward visibility.
- Mack MRU 613 rates 5-stars in the forward crosswalk rating but 1-star in the passenger bike lane rating.

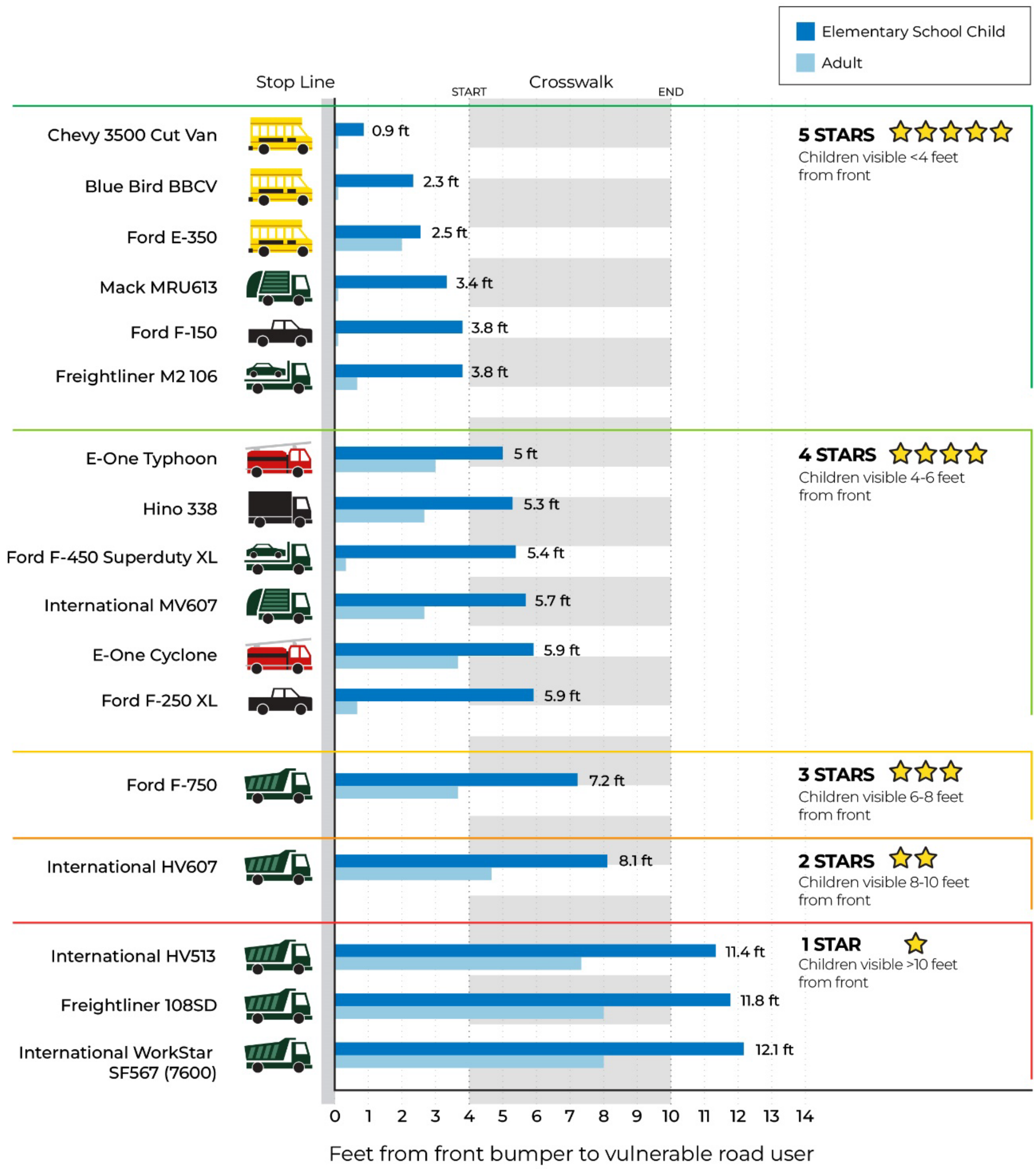


Figure 7. Nearest point at which an adult and child are visible to a driver in a standard crosswalk overlaid with a potential five-star rating system. The number in feet corresponds to the distance from the bumper to a child in the crosswalk.

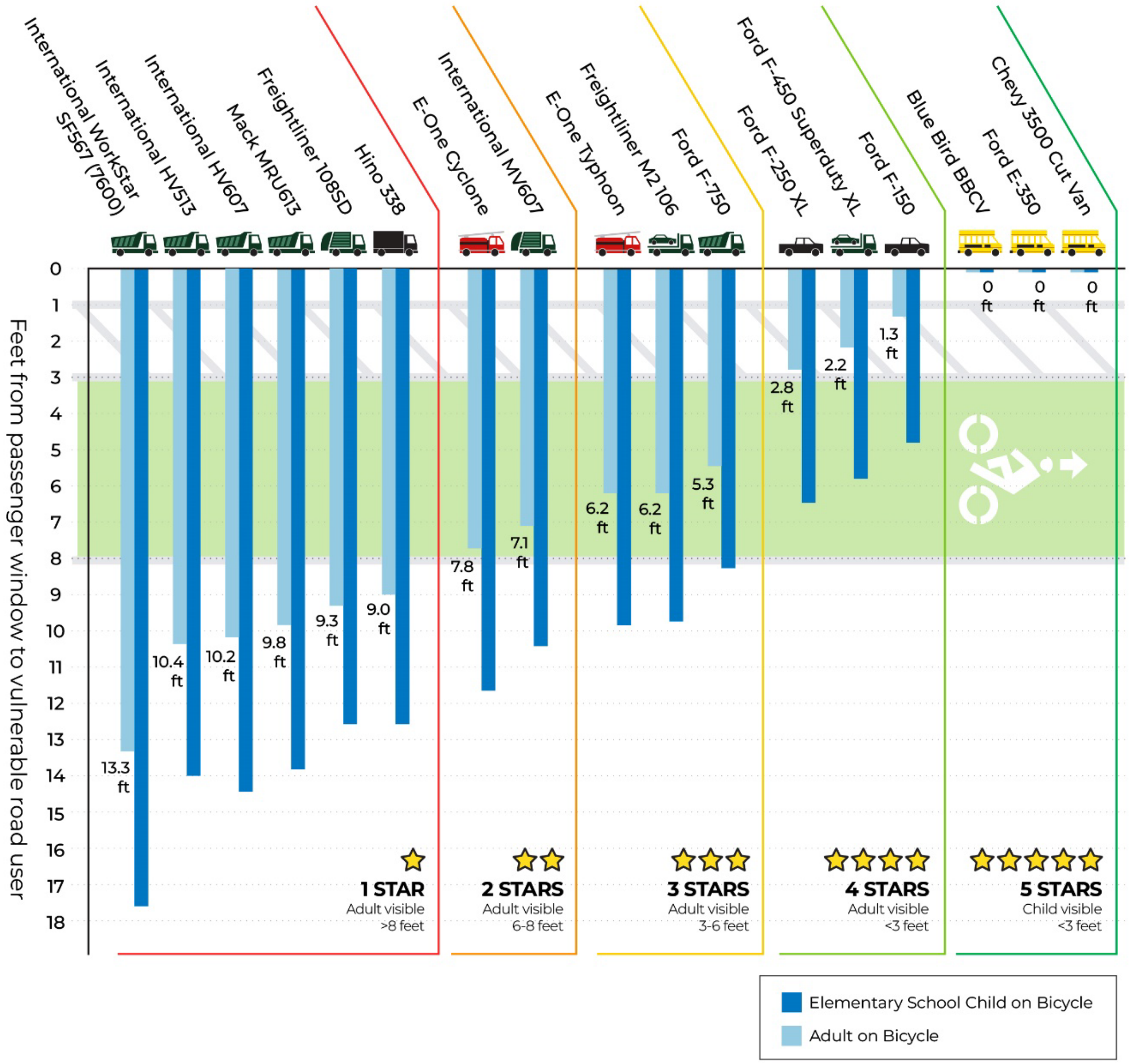


Figure 8. Nearest point at which an adult and child are visible to a driver in a buffered bike lane overlaid with a potential five-star rating system. The number in feet corresponds to the distance from the bumper to an adult on a bicycle.

4 Implementation Next Steps

4.1 Incorporating direct vision in procurement

4.1.1 Document and Language Options

Volpe reviewed the City's procurement system for recent vehicle purchases and identified three potential options to incorporate direct vision criteria:

- Add direct vision to the truck side guard ordinance attachment in solicitations
- Add a bullet under Safety under Details and Spec attachment
- Add a row to the Specifications grid in the Details and Spec attachment

In consultation with the City, Volpe proposes the last option. The City has indicated that this document is the most likely to be reviewed in detail by bidders for compliance and proposal preparation.

The following are three options for language that the City could use for an additional Direct Vision Criteria row in the Details and Spec attachment. It would alert potential bidders to this requirement and link to a specification that they could reference.

Option 1

In line with the yes/no questions, the City could add:

- "The vehicle complies with the City of Boston direct vision specification [LINK TO BE ADDED]"
    - Note: The direct vision specification would link to summarize the rating system described in Section 4.1.3.

Option 2

If it is possible to request and collect numeric responses from bidders, request VRU distances instead of yes/no. Some vehicles may be close to the standard and some may be far off. A numeric response would offer the City more information in choosing vehicles.

- "The forward distance to a child VRU is: _____"
- "The passenger side distance to an adult VRU is:_______"

If this option is chosen, the instructions should consider a standard that the person taking the measurements should be no taller than a certain height.

Option 3

Option 2 may have discrepancies because it does not standardize for the height of the person taking the measurements from the driver seat. A possible option is to request more information about the driver.

- "The forward distance to a child VRU is: _____"

- "The passenger side distance to an adult VRU is:_______"
- "The height of the person in the driver's seat taking the visibility measurements is:_______"

Accompanying any of these options, the City could add another row for provision of blind zone countermeasures on vehicles, the City could specify these to include mirrors and side guards as already prescribed by City ordinance, in addition to the safe system requirements that TfL's DVS requires for zero-star vehicles—see Section 0.

- "If the vehicle does not comply with the City of Boston direct vision specification, the vehicle is equipped with specified blind zone safe system countermeasures."

4.1.2 Proposed Reporting Method

The following proposed direct vision reporting method, consistent with the language Option 2 above, represents a near-term implementable approach. This physical, traffic cone-based reporting method could potentially allow the City of Boston to test and implement a procurement policy within months by limiting the burden on bidders and aiding in independent verification.

The method relies on two traffic cones or other objects of specific heights, a tape measure, and two individuals, one of whom is of a certain height. Bidders would measure how far forward and to the passenger side the average height male driver can see a given VRU from the vehicle.

When the driver seat is properly positioned for a driver who is not taller than 5' 9" height: [20]

- *Request the distance forward of the center of the vehicle bumper at which the driver can first see the top of a 3-foot cone. This is the forward distance to a child VRU.*
- *Request the distance beyond the exterior of the passenger side door at which the driver can first see the top of the 4-foot cone. This is the passenger side distance to an adult VRU.*

[20] The average height male adult in the U.S. population is 69 inches, while the average height female adult in the U.S. is 63.5 inches. https://www.cdc.gov/nchs/fastats/body-measurements.htm

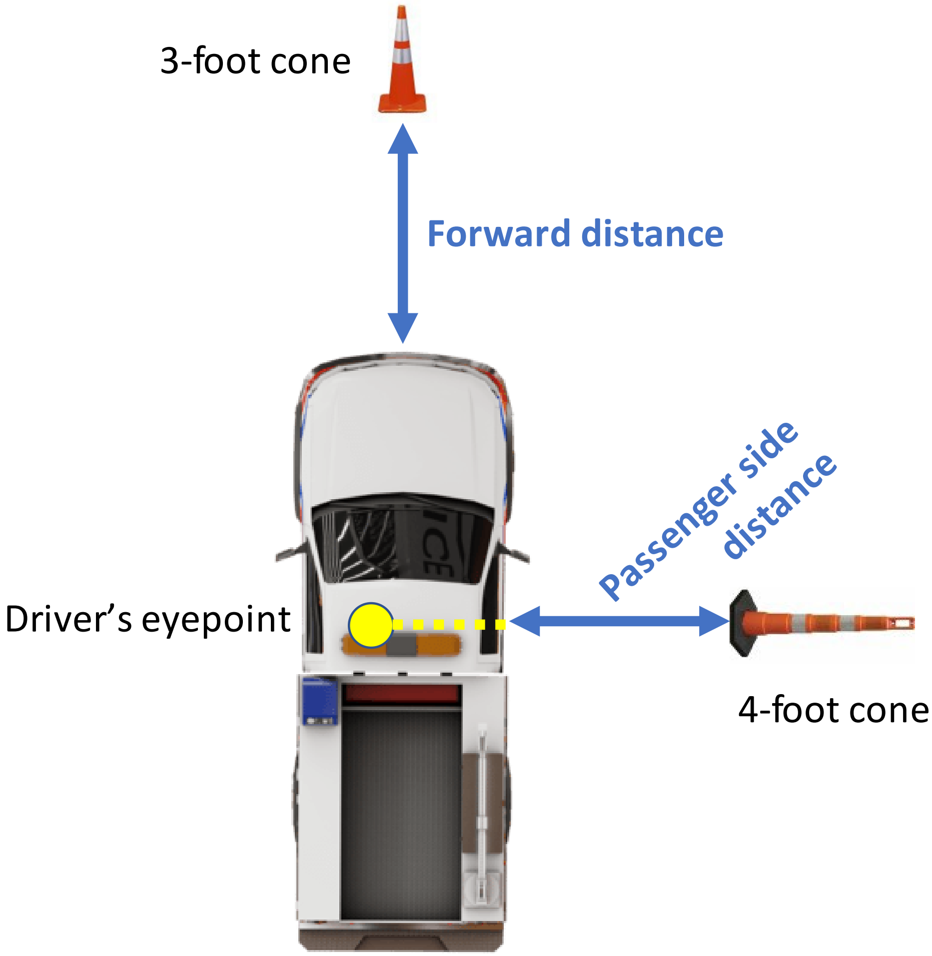


Figure 9. Proposed near-term cone method of direct vision reporting for bidders.

For reference:[21]

A 3-foot cone approximates a grade school child VRU:

- Grade school child: 37 inches to shoulder
- Grade school child bicyclist: 35 inches to shoulder

A 4-foot cone approximates an adult VRU:

- Adult: 49 inches to shoulder
- Adult bicyclist: 47 inches to shoulder

[21] Heights of all VRUs, 5th percentile height for the U.S. population:

- Preschool child: 28 inches to shoulder
- Grade school child: 37 inches to shoulder
- Wheelchair user: 39 inches to shoulder
- Adult: 49 inches to shoulder
- Grade school child bicyclist: 35 inches to shoulder
- Adult bicyclist: 47 inches to shoulder

By incorporating a modest data collection request into the method, rather than a binary yes/no answer, Volpe anticipates this approach would over time enable broader analysis of vehicle options on the U.S. market.

The VRU distance-based measurements of the traffic cone approach align with two corresponding outputs from the VIEW app. The VIEW measurement could be performed concurrently for additional estimated outputs, such as the total numbers of VRUs of different types that are obscured, not just the number of one specific VRU type in one dimension along each of the two principal axes measured in the cone method. However, the added complexity and learning curve of the VIEW method, requiring users to exercise care in acquiring and then processing the panoramic photo on a computer, could pose a barrier to its near-term use by City vendors and contractors. The VIEW app method is still under development and at present introduces about 20% error in how far the ground can be seen versus the physical measurement,[22] and in some cases larger error rates can occur. The cone method may therefore also be more defensible as a near-term procurement requirement, for example, if a vendor potentially disputes a purchase decision based on a direct vision measurement.

Figure 10. Setup for 3-foot and 4-foot cone method of blind zone measurement.

Volpe is working to understand and minimize error in future iterations of the VIEW tool, and the City could revisit its preferred direct vision reporting method pending further validation of VIEW's error rates across different vehicle types, especially if bidders broadly demonstrate they are capable of accurately and reliably carrying out the simpler cone method as a first step. The approach also leaves open the door to potentially collecting and reporting more visibility data points consistent with the UNECE Regulation 167, either based on the average minimum VRU distance at 13 specific points surrounding the vehicle cab,[23] or a CAD-based calculation of the visible volume assessment, should either vehicle CAD models or 3-dimensional scans become more widely available. These are seen as compatible but longer-term reporting methods for managing vehicles' direct vision performance at a city procurement level, potentially in a future in which manufacturers, government, or a third party assumes responsibility for direct vision assessment rather than vendors and bidders.

[22] Evaluating the performance of a web-based vehicle blind zone estimation application: Validation and policy implications, accepted for *Frontiers in Future Transportation*, March 2023

[23] See UNECE 167 physical method: https://unece.org/sites/default/files/2022-10/ECE_TRANS_WP.29_2022_140r1e.pdf (Annex 6)

4.2 Incorporating direct vision in driver training

As a baseline data point for current driver training treatment of direct vision and for the potential of informing future supplemental training by the City or others, Volpe reviewed current CDL questions and answers that licensees are required to learn to receive a school bus endorsement and Class A or B commercial vehicles.

The CDL training curriculum currently teaches licensees about the existence of blind zones but appears to provide limited content regarding where VRUs can and cannot be seen from different types of commercial vehicles. Volpe identified one CDL test question from the test question bank for the school bus CDL endorsement.[24]

The left and right danger zones extend up to _______ from the left and right sides of the school bus.

- 10 feet
- 5 feet
- 20 feet

Bingo!

EXPLANATION: The danger zones may extend as much as 30 feet from the front bumper with the first 10 feet being the most dangerous, 10 feet from the left and right sides of the bus and 10 feet behind the rear bumper of the school bus.

Next Question

For comparison, the Blue Bird buses that Volpe measured allow a driver of six feet stature to see the ground at about 21-22 feet in front of the bus and first see a grade-school child at 2-3 feet in front. The 30-foot front danger zone described in the training appears to be conservatively long for the Blue Bird buses that Boston Public School owns.

One training opportunity may be to incorporate more specific knowledge about measured vehicle blind zones, such as those measured in this study or collected in VIEW or on the NIOSH blind area diagrams,[25] into City and contractor driver training, especially for heavy/severe-duty work trucks whose blind zones are generally found in this study to obscure the largest number of VRUs.

[24] https://www.cristcdl.com/massachusetts/

[25] https://www.cdc.gov/niosh/topics/highwayworkzones/bad/imagelookup.html

4.3 Communication and coordination

Communication and coordination may be important to promote awareness, feedback on, and potential adoption of the City's direct vision specification by both bidders subject to City procurement as well as by other jurisdictions and private entities in North America. Key partners that the City may engage include, but are not limited to, the National Association of City Transportation Officials, peer cities, safety NGOs such as National Safety Council and Together for Safer Roads, safety advocacy groups, and standards development organizations such as ISO. Volpe anticipates disseminating and fostering discussion about the City's direct vision specification, including identifying future opportunities to work toward harmonization with international standards, through coordination with entities such as USDOT modal agencies, Transport Canada, the United Nations Economic Commission for Europe, and academic researchers.

4.4 Future work

Subject to available resources, Volpe anticipates several next steps to build on the present effort. These next steps include more standardized data collection, measurement of a broader set of vehicles, and assessing the potential benefits of countermeasures for low vision vehicles that may not rate highly on the City's rating system.

Standardized measurements, for example, using standardized camera rigs, would provide blind zone measurements for representative drivers rather than a six-foot male. This approach could repeatably account for shorter drivers' visibility and gender, for example fifth percentile male and female height drivers. Future work should seek to measure a wider set of vehicles to support market analysis, including increased coverage of consumer vehicles. Finally, while the Transport for London "Safe System" set of mitigation technologies for zero-star heavy goods vehicles provides a reasonable and established starting point for Boston to consider similar countermeasures, future research would be beneficial to review and help downselect among these and other solutions, including but not limited to bird's eye view cameras and moving off information systems.[26]

[26] https://unece.org/fileadmin/DAM/trans/doc/2020/wp29grsg/GRSG-118-36e.pdf

5 Appendix

5.1 VIEW app

The VIEW app provides an opportunity to create a database of these findings that can be shareable across stakeholders. The project team collected valuable validation data during this collaboration with the City of Boston. All vehicles have been entered into the VIEW app and are searchable for detailed visualizations on side, front, and overhead blind zones.

Through this process, the project team noted that VIEW outputs can, in some instances, have significant error rates that require fixes to the model assumptions. In general, the Volpe analysis found that VIEW blind zone results directionally agree with field measurements and may be helpful as an illustrative comparison of Boston fleet vehicles to other vehicles on the market not measured within the scope of this study. The Volpe Center will be conducting ongoing improvements to the VIEW app to improve the accuracy and user experience, with the expectation that the VIEW app outputs will more closely align with field measurements in the future.

To input vehicles into the VIEW app, a user must collect four measurements, labelled A, B, C, and D in Figure 11. VIEW app measurements visual These are all in relation to the smartphone or tablet that is taking the image, but the smartphone or tablet lens is assumed to represent the driver eye point for VIEW blind zone calculations. From the eye point, the measurements are as follows: A) lens height from the ground, B) lens distance to the passenger window, C) lens distance to the five-foot measurement pole, and D) lens distance to the front bumper. The measurement pole should be place directly in front of the driver at a point where the bottom of the pole is not visible but the one-foot marker is visible to the driver.

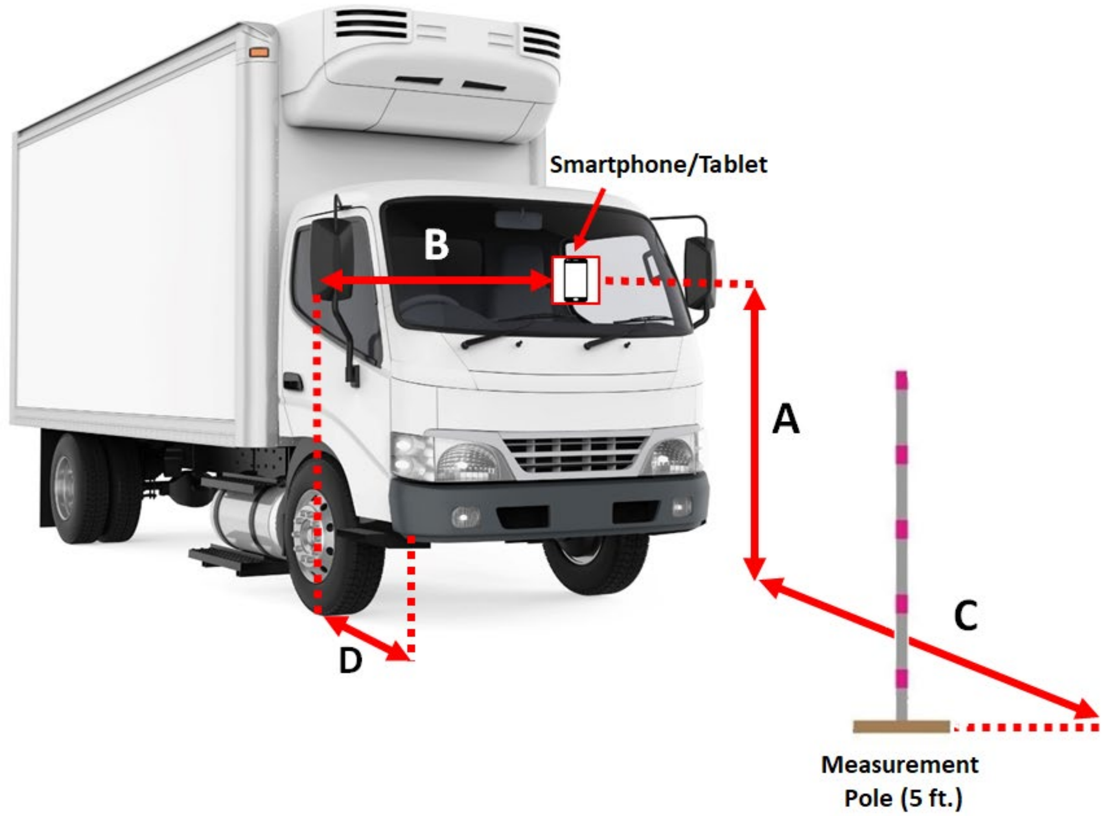


Figure 11. VIEW app measurements visual

5.2 Notional Market Analysis

The project team identified the potential to compare the City of Boston fleet with other vehicles outside their fleet. Figure 12, Figure 13, and Figure 14 show how field measurements for the City of Boston vehicles compare with four vehicles not in the City of Boston fleet: 2021 Dennis Elite NAS1 truck, an Electric Bluebird school bus, a Thomas Built school bus, and a Lion school bus.

The electric Bluebird school bus appears to have slightly different dimensions but slightly higher visibility, although all perform exceedingly well. The Bluebird school buses appear to have similar visibility to the Thomas Built and Lion school buses, and the blind zones of the Type C and Type D buses appear to be similarly small. Dennis Elite NAS1 appears to outperform other Class 8 trucks on forward visibility but not to the same extent on passenger side visibility, as shown in Figure 14.

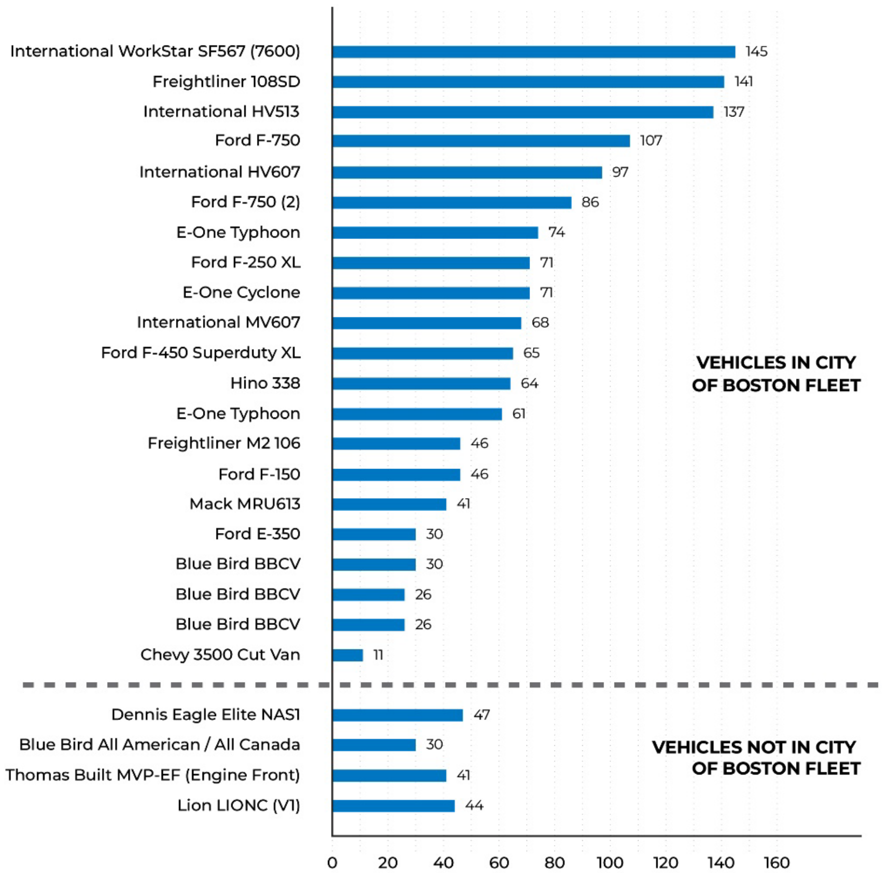


Figure 12. Forward distance to nearest visible elementary school child between field measurements (units in inches)

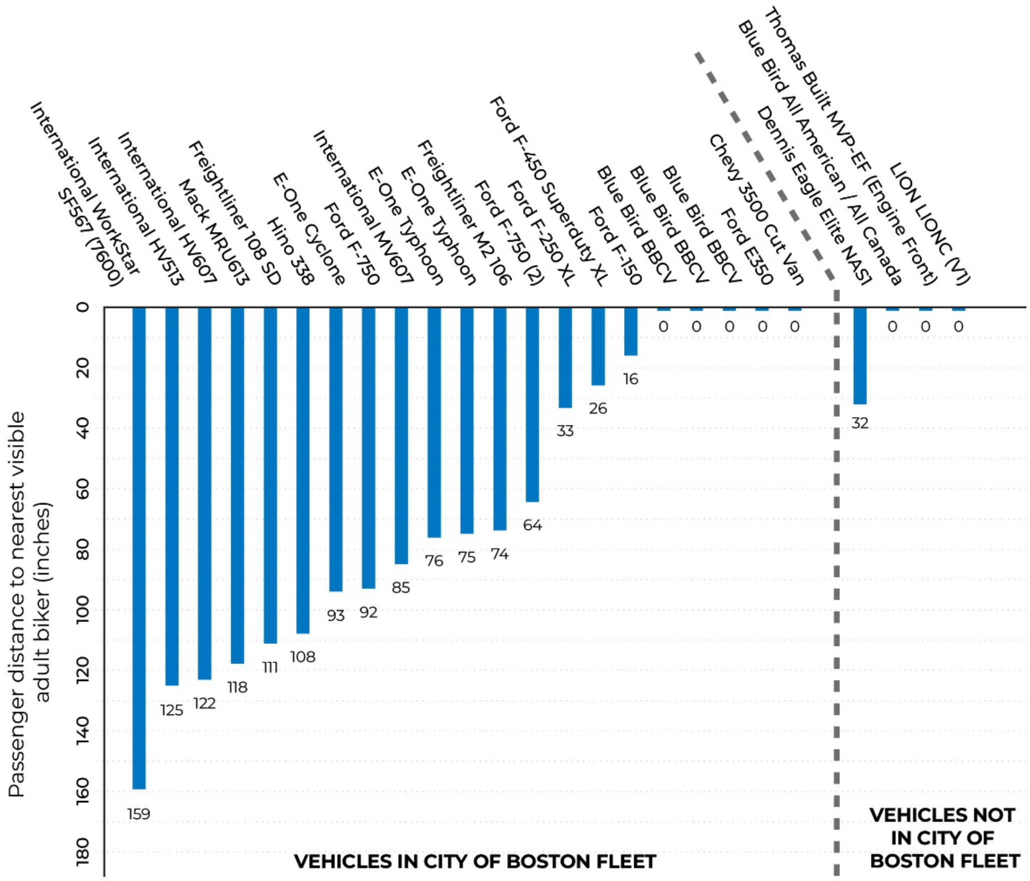


Figure 13. Passenger distance to nearest adult bicyclist between field measurements (units in inches)

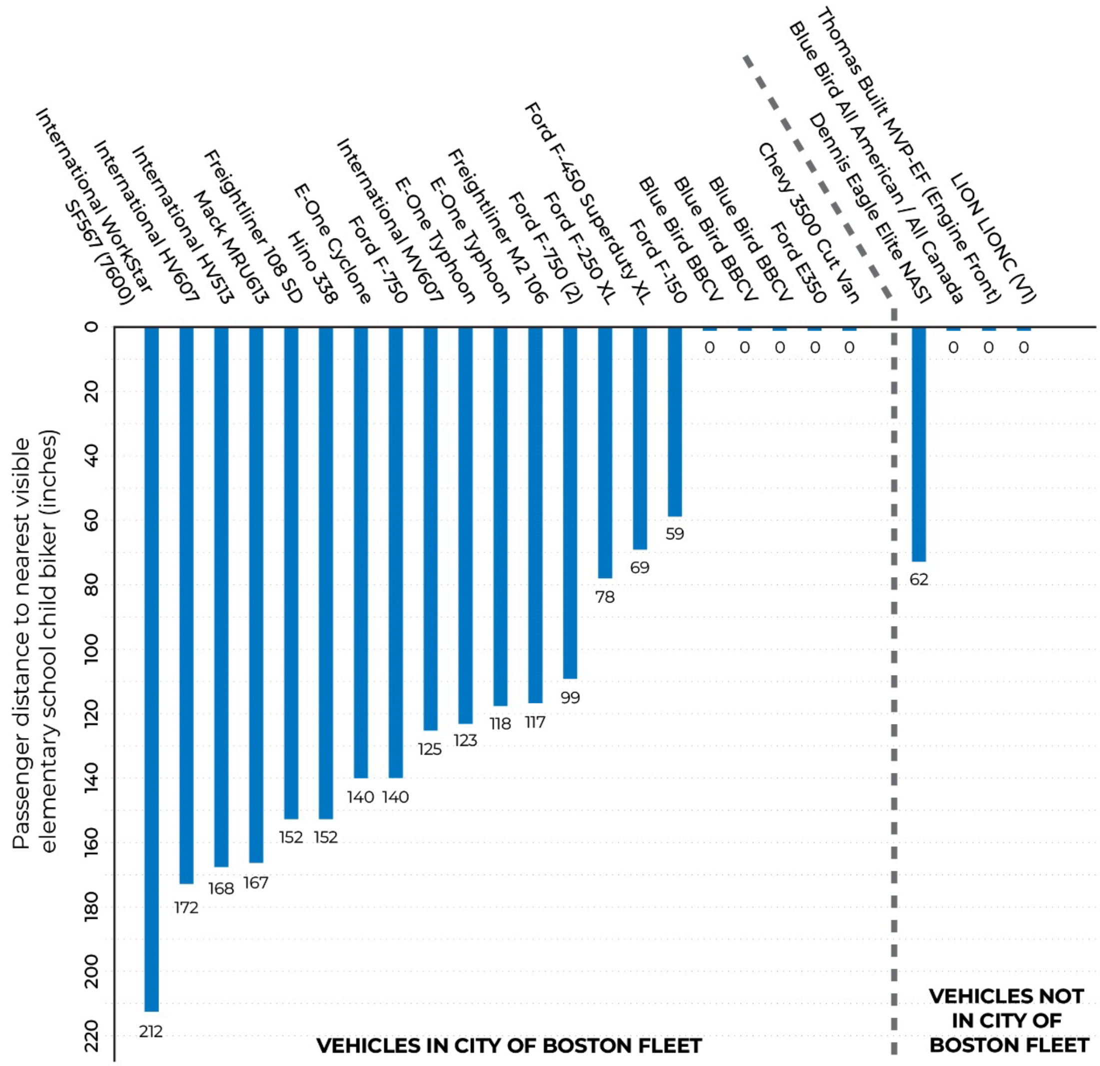
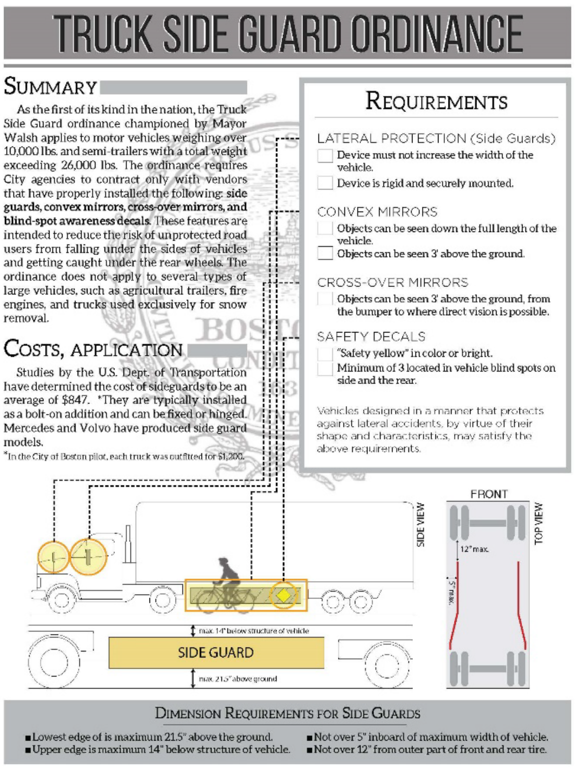


Figure 14. Passenger distance to nearest visible elementary school child bicyclist between field measurements (units in inches)

5.3 City of Boston Procurement System Elements

The following are elements of the City's existing vehicle procurement process that could be considered for potential future addition of direct vision criteria.

5.1.1 Truck Side Guard Ordinance



5.1.2 Specifications (safety)

EV00012002 (2) 2022 or Newer ½ Ton Pick Up Trucks Per Specification Enclosed or Approved Equal -
Advertised Date: 03/06/2023- Open Date 03/22/2023 REQ# 416749

****You must complete this document by answering YES/No for each item contained in the specification. If you check NO you MUST provide supporting documentation with the item # and your reason for the check****

GENERAL

- **The equipment required under these specifications is to be used by the City of Boston Public Works Department. The equipment shall be new, of the latest production model as evidenced by the manufacturer's published literature and it shall conform to all specifications contained herein.**
- **Detailed specifications of the exact equipment offered must accompany the bid. Any and all supplies, parts and/or attachments not specifically mentioned but necessary to ensure a complete and safe product shall be furnished by the successful bidder.**
- **The equipment shall conform in strength, quality of material, and workmanship to what is usually provided by good engineering practice. Any allied equipment shall be installed in such a manner so as not to adversely affect the original manufacturer's product.**

SAFETY

- **The completed equipment package shall comply with all applicable Federal and State Motor Vehicle Regulations and Safety standards and codes, and any other applicable regulations in force at the time of delivery. All applicable warnings and warning labels required by law must also be complied with accordingly.**

STANDARDIZATION

- **All equipment delivered under the contract resulting from these specifications will be built with identical and interchangeable parts and components.**

DELIVERY

- **Delivery date is an important factor in determining the award and shall be stated as part of the bid. The successful bidder shall deliver the equipment complete, serviced and ready to operate, to the City of Boston Central Fleet Management (CFM). Arrangements shall be made by calling 617-635-1281, Monday through Friday, 7AM until 3PM. Vehicles or equipment delivered without a delivery appointment will not be accepted upon delivery.**

WARRANTY

- **All warranty work shall have a full, no cost, 100% parts and labor coverage. Pickup and delivery of the vehicle shall be included as part of any warranty repair or factory/dealer recall. A manufacturer's authorized representative shall perform the warranty work.**
- **In addition to the manufacturer's warranty, the awarded contractor must warranty all other allied equipment against faulty workmanship and materials for three (3) years. An official**

5.1.3 Specifications (yes/no)

EV00012002 (2) 2022 or Newer ½ Ton Pick Up Trucks Per Specification Enclosed or Approved Equal -
Advertised Date: 03/06/2023- Open Date 03/22/2023 REQ# 416749

warranty contract statement or information booklet stipulating warranty terms offered must accompany the bid at the time of the bid opening and be endorsed by the manufacturer.

- **Vendor will also include the ability for the City of Boston Central Fleet Management (CFM) staff to perform warranty and factory recalls in-house by certified CFM technicians. Requirements and labor/parts reimbursement rates shall be provided as part of bid.**

SPECIFICATIONS: It is the intent of this specification that the bidder shall supply two (2) new 2022 or later model year ½ Ton Pick-up Trucks.

Indicate compliance with checking either a YES or NO answer. — A 'YES' answer indicates 100% compliance with the entire statement. Manufacturer's bid is allowed to meet, or exceed, stated specifications, unless otherwise quantified. — Explain all 'NO' answers in detail on a separate page, clearly referencing the relevant non-conforming item(s) by section and item number. - Unit literature must be submitted identifying location by number of each specification requirement below (i.e. item #1 on page 3), highlighted and numbered for ease of reference on product literature.	**Compliance Yes/No**
1. Units bid shall consist of two (2) new 2022 or later ½ Ton Pick-up Trucks.	
2. Ability for the City of Boston Central Fleet Management (CFM) staff to perform warranty/factory recalls in-house by certified CFM technicians and the City to be reimbursed for parts and labor.	
3. Both vehicles must be delivered & invoiced no later than 6/30/2023. No exceptions.	
4. Engine – 2.7L, Turbo, 310 HP	
5. 8-speed automatic transmission.	
6. Standard/regular cab.	
7. 6.5 Foot Bed	
8. Vinyl Seats (40/20/40 split).	
9. Cab running boards (both sides).	
10. Steel Wheels.	

5.4 Transport for London DVS Countermeasures for Low-Vision Trucks

Transport for London's direct vision standard implementation has required various countermeasures for low-vision trucks. Figure 15. Overview of Counter-Measures from Transport for London Direct Vision Standard (for more details and specifications, see: describes these counter-measures for a standard dump truck, which include Class 5 and 6 mirrors, blind-spot cameras, close-proximity sensors that alert the driver, side guards, audible external alerts, and warning signage placed on the rear of the truck.

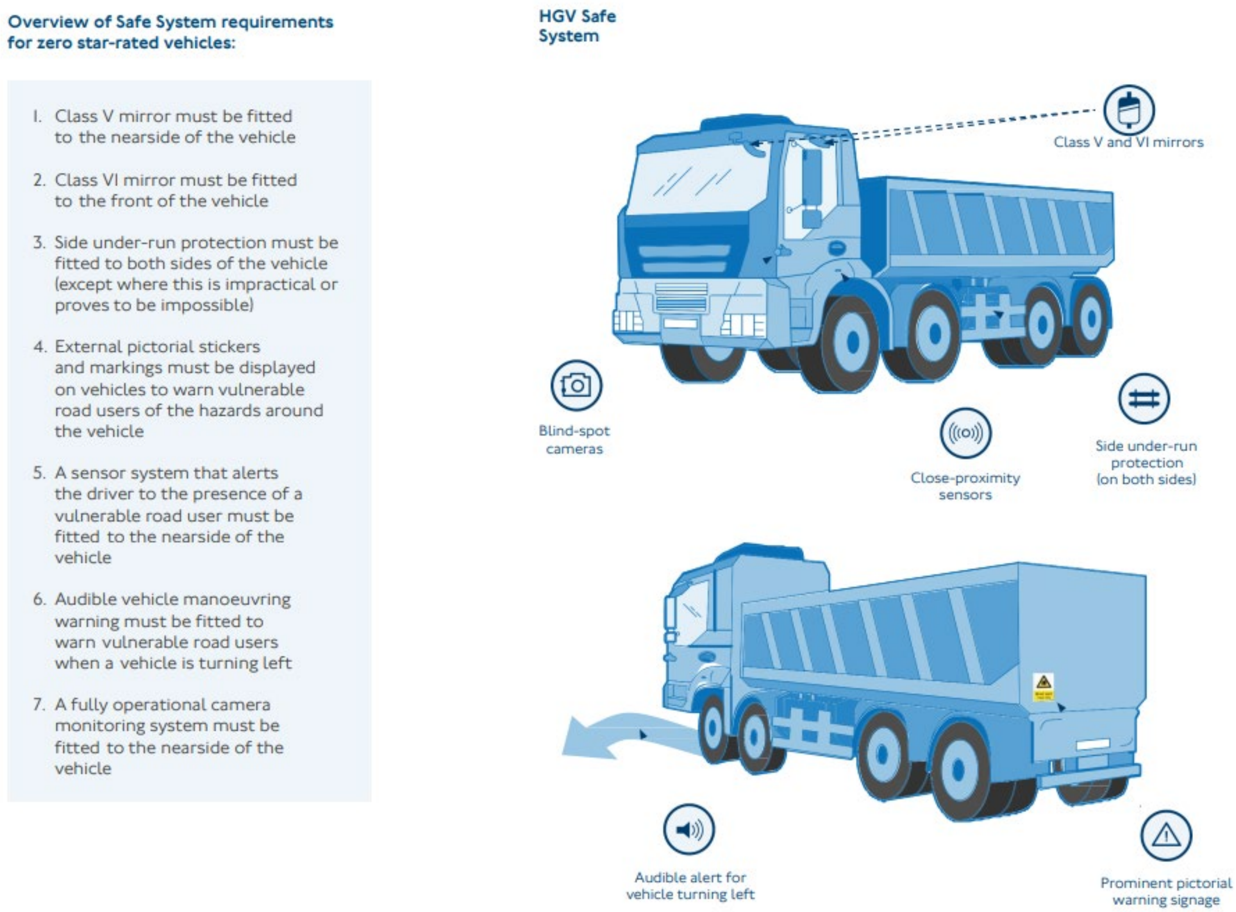


Figure 15. Overview of countermeasures from Transport for London Direct Vision Standard (for more details and specifications, see: https://content.tfl.gov.uk/hgv-safety-permit-guidance-for-operators-entering-london.pdf)

5.5 New Massachusetts Vulnerable Road User Law

On April 1, 2023, new vulnerable road users laws went into effect in Massachusetts as part of "An Act to Reduce Traffic Fatalities," intended to increase roadway safety across the Commonwealth. Massachusetts now defines "vulnerable user" on its roads to include:

- People walking and biking
- Roadside workers
- People using wheelchairs
- Scooters, skateboards, roller skates, and other micromobility devices
- Horse-drawn carriages
- Farm equipment

The law also states, "In passing a vulnerable user, the operator of a motor vehicle shall pass at a safe distance of not less than 4 feet and at a reasonable and proper speed."

Relevant to findings in this report, many vulnerable road users may not be visible at 4 feet away from the passenger side.

U.S. Department of Transportation

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