TSB Recommendation R15-02

Bus crashworthiness

The Transportation Safety Board of Canada recommends that the Department of Transport develop and implement crashworthiness standards for commercial passenger buses to reduce the risk of injury.

Rail transportation safety investigation report	R13T0192
Date the recommendation was issued	02 December 2015
Date of the latest response	January 2024
Date of the latest assessment	February 2024
Rating of the latest response	Satisfactory in Part
File status	Dormant

Summary of the occurrence

On 18 September 2013, at about 0832 Eastern Daylight Time, westward VIA Rail Canada Inc. (VIA) passenger train No. 51 departed from the VIA station in Ottawa, Ontario, on time and proceeded en route to Toronto, Ontario. At 0847:27, OC Transpo double-decker bus No. 8017 departed from the Fallowfield Station on the OC Transpo bus Transitway. At 0848:06, while proceeding at about 43 mph, the train entered the OC Transpo Transitway crossing, located at Mile 3.30 of VIA's Smiths Falls Subdivision. At the time, the crossing lights, bells and gates were activated. The northbound bus was travelling at about 5 mph with the brakes applied when it struck the train. As a result of the collision, the front of the bus was torn off. The train, comprising 1 locomotive and 4 passenger cars, derailed but remained upright. Among the bus occupants, there were 6 fatalities and 9 serious injuries, and about 25 minor injuries were reported. No VIA crew members or VIA passengers were injured.

The Board concluded its investigation and released report R13T0192 on 02 December 2015.

Rationale for the recommendation

Structural deformation can be beneficial during a collision as energy is absorbed and dissipated that would otherwise be transmitted directly to the occupants. The basic principle of crash energy management is to ensure that, during a collision, the unoccupied spaces deform before

the occupied spaces. Survivability is influenced by how well the impact is absorbed by features of the vehicle and directed away from the occupants. Any structural damage of the container should not reduce the size of the survivable volume or open it up to the elements to the point where it compromises occupant survivability.

Transport Canada (TC), through its Motor Vehicle Safety Directorate, sets safety standards for the design, construction and importation of motor vehicles in Canada. These standards are known as the *Canada Motor Vehicle Safety Standards* (CMVSS) and are governed by the *Motor Vehicle Safety Act* and *the Motor Vehicle Transport Act* through the *Motor Vehicle Safety Regulations*. The *Motor Vehicle Safety Regulations* specify the requirements respecting safety for motor vehicles and related components. Pursuant to the regulations, the CMVSS identify the prescribed tests required for the certification of vehicles of various weight categories.

The CMVSS requirements vary according to the weight and type of vehicle. The heaviest vehicle weight category includes tractor-trailers that transport commodities and most transit and interprovincial buses that can transport up to 100 passengers. While these vehicles must meet a baseline of essential safety criteria (brakes, steering, etc.) and there are some vehicle safety standards that apply only to this weight category, these vehicles are generally subject to the fewest safety standards. The Alexander Dennis Limited (ADL) E500 buses were designed in accordance with, and were fully compliant with, the legislative requirements of the Federal Motor Vehicle Safety Standards (FMVSS) in the United States and the CMVSS, as well as all applicable state and provincial requirements.

In this occurrence, 4 of the 6 fatally injured occupants were seated in the front row on the upper deck of the ADL E500 bus, which was an area that was structurally compromised during the accident. During the accident, the framing of the upper deck and lower deck floor was torn away. The failure of the bus structure ultimately resulted in the driver, the driver station and seat as well as 8 passengers and 4 passenger seats on the upper deck being ejected from the bus. Although the ADL E500 met all regulatory requirements, the front-end framings were not designed to provide any impact protection for upper deck occupants seated in the front row, and there was no front bumper, nor were these features required by the CMVSS.

During the investigation, other bus designs were reviewed for comparison. The following observations were made:

- Passengers positioned behind the yellow line – Passengers standing on a single-deck bus and passengers standing on the lower deck of a double-decker bus are required to be behind the yellow line located on the floor just behind the driver's station.
- In this accident, although a number of passengers on the lower deck were injured, only 1 passenger standing behind the yellow line sustained fatal injuries. In comparison, all 4 passengers seated in the front row of the upper deck, a location that was directly above the driver station and forward of the yellow line, sustained fatal injuries. Therefore, under the same circumstances, it is less likely that passengers on a single-deck bus would have been exposed to an area that was compromised by the collision.

- School bus – School bus design includes elements that are meant to reduce the effects of a collision. School buses must meet rollover protection standards. They also have a raised underframe, increased body strength, full-length horizontal impact rails and interior compartmentalization. TSB Railway Investigation Report R13W0083 indicated that school buses have an increased ability to withstand an impact and to protect occupants during a vehicle accident.

Vehicles imported to Canada must conform to the applicable CMVSS for the type of vehicle. The manufacturer is responsible for conducting all tests required to meet the CMVSS and for providing copies of the test results to TC. TC reviews the test results and provides approval for importation. Otherwise, there is no formal inspection or risk assessment of the vehicle required prior to delivery, regardless of the vehicle design features.

In contrast, the American Public Transportation Association (APTA) has developed guidelines for the procurement of transit buses to help transit agencies prepare contracts that contain all necessary provisions and incorporate best available practices. The principal crashworthiness requirements in the APTA guidelines pertaining to transit buses include the following considerations (among others):

- Technical specification (TS) 23.2 requires that a bus be designed such that, in the event of a rollover or side impact, its structure is sufficiently robust to maintain a survivable volume with only small permanent deformations allowed.
- TS 70.1 requires the installation of bumpers to provide impact protection to the front and rear of the bus.
- The technical specifications also include static and dynamic strength requirements for passenger seating and seat back handholds to minimize the potential for occupant injuries.

The APTA guidelines include crashworthiness requirements that exceed the requirements specified by the CMVSS and FMVSS. Federal regulations do not require compliance with the more stringent APTA guidelines.

Additionally, in a letter from the National Transportation Safety Board (NTSB) to the National Highway Traffic Safety Administration (NHTSA),[1] the NTSB outlined the findings from its special investigation,[2] which examined bus issues and evaluated the FMVSS that govern bus design. The NTSB was concerned that bus passengers may not be adequately protected in collisions. The investigation determined that, while standards within the FMVSS exist for large school buses relating to passenger seating, crash protection and body joint strength, there were no similar standards that applied to other types of large buses, such as motorcoach or transit buses.

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1 National Transportation Safety Board Safety Recommendation Letter to the United States National Highway Traffic Safety Administration, dated 02 November 1999.

2 National Transportation Safety Board, Bus Crashworthiness Issues, Highway Special Investigation Report NTSB/SIR-99/04, 1999.

The CMVSS contain no requirements for frontal impact, side impact, rollover or crush protection for vehicles with a gross vehicle weight rating (GVWR) in excess of 11 793 kg (26 000 pounds), which includes most transit buses. As a result, buses in this weight category can have different structural features that may not adequately protect the travelling public. Considering the consequences of this accident, the Board recommended that

> the Department of Transport develop and implement crashworthiness standards for commercial passenger buses to reduce the risk of injury.
>
> **TSB Recommendation R15-02**

Previous responses and assessments

February 2016: response from Transport Canada

Transport Canada acknowledges the recommendation.

TC also recognizes that extremely high forces were involved in the collision that are beyond reasonable expectations of structural integrity for any road vehicle.

Transport Canada will evaluate the existing crashworthiness of commercial passenger buses by undertaking a review of accident data from urban centers around the world, including this case, to identify leading risks. Should this analysis identify suitable opportunities for possible standards to improve crash safety on buses, it could then be used to guide the implementation of a crashworthiness test program at the Motor Vehicle Test Center. If appropriate, guidelines for possible future standards could be prepared in consultation with stakeholders and published. If suitable opportunities for new standards are not identified during the process, a report on the analysis will be provided.

It is important to note that the United States does not currently have any structural crashworthiness standards in place for large commercial passenger buses. The United Nations vehicle safety regulations deal only with structural crashworthiness requirements during a bus roll over-type collision. Similar to the existing United States regulation, Canada expects to propose regulatory requirements for the installation of seat belts on many types of commercial buses. Any potential standard would only apply to new vehicles and as such would need to have a positive cost benefit analysis to be considered for a mandatory requirement.

March 2016: TSB assessment of the response (Satisfactory in Part)

TC has acknowledged this recommendation.

TC will conduct a review of accident data from urban centres around the world to evaluate the existing crashworthiness of commercial passenger buses. If the data analysis supports suitable opportunities for standards to improve crash safety on buses, TC indicates that the analysis could be used to guide the implementation of a crashworthiness test program, possibly leading to the development of guidelines for future standards in consultation with stakeholders.

The Board notes that TC will be examining accident data from around the world to identify leading risks for commercial passenger buses. Beyond this commitment, there are no explicit plans for the development and implementation of crashworthiness standards for commercial passenger buses to reduce the risk to passengers. Furthermore, no specific timeline has been provided for the planned review and analysis.

Therefore, the Board considers the response to Recommendation R15-02 to be **Satisfactory in Part**.

February 2017: response from Transport Canada

TC is conducting a literature review that is expected to be completed by spring 2017. The analysis will help guide any crashworthiness test program.

The crashworthiness test program is contingent on acquiring a bus shell, either in part or in whole. TC has searched extensively to acquire such a shell, but has not yet been successful. TC is in discussions with industry to explore an approach, where industry could provide structural expertise, fabrication of test bucks, modifications and oversight of testing as required. It is possible that this could include both commuter bus test bucks, as well as transit bus test bucks.

The test buck structure(s) will be incrementally modified (strengthened) and subjected to acceleration pulses. The effect of incrementally strengthening the structure will be evaluated with respect to unrestrained occupant protection. Following completion of the test matrix and analysis of the data, a report on the findings and next steps will be prepared.

The 3 year project is planned as follows:

- Year 1: Acquisition;
- Year 2: Construction/modification of sled buck preliminary testing; and
- Year 3: Test completion, data analysis, report preparation.

In addition, TC has issued a *Canada Gazette*, Part I publication to propose regulatory requirements for Electronic Stability Control on most truck tractors and buses with a Gross Vehicle Weight Rating (GVWR) greater than 11 793 kilograms (26 000 pounds). TC has received comments following the Part 1 publication and is now preparing the Part 2 submission.

TC is also preparing a *Canada Gazette*, Part I publication to propose regulatory requirements for the installation of seat belts on many types of commercial buses.

March 2017: TSB assessment of the response (Satisfactory Intent)

TC is conducting a literature review on bus crashworthiness that is expected to be completed by spring 2017. Following this literature review, TC will initiate a crashworthiness test program to be completed over 3 years. This project has been planned as follows:

- Year 1 – Acquisition of a bus shell (either in part or in whole).
- Year 2 - Construction/modification of sled buck preliminary testing.

- Year 3 - Test completion, data analysis, and report preparation.

In the short term, TC has initiated a number of regulatory changes that are aimed at improving the safety of bus passengers. These potential regulatory changes include

- the requirement to have electronic stability control on most truck tractors and buses with a gross vehicle weight rating (GVWR) greater than 11 793 kg (26 000 pounds); and
- the installation of seat belts on many types of commercial buses.

The Board notes that TC will be completing its literature review on bus crashworthiness shortly, and has initiated a number of regulatory changes to improve the safety of bus passengers. The Board looks forward to the initiation and completion of the crashworthiness test program, which will include a report on the findings and next steps.

The Board considers the response to Recommendation R15-02 to show **Satisfactory Intent**.

January 2018: response from Transport Canada

The literature review was completed in March 2017. The analysis will help guide any crashworthiness test program. The review has found that current literature focuses primarily on seat belts and compartmentalization in school buses. There is less research on the structural integrity of other types of buses (transit, intercity, motor coaches), particularly as it pertains to occupant protection.

TC has searched extensively to acquire a bus shell, but has not been successful. TC has had discussions with industry to explore an approach, where industry could provide structural expertise, fabrication of test bucks, modifications and oversight of testing as required. It is possible that this could include both commuter bus test bucks as well as transit bus test bucks. Test bucks would be used for repeated exploratory testing on a decelerative sled. Tender documents are being prepared to proceed with a competitive tender process, with a target to award a contract by the 4th quarter of 2018.

TC published a *Canada Gazette*, Part I, publication that proposed regulatory requirements for the installation of seat belts on many types of commercial buses. Issued in the *Canada Gazette*, Part I, on 18 March 2017. A *Canada Gazette*, Part II, is being prepared and publication is planned for 2018. It is expected that seat belts will improve bus occupant safety in severe bus collisions, especially in rollovers. In addition, introducing requirements for seat belts that are optionally installed on school buses would ensure that lap-only seat belts cannot be installed and that all seat belts that are optionally installed are installed correctly. In certain collisions, lap-only belts in school buses can increase injury risk compared to existing compartmentalization features.

An amendment to add section 136 – Electronic Stability Control (ESC) Systems for Heavy Vehicles, to the *Motor Vehicle Safety Regulations* was published in the *Canada Gazette*, Part II, on 14 June 2017. The standard requires mandatory fitting of ESC systems on most truck tractors and buses with a gross vehicle weight rating greater than 11,793 kilograms. As of December 2017, most new truck tractors will require ESC technology. Most school buses and inter-city

buses will follow in June 2018. While an ESC standard is not for crashworthiness, it is nevertheless an important safety measure for crash avoidance. Rollover and loss-of-control crashes involving heavy vehicles are a serious safety issue. Requiring ESC systems will help reduce the occurrence of rollovers and assist the driver in maintaining directional control of the vehicle during, for example, emergency maneuvers (swerving or braking to avoid an obstacle) or cornering on slippery surfaces. The buses targeted with this standard include motor coaches; which exhibited the majority of fatalities in collisions that ESC systems are capable of preventing. The Department is also requiring that ESC systems be required for school buses. This measure improves occupant safety by further reducing the potential for collisions involving school buses. Finally, the regulation is also applicable to a range of intercity buses.

March 2018: TSB assessment of the response (Satisfactory Intent)

The literature review on bus crashworthiness was completed in March 2017. The review indicated that research on the structural integrity of buses (transit, intercity, motor coaches) is limited, particularly as it pertains to occupant protection.

TC has continued to search for a bus shell, but has not been successful. With the possibility that a bus shell will not be available, TC had discussions with industry to explore an alternate approach. For this revised approach, industry would provide structural expertise, fabrication of test bucks, modifications to the test bucks, and oversight of testing as required. A competitive tender process has been initiated, with the contract to be awarded by late 2018.

TC reviewed its regulatory requirements relating to occupant protection on commercial buses and on school buses, resulting in the following proposed changes:

- In March 2017, TC published proposed regulatory requirements for the installation of seat belts on various types of commercial buses in the *Canada Gazette*, Part I. The *Canada Gazette*, Part II, publication is being prepared and is expected to be issued in 2018.
- In June 2017, an amendment to the *Motor Vehicle Safety Regulations* to add electronic stability control (ESC) systems on heavy vehicles was published in the *Canada Gazette*, Part II. Effective December 2017, most of the new truck tractors will be required to have the ESC technology. Starting June 2018, most of the new school buses and inter-city buses will also be required to have the ESC technology.

The Board is encouraged that TC has taken a leadership role in the assessment of bus crashworthiness, and that continued progress is being made. The Board is also encouraged that a number of changes have been proposed or implemented to the *Motor Vehicle Safety Regulations*, resulting in improved occupant safety for commercial buses and school buses.

The Board considers the response to Recommendation R15-02 to show **Satisfactory Intent**.

February 2019: response from Transport Canada

Statistics drawn from the National Collision Database show that human error (e.g. speeding, distracted driving, impaired driving) continues to be a major contributing factor in fatal collisions in Canada. In addition, statistics from the National Collision Database indicate that road users outside the bus (e.g. pedestrians, cyclists) are vulnerable to heavy vehicles, including transit buses. Based on this evidence, Transport Canada's efforts to improve commercial passenger bus safety extend beyond the structure of the bus, and recognizes that potential measures to strengthen the structure of the bus could have unintended, adverse impacts on crash avoidance and vulnerable road users. As such, Transport Canada is addressing the issue of crashworthiness as part of a comprehensive, multi-pronged approach to commercial passenger bus safety that includes measures to support: structural crashworthiness, crash avoidance, human factors (the driver), and road users outside the bus.

- **Structural crashworthiness:** In 2017, Transport Canada completed its review of accident data from urban centres to support the potential development of a standard for crashworthiness. Building on this review, the Department has worked with industry to develop a comprehensive research plan to examine new technologies to help protect bus passengers in the event of a collision. This includes working with bus manufacturers to develop appropriate and effective ways to enhance the safety of passengers in buses, and the acquisition of a highly specialized, custom-made test device, referred to as a test buck. The acquisition of the test buck is a multi-year and iterative process, given the complex design considerations, and the need to seek out qualified and available bidders through a competitive process. The department continues to work in collaboration with Public Services and Procurement Canada on options to contract this work, with a view to launching the competitive process in fall 2019. Results of these efforts would inform next steps for a possible crashworthiness standard.

  In July 2018, in order to improve bus occupant safety in severe collisions, Transport Canada published a final regulation mandating seat belts on commercial passenger buses (e.g. medium and large highway buses). This regulation includes technical requirements for the optional installation of seat belts on school buses.
- **Crash avoidance:** In June 2017, TC published a regulation to mandate electronic stability control in commercial passenger buses and heavy trucks. These control systems are an important crash avoidance technology that would improve driver control and help prevent rollovers. As of June 2018, commercial passenger buses over 14,969 kg (i.e. motor coaches, highway buses, school buses) must be equipped with electronic stability control. By August 1, 2019, this requirement extends to commercial passenger buses over 11,793 kg.
- **Human factors** (the driver): On January 21, 2019, the federal/provincial/territorial Council of Ministers Responsible for Transportation and Highway Safety agreed to develop a national standard for entry-level training for commercial drivers, including bus drivers, by January 2020. Transport Canada is exercising a leadership role with

respect to this standard, including bringing forward this proposal to the Council of Ministers, and working with provinces/territories to develop the national standard.

Transport Canada is also working with partners to finalize the publication of a regulation on electronic logging devices to help track the hours of commercial drivers (e.g. motor coach drivers) to reduce the risk of driver fatigue. It is anticipated that this regulation will be published in Canada Gazette Part II in Spring 2019.

In addition, the department continues to conduct ongoing assessments of emerging technologies to help mitigate the risk of driver error, such as advanced driver assist systems. This work complements *Transport Canada Guidelines to Limit Distraction from Visual Displays in Vehicles*, explained further in the Department's response to Recommendation R15-01, which provides evidence-based guidance to reduce driver distraction through the safe design, installation, and use of in-vehicle visual displays.

- **Road users outside the bus:** In parallel, recognizing pedestrians and cyclists outside the bus are statistically more vulnerable than those inside the bus, in August 2018, Transport Canada published a report, entitled *Safety Measures for Cyclists and Pedestrians around Heavy Vehicles*, that describes a series of safety measures to support jurisdictions in better protecting vulnerable road users (e.g. automated enforcement technologies, such as speed and red-light cameras; roadway and cycling infrastructure, such as segregated cycling tracks; and visibility and awareness measures, such as warnings in heavy trucks to detect nearby pedestrians). As part of this initiative, Transport Canada has also launched on-road field trials, in collaboration with municipal partners, to evaluate the effectiveness of enhanced detection/visibility systems on a range of commercial vehicles.

March 2019: TSB assessment of the response (Satisfactory in Part)

TC is addressing bus crashworthiness as part of a multi-pronged approach to commercial passenger bus safety that includes measures to support: structural crashworthiness, crash avoidance, human factors (the driver), and road users outside the bus.

In 2018, specific progress and observations were made in 4 areas:

- **Structural crashworthiness:** TC continued its work with bus manufacturers to develop a comprehensive research plan to examine new technologies to help protect bus passengers in the event of a collision. In collaboration with Public Services and Procurement Canada, TC expects to initiate a competitive process in Fall 2019 to acquire a highly specialized, custom-made test device, referred to as a test buck. Results of these efforts will inform next steps for a possible crashworthiness standard.

  In July 2018, to further improve bus occupant safety in severe collisions, TC published its regulation that mandates seat belts on commercial passenger buses. In addition, this regulation includes technical requirements for the optional installation of seat belts on school buses.
- **Crash avoidance:** In June 2018, the requirement for electronic stability control became mandatory for commercial passenger buses over 14 969 kg (i.e. motor coaches, highway

buses, school buses). In August 2019, the requirement for electronic stability control will be extended to commercial passenger buses between 11 793 kg and 14 969 kg.

- **Human factors** (the driver): In January 2019, the Council of Ministers Responsible for Transportation and Highway Safety agreed that a national standard for entry-level training for commercial drivers (including bus drivers) must be developed by January 2020. Working with the provinces/territories, TC has taken a leadership role to develop this national standard.

  TC is finalizing a regulation on electronic logging devices to track the hours of commercial drivers (e.g., motor coach drivers) to help reduce the risk of driver fatigue. This regulation is expected to be published in the *Canada Gazette*, Part II in Spring 2019. TC is also assessing emerging technologies that help mitigate the risk of driver error, such as advanced driver assist systems.
- **Road users outside the bus:** In August 2018, recognizing that pedestrians and cyclists outside the bus are statistically more vulnerable than those inside the bus, TC published a report, entitled *Safety Measures for Cyclists and Pedestrians around Heavy Vehicles*. The report identifies a series of safety measures to help protect vulnerable road users. As part of this initiative, TC has also launched on-road field trials to evaluate the effectiveness of enhanced detection/visibility systems on a range of commercial vehicles.

The Board acknowledges that continued progress is being made as part of TC's multi-pronged, comprehensive approach to commercial passenger bus safety. However, in light of the recent Humboldt and OC Transpo bus accidents, the Board is concerned by the apparent lack of urgency in TC's response. The Board believes that the structural crashworthiness assessment work, including the acquisition of a suitable test buck, must be significantly accelerated to allow for the timely development and implementation of crashworthiness standards for commercial passenger buses. The Board considers the response to Recommendation R15-02 to be **Satisfactory in Part**.

December 2019: response from Transport Canada

Transport Canada is strengthening commercial passenger bus safety through a multi-pronged approach that includes structural crashworthiness, crash avoidance, human factors (the driver), and protecting road users outside the bus.

- **Structural Crashworthiness**: Transport Canada is prioritizing bus safety through a research program to assess potential measures to better protect passengers. The Department has acquired two decommissioned transit buses and, beginning in summer 2019, undertook a series of full-scale crashworthiness tests as a preliminary investigation to assess how increasing the structural stiffness of a transit bus could influence occupant safety in the event of a collision. The goal of the test series was to examine the impacts of increasing structural rigidity on intrusion and potential occupant injuries. A matched pair of transit buses were chosen to reduce the influence of other vehicle design considerations while maintaining a vehicle-to-vehicle test

scenario, which provides a more realistic portrait of conditions encountered in a real-world collision. Matched pairs also expedited repeatability of the tests.

In July 2019, a transit bus-to-transit bus offset frontal crash test, at 40 kilometres per hour, was performed at Transport Canada's Motor Vehicle Test Centre to establish baseline results for occupant protection in a non-reinforced, original equipment manufacturer chassis. The target vehicle was loaded with several anthropomorphic test devices (ATDs – or "crash test dummies") to evaluate occupant protection.

A second test was conducted in October 2019, this time with a reinforced structure. Specifically, the structural stiffness of the chassis and vehicle frame was enhanced, with reinforcements added to the vehicle's A-pillar, front bumper, window frame and roof sections in order to increase the structural stiffness in the targeted frontal impact area. For repeatability, the crash configuration, speed, and ATD positioning were replicated to align with the first crash test.

Results are currently being evaluated. Preliminary findings from this crash configuration[3] suggest that increased structural rigidity could negatively impact occupant safety. Specifically, the stiffened structures may reduce the bus' attenuation of the impact, causing more force to be transferred to the bus occupants. In addition, the increased structural stiffness may also impact other key aspects of bus and road user safety, such as risks to other road users/vehicles involved in collisions with a "reinforced" bus, and bus manoeuverability.

These results are still under review (final results expected by March 2020), and efforts are also underway within Transport Canada to finalize the construction of a specialized sled test device – commonly referred to as a test buck – in December 2019. The acquisition of a test buck through a Request for Proposals (RFP) issued by the Department in June 2019 did not yield any bids. As such, Transport Canada's Motor Vehicle Test Centre initiated plans to construct the device internally, using the post-crash transit buses from the full scale testing. The test device will facilitate repeatable tests in support of ongoing occupant protection research efforts, with test buck validation occurring through March 2020, and the launch of a sled test program in April 2020.

This work complements Transport Canada's ongoing efforts to advance its multi-pronged approach to commercial passenger bus safety, including:

- **Crash avoidance**: As of August 2019, Transport Canada's regulation making electronic stability control mandatory in commercial passenger buses and heavy trucks is fully in force. Electronic stability control is an important crash avoidance technology that improves driver control and helps prevent rollovers. In June 2017, the Department

[3] By design, this research crash configuration is fundamentally different from the American Public Transportation Association (APTA) test protocols. Transport Canada's approach involved developing a crash test specifically intended to evaluate the effects of structural stiffening on the injury risk to occupants when a transit bus strikes another heavy vehicle (of similar weight and dimensions). In contrast, the APTA test standards relate to roof-crush testing, impact from a smaller light-duty passenger vehicle (4000 lbs), and a 2000 lb "static load" pressure test. As such, a comparison of the findings is not applicable.

published a regulation to mandate this technology. As of June 2018, this regulation came into force for commercial passenger buses over 14,969 kg (i.e. motor coaches, highway buses, school buses), and on August 01, 2019, the requirement extended to commercial passenger buses over 11,793 kg.

- **Human factors**: On June 13, 2019, Transport Canada amended section 77 (1) of the Commercial Vehicle Drivers Hours of Service Regulations, mandating the use of electronic logging devices to help track the hours of commercial drivers (e.g. motor coach drivers) to reduce the risk of fatigue-related collisions. Electronic logging devices replace paper-based daily logbooks to provide a more effective means to monitor compliance with the work-rest rules that mitigate the safety risk of driver fatigue.

  Consistent with the January 21, 2019 direction from the federal/provincial/territorial Council of Ministers Responsible for Transportation and Highway Safety, Transport Canada also continues to exercise leadership in working with provinces and territories to finalize a national standard for entry-level training for commercial drivers, including bus drivers. The standard, which will help ensure that commercial drivers have the necessary knowledge and skills to safely operate their vehicles, is on track for presentation to the Council of Ministers at their next meeting on February 14, 2020.

  In addition, the department continues to conduct ongoing assessments of emerging technologies to help mitigate the risk of driver error, such as advanced driver assist systems (e.g. automatic emergency braking).
- **Road users outside the bus**: Transport Canada is working with key partners toward the implementation of *Safety Measures for Cyclists and Pedestrians around Heavy Vehicles*, which describes a series of safety measures to support jurisdictions in better protecting vulnerable road users (e.g. automated enforcement technologies, roadway and cycling infrastructure, and visibility and awareness measures). Specifically, efforts are underway to evaluate jurisdictional pilot projects, including Transport Canada's on-road trial to examine the effectiveness of enhanced detection/visibility systems installed on a range of commercial vehicles (by March 2020), and develop a proposed critical path toward regulations to enhance vulnerable road user safety for the Council of Ministers' consideration at their next meeting in 2020.

March 2020: TSB assessment of the response (Satisfactory Intent)

TC is strengthening commercial passenger bus safety through a multi-pronged approach that includes structural crashworthiness, crash avoidance, human factors (the driver), and protecting road users outside the bus.

In 2019, specific progress was made in 4 areas:

- **Structural Crashworthiness**: TC acquired 2 decommissioned transit buses. A series of full-scale crashworthiness tests were undertaken to assess how structural stiffness of a transit bus affects occupant safety during a collision:

- In July 2019, an offset frontal crash test at 40 km/h involving the 2 transit buses was performed at TC's Motor Vehicle Test Centre. Baseline results were established for occupant protection in a non-reinforced, original equipment manufacturer chassis.
- In October 2019, a second test was conducted with a reinforced structure. The structural stiffness of the chassis and vehicle frame was enhanced with reinforcements to the A-pillar, front bumper, window frame and roof sections. The crash configuration, speed, and positioning of the anthropomorphic test devices (ATDs) were replicated to align with the first test.

Preliminary findings from this crash configuration suggest that increased structural rigidity could negatively affect occupant safety. By design, the crash configuration for TC's research is fundamentally different from the APTA test protocols. As such, a comparison of the findings against APTA standards is not applicable. The final results are expected by March 2020.

In addition, TC is finalizing the construction of a specialized sled test device (i.e., test buck). This test device is being constructed using the post-crash transit buses from the full-scale testing. The test device will facilitate repeatable tests in support of ongoing occupant protection research efforts. Validation of the test device will be completed by March 2020. The sled test program will be launched in April 2020.

- **Crash avoidance**: Electronic stability control is an important crash avoidance technology that improves driver control and helps prevent rollovers. In June 2017, the Department published a regulation to mandate this technology. As of June 2018, this regulation came into force for commercial passenger buses over 14 969 kg (i.e., motor coaches, highway buses, school buses). On 01 August 2019, the requirement extended to commercial passenger buses over 11 793 kg.
- **Human factors**: On 13 June 2019, TC amended section 77 (1) of the *Commercial Vehicle Drivers Hours of Service Regulations*, mandating the use of electronic logging devices to help track the hours of commercial drivers (e.g., motor coach drivers) to reduce the risk of fatigue-related collisions. Electronic logging devices will provide a more effective means to monitor compliance with the work-rest rules that mitigate the safety risk of driver fatigue.

  TC is working with provinces and territories to finalize a national standard for entry-level training for commercial drivers, including bus drivers. The standard will help ensure that commercial drivers have the necessary knowledge and skills to safely operate their vehicles. The draft standard was presented to the Council of Ministers on 14 February 2020.

  In addition, TC is continuing to assess emerging technologies, such as advanced driver assist systems, to help mitigate the risk of driver error.
- **Road users outside the bus**: TC is working with key partners toward the implementation of *Safety Measures for Cyclists and Pedestrians around Heavy Vehicles*. A number of pilot projects are being evaluated, including an on-road trial to examine the effectiveness of enhanced detection/visibility systems installed on a range of commercial vehicles.

The Board acknowledges that continued progress is being made as part of TC's multi-pronged, comprehensive approach to commercial passenger bus safety. The Board considers the response to Recommendation R15-02 to show **Satisfactory Intent**.

January 2021: response from Transport Canada

Since Transport Canada's last progress update (December 2019), the Department has taken concrete steps to implement its comprehensive, multi-pronged approach to commercial passenger bus safety, recognizing that efforts must extend beyond the structure of the bus. In particular, Transport Canada has continued to focus its efforts on four key areas, including: structural crashworthiness, crash avoidance, human factors (the driver), and road users outside the bus.

- **Structural crashworthiness:** On October 23, 2020, researchers at Transport Canada's Motor Vehicle Test Centre finalized a report on the findings from their 2019 crash test program designed to provide an evidence-based approach to improving occupant protection on transit buses.

  Two vehicle-to-vehicle tests were conducted to compare the performance of structurally reinforced buses to conventional buses. Test results found that, while structural strengthening reduced the severity of the impact on the driver, it negatively impacted occupant safety. More specifically, the structural strengthening added to the front end of the bus contributed to a slight increase in peak acceleration, which caused more force to be transferred to the bus occupants.

  Potential sources of injury included interior structures such as grab handles and seatbacks. Currently, there are no specific requirements designed to mitigate the risk of injury associated with contact on these hard structures. By comparison, in passenger vehicles, several regulations and technologies exist to reduce the force of contact with hard interior surfaces of the vehicle (e.g. energy-absorbing materials for sun visors and armrests).

  Building on these findings, the Motor Vehicle Test Centre constructed a specialized sled test device known as a sled buck to investigate potential safety countermeasures. The sled buck represents a section of a transit bus passenger compartment to allow for repeatable tests. The open frame design of the sled buck also optimizes high-speed video views that are critical for examining dummy responses in greater detail. Between March and July 2020, the Motor Vehicle Test Centre conducted 13 sled tests to verify whether dummy motions observed in the bus crash tests could be consistently reproduced by sled testing. Since the dummy motions between the bus crashes and the sled tests were similar, the results from this preliminary validation exercise indicate that the sled buck can be used as a reliable testing device for ongoing occupant protection research efforts. It was also found that crash pulse severity, dummy posture (e.g. reclined/upright), and seat placement were all found to influence the response of the dummies.

  The final report is now available online. Taking action on these findings, Transport Canada is working to identify an international forum mandated to work on issues

related to transit bus occupant protection, with a view to leading efforts among partners towards the development of occupant protection guidelines for transit buses. In addition, in support of continuous improvement and with a view to augmenting its research and testing capacity, Transport Canada continues to conduct crash tests with available decommissioned transit buses. Future sled tests will also include newer seat models with advanced occupant protection measures to investigate potential safety countermeasures.

It is also important to note that, in line with its commitment to improving bus occupant safety, Transport Canada's regulation mandating seat belts on medium and large highway buses (e.g. motor coaches) came into effect on September 1, 2020. As of this date, newly built highway buses will require seat belts in order to prevent passengers from being ejected in severe collisions (e.g. rollovers).

- **Crash avoidance**: Recognizing that crash avoidance is the key to saving lives, Transport Canada has adopted a future-ready approach to strengthening bus safety which includes research and testing, stakeholder engagement (including industry and the provinces/territories), and regulatory development. Taken together, these initiatives will ensure that Canadians can benefit from important advancements in crash avoidance technologies, while being secure in the knowledge that their well-being is protected. In keeping with this priority, Transport Canada has made great progress to support the development of safety standards and guidelines for advanced driver assistance systems (ADAS), including collision warning, automatic emergency braking (AEB), lane-keeping assist, and stability control. The Motor Vehicle Test Centre conducts between 2000 and 2500 crash avoidance tests each year to evaluate the degree to which these advanced vehicle technologies reduce the number and severity of collisions. Work is now underway to develop a regulatory package for these technologies, beginning with pre-publication on the Department's public consultations platform, Let's Talk Transportation on September 1, 2020. In particular, Transport Canada launched two public consultations seeking feedback on mandating ADAS and AEB technologies with proven safety benefits for all types of vehicles, including commercial passenger buses. Consultations ended on October 7, 2020 and Transport Canada is working to incorporate feedback into the development of policy options to inform the way forward for regulations, with a view towards publication in *Canada Gazette*, Part I in Spring 2022.
- **Human factors (the driver):** Together with the provinces and territories, Transport Canada exercised a leadership role to finalize a national entry-level training standard for commercial drivers which was approved by the Council of Ministers Responsible for Transportation and Highway Safety on February 14, 2020. Embedded in the National Safety Code for Motor Carriers, the standard will help ensure that commercial drivers have the necessary knowledge and skills to safely operate their vehicles.

  As described above, Transport Canada is continuing to explore the possibility of establishing new requirements under the Canada Motor Vehicle Safety Standards to support the development and implementation of ADAS and AEB technologies, which could improve commercial bus passenger safety by helping the driver with certain

elements of the driving task. Recognizing that human error continues to be a major contributing factor in fatal collisions in Canada, Transport Canada also conducts driving simulator research to help develop methods for evaluating the safety of driver interactions with these vehicle technologies. To complement these efforts, Transport Canada uses an eye-tracking system that measures how these vehicle technologies affect drivers' monitoring behaviour and patterns. Since the ADAS technologies presently available on the vehicle market require drivers to remain engaged and monitoring the road-traffic environment at all times, the combination of driving simulator and eye tracker data will help inform the development of standards and guidelines around the safe use of these new and emerging vehicle technologies.

In parallel, Transport Canada commissioned a public opinion research survey in January 2019 to better understand what Canadian drivers know about automated vehicle technologies (including ADAS and AEB) and how they learn about them. In the final report published in August 2019, results suggested that the public still remains largely unfamiliar with these technologies, and significantly concerned/skeptical about their use. Further, significant numbers of respondents were unable to identify the correct purpose of select ADAS features or appeared to confuse the difference between features that provide a warning signal to the driver versus those that assist with the driving task e.g. forward collision warning versus automatic emergency braking. The results of this study are applicable to all types of vehicles, reinforcing the need for training and informing the development of tools and resources to support the safe introduction of ADAS and AEB technologies on commercial passenger vehicles moving forward, similar to Transport Canada's Guidelines to Limit Distraction from Visual Displays in Vehicles. Building on these findings, Transport Canada intends to initiate a second study on consumer awareness and acceptance in 2021 in order to identify key areas of focus to keep pace with rapidly evolving vehicle technologies.

Transport Canada continues to spearhead efforts to implement the June 13, 2019 amendment to the *Commercial Vehicle Drivers Hours of Service Regulations*, mandating the use of electronic logging devices (ELDs) by June 2021, in order to help track the hours of commercial drivers (e.g. motor coach drivers) to reduce the risk of fatigue-related collisions. ELDs replace paper-based daily logbooks to provide a more effective means to monitor compliance with the work-rest rules that mitigate the safety risk of driver fatigue.

- **Road users outside the bus**: Statistics from the National Collision Database indicate that road users outside the bus (e.g. pedestrians, cyclists) are vulnerable to heavy vehicles, including transit buses, which is why Transport Canada continues to work with key partners toward the implementation of the Safety Measures for Cyclists and Pedestrians around Heavy Vehicles, which describes a series of safety measures to support jurisdictions in better protecting vulnerable road users (VRUs).

  At the February 14, 2020 meeting of the Council of Ministers Responsible for Transportation and Highway Safety, Ministers agreed to pursue measures to protect vulnerable road users, including advancing regulations in this area, and a commitment to ongoing research to strengthen the evidence base for new and emerging vehicle

technologies. Moving from guidance to action, Transport Canada has completed on-road field trials to evaluate the effectiveness of enhanced detection and visibility systems (e.g. 360° cameras and sensors) on a range of commercial vehicles. In parallel, Transport Canada continues to conduct the necessary research and testing required to inform the development of the ADAS and AEB regulatory packages, including under real world conditions (e.g. varying weather conditions). The results of this work will be published in early 2021. This work is complemented by research and testing taking place at our Motor Vehicle Test Centre under a wide range of winter weather and road conditions.

March 2021: TSB assessment of the response (Satisfactory in Part)

TC is strengthening commercial passenger bus safety through a multi-pronged approach that includes structural crashworthiness, crash avoidance, human factors (the driver), and protecting road users outside the bus.

In 2020, progress was made in 2 areas:

Structural crashworthiness:

- Researchers at TC's Motor Vehicle Test Centre finalized a report on the findings from their 2019 crash test program designed to provide an evidence-based approach to improving occupant protection on transit buses.
- The Motor Vehicle Test Centre conducted tests for occupant safety on a constructed specialized sled test device. Results are included in a final report.

Crash avoidance:

- TC supported the development of safety standards and guidelines for ADAS with a goal of publication in the *Canada Gazette*, Part I in spring 2022.

TC has also made progress in 2 additional areas for **human factors** and **road users outside the bus**. While these elements are not directly related to the safety deficiency identified in this recommendation, the Board notes these developments in commercial passenger bus safety.

The Board acknowledges that TC Road Safety has made some progress with regards to commercial passenger bus safety. The introduction of a new regulation mandating seat belts on medium and large highway buses (e.g. motor coaches) on 01 September 2020 is a step forward to improve the safety of passengers on newly built highway buses. However, there is no clear understanding of a path forward for improvements to the crashworthiness requirements for commercial passenger buses under the CMVSS indicated in the response. Additionally, there is no projected timeline for the development of occupant protection guidelines for commercial passenger buses. The Board considers the response to Recommendation R15-02 to be **Satisfactory in Part**.

November 2021: response from Transport Canada

Transit buses are one of the safest means of transportation in Canada, since they are much heavier than light duty vehicles with low floors that typically contact light duty vehicle bumper systems in the event of a collision. In addition, transit buses are driven by trained, professional drivers, on planned or dedicated transit routes, typically at low speeds with frequent stops. To illustrate the level of protection afforded by transit buses, between 2015 and 2019 the average fatalities per year of transit bus occupants in Canada was 0.4 (or 0.02% of road fatalities). In fact, the greatest risk to the safety of passengers is outside the bus, either from the bus itself or from surrounding traffic, with 90% of fatalities involving transit buses being attributed to occupants of other vehicles or vulnerable road users.

Over the past three years, Transport Canada's transit occupant protection research program has focused on the performance of structurally reinforced transit buses. Building on the "Interim Report: Transit Bus Research",[4] ongoing crashworthiness testing conducted at Transport Canada's Motor Vehicle Test Centre does not point to the need for standard setting at this time. In fact, the current scientific evidence suggests that, while structural strengthening may reduce the severity of the impact on the driver, it negatively impacts occupant safety.

These findings also align with the current U.S. approach to crashworthiness standards for commercial passenger buses. In its original recommendation to Transport Canada, the Transportation Safety Board referenced a 1999 report and recommendations from the U.S. National Transportation Safety Board (NTSB) to the U.S. National Highway Traffic Safety Administration (NHTSA) which noted a lack of crashworthiness standards governing large buses, such as motor coach (highway) or transit buses. To address the NTSB recommendations, NHTSA published a Final Rule on occupant protection systems and several notices of proposed rule making (NPRMs) which propose requirements for ejection prevention and roof strength (with Final Rules expected by early next year). It is important to note that NHTSA has specifically excluded transit buses from these requirements, focusing instead on motor coaches and other large buses. Transport Canada has already adopted the Final Rule changes on occupant protection systems,[5] and has extended the applicability of these requirements to smaller passenger buses. Moving forward, Transport Canada will continue to closely monitor and review the Final Rules for these standards to ensure alignment and harmonization with NHTSA requirements for commercial passenger buses, consistent with the *Canada-United States Security and Prosperity Partnership* to reduce regulatory differences and facilitate international trade while maintaining high levels of safety.

For these reasons combined, Transport Canada has concluded that there is no clear path for incorporating structural crashworthiness standards for transit buses into the *Canada Motor*

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4 https://tcdocs.ingeniumcanada.org/sites/default/files/2020-12/Transit%20Bus%20Research%20-%20Interim%20Report.pdf (last accessed 04 January 2023).

5 https://canadagazette.gc.ca/rp-pr/p2/2018/2018-07-11/html/sor-dors143-2-eng.html (last accessed 04 January 2023).

Vehicle Safety Standards at this time. Transport Canada is instead focusing on the development of evidence-based occupant protection guidelines combined with efforts that extend beyond the structure of the bus. At the same time, Transport Canada is committed to working towards *Vision Zero* – zero fatalities, zero injuries – on Canada's roads in keeping with *Canada's Road Safety Strategy 2025* and is continuously looking for ways to improve road safety, including in the context of commercial passenger buses. In keeping with this objective, Transport Canada continues to make great progress on its comprehensive, multi-pronged approach to commercial passenger bus safety that includes measures to support: structural crashworthiness, crash avoidance, human factors (the driver), and road users outside the bus. Ultimately, these activities will help maintain public trust in Canada's transit transportation system in a manner that is transparent, evidence-based, and entrenched in a commitment to safeguarding passengers.

Structural Crashworthiness:

Transport Canada continues to conduct crashworthiness research to strengthen the evidence base and inform decision-making. Since the publication of the "Interim Report: Transit Bus Research" in December 2020, Transport Canada has conducted two further transit bus crash tests and acquired three additional 40-foot single-deck transit buses. Two of these vehicles will be used for a third and fourth test scheduled to take place in winter 2022. In addition, an extensive program of sled testing employing a test buck has been underway to investigate potential safety countermeasures and inform occupant protection research efforts. These tests have been complemented by finite element modelling in partnership with the University of Waterloo to validate real-world kinematic and kinetic responses and address the limitations of the crash test dummies. Taken together, the occupant protection research program can now identify likely sources of injury and the factors that can affect the severity of injury. As a result, investigations into alternative seat designs are underway to examine how certain seat features (such as geometry or materials) may improve the protection of passengers.

In order to respond to these evidence-based transit bus safety risks and target resources to address the most vulnerable aspects of transit bus design, Transport Canada is moving forward with the development of occupant protection guidelines to establish recommendations for manufacturers and operators on aspects of bus design and improve the safety of passengers and other road users. This work will be supported by the scientific evidence produced by the crashworthiness research program. In particular, the Department will produce an initial report by summer 2022, which will provide a description of the injury mechanisms, propose preliminary countermeasures, and recommend evaluation test methods for industry. This will be followed by engagement and consultation with key stakeholders (early fall 2022), including the presentation of results at technical fora, with a view to formalizing the report's recommendations in the form of guidelines published on Transport Canada's website by late fall 2022. Since global research on occupant protection is constantly evolving, these guidelines will remain evergreen, and may be updated based on future research efforts and ongoing stakeholder engagement.

Crash Avoidance:

Transport Canada continues to evaluate technologies that have the potential to reduce the likelihood or severity of collisions that result in transit user injuries or fatalities, including advanced driver assistance systems (ADAS). Recognizing that integration of ADAS technologies into newly manufactured transit bus operations remains at a nascent stage globally, ongoing research will serve as a benchmark to establish their performance in these types of vehicles, while addressing questions about their efficacy in Canadian transit applications.

In support of this objective, Transport Canada is planning to undertake track-testing of several aftermarket ADAS technologies on standard 40-foot transit buses throughout Spring/Summer 2022, using controlled repeatable testing methodologies. By January 2023, Transport Canada plans to synthesize results from its ADAS testing into an accessible guide for Canadian transit authorities – specifically to provide practical advice, guidance and recommendations on the deployment, operation and maintenance of ADAS technologies in Canada. This would be published on the Transport Canada website, and periodically updated as new research findings are generated.

In parallel, Transport Canada is exploring the benefit of replacing rear-view mirrors with camera monitoring systems as means of reducing blind spots, including in transit buses. Traditionally, large side mirrors have been found to create blind spots ahead of the vehicle thereby impeding the detection of vulnerable road users. Camera monitoring systems have evolved significantly over the past few years to the point where mirrors are no longer needed. As a result, Transport Canada has begun issuing exemptions from *Canada Motor Vehicle Safety Standards* requirements on a case-by-case basis to companies who wish to install cameras instead of mirrors, provided they meet certain safety conditions. The safe design, installation, and use of these camera systems is informed by Transport Canada's Guidelines to Limit Distraction from Visual Displays in Vehicles.[6]

Human Factors (the driver):

Distracted driving continues to be a major contributing factor to collisions in Canada and internationally. In order to limit driver distraction resulting from new vehicle technologies or mitigate its consequences, Transport Canada is conducting research that will inform national and international standards and regulations for motor vehicle safety. More specifically, Transport Canada is examining driver distraction in the context of automation and is contributing to international discussions at the United Nations Economic Commission for Europe on the types of distracting tasks that may still be unsafe in an automated vehicle. The Department's latest research efforts focus on assessing the human factors design of the human-machine interfaces on ADAS technologies available in Canada, which will inform ongoing standards development with the International Organization for Standardization for methods to

6 https://tc.canada.ca/en/road-transportation/stay-safe-when-driving/transport-canada-guidelines-limit-distraction-visual-displays-vehicles (last accessed 04 January 2023).

assess driver state and driver monitoring technology. The Department also continues to assess the performance of automated emergency braking (AEB) systems that may help to avoid or reduce the consequences of distraction.

Road users outside the bus:

As part of its assessment of ADAS performance for transit buses, the department has begun a preliminary review of collision investigation cases involving city buses to identify the types of incidents involving vulnerable road users, in order to assess whether ADAS technologies could have contributed to reducing the probability or severity of the incident. Findings will help characterize the type of collisions that ADAS can potentially mitigate and prioritize testing of systems and scenarios that provide the most benefits by design.

At the same time, TC will continue to evaluate emerging vehicle technologies in the context of reducing collisions between heavy vehicles (including transit buses) and pedestrians, including AEB and pedestrian AEB, in combination with passive technologies like Forward Collision Warning, Pedestrian/cyclist warning, lane support warning, blind spot cameras, and direct visibility.

March 2022: TSB assessment of the response (Satisfactory in Part)

TC is strengthening commercial passenger bus safety through a multi-pronged approach that includes structural crashworthiness, crash avoidance, human factors, and protecting road users outside the bus. However, TC has stated that, at this time, there is no clear path for incorporating structural crashworthiness standards for transit buses into the CMVSS.

Structural crashworthiness:

- TC's research indicated that structural strengthening negatively affects transit bus occupant safety and that there is no clear path for incorporating structural crashworthiness standards for transit buses into the CMVSS at this time.
- TC is continuing crashworthiness research using newly acquired 40-foot single-deck transit buses and occupant protection research using a purpose-built sled buck testing platform. Investigations into safety countermeasures that may improve the protection of passengers are underway with a report planned for summer 2022 and guidelines to be published in fall 2022.

Crash avoidance:

- TC continues research to reduce the likelihood or severity of collisions that result in transit user injuries or fatalities and will conduct track testing of ADAS technologies.
- TC plans to create a guide for Canadian transit authorities by January 2023 to provide practical advice, guidance and recommendations on the deployment, operation and maintenance of ADAS technologies in Canada.
- There is no mention of a previous goal of publication of ADAS guidelines in the *Canada Gazette*, Part I in spring 2022.

TC has also made progress in 2 additional areas for human factors and road users outside the bus. While these elements are not directly related to the safety deficiency identified in this recommendation, the Board notes these developments in commercial passenger bus safety.

The Board acknowledges that TC Road Safety has made some progress with regards to commercial passenger bus safety. However, ongoing TC research suggests that standard setting for structural crashworthiness is not needed at this time. As such, the Board notes that there is no plan for improvements to the crashworthiness requirements for transit buses under the CMVSS. TC has instead refocussed on occupant protection guidelines, which are projected to be published in fall 2022. Therefore, the Board considers the response to Recommendation R15-02 to be **Satisfactory in Part**.

December 2022: response from Transport Canada

Since Transport Canada's last progress update (November 2021), the Department continues to take concrete steps to implement its comprehensive, multi-pronged approach to commercial passenger bus safety, recognizing that efforts must extend beyond the structure of the bus. In particular, Transport Canada focused its efforts on four key areas, including: structural crashworthiness, crash avoidance, human factors (the driver), and road users outside the bus.[7]

Structural Crashworthiness:

Transport Canada completed a multi-year transit bus crashworthiness program in Fall 2022. The final report is available online.[8] Three approaches were used to examine the effects of structural stiffness and energy management on the protection of transit bus occupants during frontal crashes. First, five (5) full-scale transit bus crash tests were conducted. Of these, two pairs were configured to provide a direct comparison of an unmodified bus to one that had the front-left corner (or driver side) strengthened.

Second, a sled buck representing a section of a transit bus passenger compartment was constructed so that, through controlled sled testing, crash test dummy responses could be examined.

Finally, sled data was used by the University of Waterloo to develop and validate a finite element model to compare the simulated motions of the human body model to the physical dummies.

To our knowledge, Transport Canada is the only organization to have conducted testing of this type. Results are expected to contribute significantly to the body of evidence available and to the advancement of transit bus safety.

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7 All responses are those of the stakeholders to the TSB in written communications and are reproduced in full. The TSB corrects typographical errors in the material it reproduces without indication but uses brackets [ ] to show other changes or to show that part of the response was omitted because it was not pertinent.

8 https://tcdocs.ingeniumcanada.org/sites/default/files/2022-12/Transit%20Bus%20Research.pdf

As a result of the department's research efforts in this area, Transport Canada has concluded that it would not be prudent (advisable) to incorporate structural crashworthiness standards for transit buses into the *Canada Motor Vehicle Safety Standards* due to the potential for negative impacts on occupant safety. These findings align with the current United States approach to crashworthiness standards for commercial passenger buses.

The research has demonstrated that there are opportunities to improve the protection of occupants in low-to-moderate severity transit bus collisions. Based on research results and available literature, a source of potential injury on-board the bus appears to be interior structures such as grab handles and seatbacks. Further study is required in this context, as knowledge gaps remain as to the potential impacts on occupants. As a result, additional scientific work will be required in order to adapt existing measurement tools to the bus environment, including crash test dummies. Advancing new standards or guidelines in the absence of appropriate measurement tools could inadvertently increase harm.

The design and fabrication of the transit bus test buck is an important step in the development of a tool to conduct standardized tests and to aid in the development of numerical models. To advance work in this area, the Transport Canada transit bus test buck design will be made available to researchers to encourage experimentation, advance knowledge about the efficacy of safety countermeasures and improve commercial bus passenger protection.

Additionally, Transport Canada plans to submit and present its collective research findings to industry, through a peer-reviewed publication process in Fall 2023, to advance publicly available knowledge about transit bus occupant protection, solicit expert feedback on key findings, and support the development of guidance related to enhanced occupant protection in transit buses that will be published on Transport Canada's website by Spring 2024.

Crash Avoidance:

The National Research Council (NRC) is conducting a review for Transport Canada on the latest available evidence from the scientific literature on the safety risks associated with transit vehicle operation to identify general countermeasures and in particular, opportunities for new and emerging crash avoidance technologies (e.g. automatic emergency braking, blind spot warning, intelligent speed assistance). A summary of the findings, including lessons learned to guide Canadian transit authorities on the potential safety benefits of crash avoidance technologies for commercial passenger buses, is scheduled for early 2023.

Human Factors & Road Users Outside the Bus:

Transport Canada continues to be committed to advancing work in the areas of human factors and vulnerable road users (VRU) safety on an ongoing basis as technology evolves. For example, the safety performance of commercially available enhanced VRU detection/visibility systems were evaluated on the track at Transport Canada's Motor Vehicle Test Center in Fall 2022 using scenarios based on case studies of the most significant risks from real-world transit bus collisions identified by Transport Canada's multidisciplinary crash investigation team. In the

area of human factors, the department is also conducting research on the safety potential of driver monitoring technology to measure driver performance and detect risks (e.g. distraction and drowsiness).

March 2023: TSB assessment of the response (Unable to assess)

Transport Canada (TC) completed its multi-year transit bus crashworthiness program and published the final report[9] at the end of 2022. As a result of the department's research, TC has concluded that it would not be prudent to incorporate structural crashworthiness standards for transit buses into the *Canada Motor Vehicle Safety Standards* due to the potential for negative impacts on occupant safety. These findings align with the current United States approach to crashworthiness standards for commercial passenger buses.

TC has instead refocussed its efforts on occupant protection. TC's research has demonstrated that there are opportunities to improve the protection of occupants in low-to-moderate severity transit bus collisions. However, further study is required and additional scientific work is needed to adapt existing measurement tools to the bus environment, including crash test dummies. TC indicates that advancing new standards or guidelines in the absence of appropriate measurement tools could inadvertently result in negative impacts on occupant safety.

As a next step, TC will make its transit test buck design available to researchers to encourage experimentation and advance knowledge. TC also plans to submit and present its collective research findings to industry through a peer-reviewed publication process in Fall 2023. These efforts will support the development of guidance related to enhanced occupant protection in transit buses; it is expected that the guidance will be published on TC's website by Spring 2024.

In addition, TC continues to take steps to implement its comprehensive, multi-pronged approach to commercial passenger bus safety and, in this context, has made further progress in the areas of crash avoidance, human factors, and road users outside the bus.

The Board recognizes TC's efforts toward improving overall commercial passenger bus safety and is pleased that TC's research on bus crashworthiness will contribute significantly to the body of evidence available and to the advancement of transit bus safety. The Board notes that TC continues to progress research and development in the area of occupant protection and is planning to publish a guidance document by the spring of 2024. However, beyond this future guidance document, there is an absence of specificity and timing with respect to action that will reduce the risk of injury to occupants of commercial passenger buses in the event of a collision. Therefore, the Board is **unable to assess** the response to Recommendation R15-02.

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9 Transport Canada, *Final Report : Transit Bus Research*, 24 November 2022, available at https://tcdocs.ingeniumcanada.org/sites/default/files/2022-12/Transit%20Bus%20Research.pdf (last accessed 25 January 2023).

Latest response and assessment

January 2024: response from Transport Canada

Transport Canada would like to emphasize that transit buses are one of the safest means of transportation in Canada, attributing to 0.04% of road fatalities (and 0.10% of serious injuries), with 90% of these fatalities involving occupants of other vehicles or vulnerable road users (VRUs). Despite the safety record for transit buses in Canada, Transport Canada undertook significant research activities to address the Transportation Safety Board's recommendations on crashworthiness standards. In parallel, Transport Canada continues to take concrete steps to implement a comprehensive, multi-pronged approach to transit bus safety, recognizing that efforts must extend beyond the structure of the bus. In particular, Transport Canada has focused its efforts on four key areas, including: structural crashworthiness, crash avoidance, human factors (the driver), and road users outside the bus.

Structural crashworthiness

Transport Canada's transit bus crashworthiness program examined the effects of structural stiffness and energy management on the protection of transit bus drivers and passengers during frontal crashes. Since the completion of this multi-year research program, the results of this ground breaking research were peer-reviewed and published at the International Research Council on Biomechanics of Injury (IRCOBI) in September 2023,[10,11] solidifying Canada's leadership role in this space and further informing safety improvements and guidance for transit bus design across the international. These findings concluded that, while the addition of structural reinforcement to the front of the bus could mitigate certain injury responses for the driver, current crash test dummy technologies were not sufficiently representative of humans to adequately determine injury mechanisms for the passengers seated in the transit bus. Physical crash test dummy responses for all five crash tests performed suggest that several interior structures such as grab handles and seatbacks could be a source of injury for occupants, even in a low to moderate collision.

Before guidelines or regulations can be proposed, tools like digital dummies and human body models need to be developed to ensure the potential for injury can be predicted through repeatable crashworthiness testing. In the absence of these tools, and a robust evidence base, attempts to implement such requirements could be challenging. The development of this evidence base represents significant effort.

As a next step, Transport Canada will establish a collaborative graduate research program with the University of Waterloo to introduce the use of the Human Body Model as a tool to evaluate occupant protection. Moving forward, Transport Canada will conduct a scan of compatible research initiatives with international partners to identify opportunities for collaboration. This

[10] https://www.ircobi.org/wordpress/downloads/irc23/pdf-files/2359.pdf

[11] https://www.ircobi.org/wordpress/downloads/irc23/pdf-files/2357.pdf

includes the latest research conducted by the United Kingdom's Transport Research Laboratory for the London Transit Authority in support of Vision Zero for London (zero deaths in, or by, a London bus by 2030).

Crash avoidance

Crash avoidance is the key to saving lives in the context of road transportation, with crash avoidance technologies estimated to reduce 80% of fatalities attributable to driver error. With this in mind, Transport Canada believes that its crash avoidance work will lead to an overall reduction in residual risk for all road users, including transit buses.

In 2023, the National Research Council performed a comprehensive literature review for Transport Canada, focusing on crash avoidance measures for transit bus safety, which was published in May 2023[12]. The literature review aimed to investigate inherent risks and available countermeasures, as well as identify potential safety benefits of crash avoidance technologies. Specifically, it included a scan of collision statistics and incident reports from Canada, the United States (US), and internationally, which underscored the heightened frequency of collisions between buses and VRUs relative to other incidents. The most common transit bus collisions with VRUs occurred during left turns at intersections, attributed to obstructed views, driver distractions, and pedestrians' inattentiveness. The review summarized the potential for emerging technologies such as crash avoidance systems to mitigate these types of accidents, in combination with infrastructure upgrades and driver training.

Moving forward at the international level, there is an increasing focus on the integration of crash avoidance technologies within the transit bus sector to prevent fatalities and serious injuries. In keeping with this objective, Transport Canada worked with the University of Warwick on a study on the qualification of virtual testing tools for Automated Driving Systems (ADS). Virtual testing can be used to verify and validate ADS safety in addition to traditional track and real-world testing, and has advantages over these traditional testing methodologies such as providing the ability to expose the ADS to challenging driving scenarios safely. For simulation results to be trusted as part of the safety case of an ADS, it is essential to prove that the simulation results are representative of the real world, thus validating the simulation platform itself.

Building on the virtual testing project, in 2023 Transport Canada also initiated research work on safety critical driving scenarios for validating ADS, which will examine how scenario generation methodologies for all vehicle types can be adapted and applied to Canada's driving environment using Canadian data sources. Results from this research will lead to the development of a catalogue of scenarios specific to the Canadian driving environment and will inform the ongoing development of guidance, including globally aligned regulations for validating ADS safety through Transport Canada's work at the World Forum for Harmonization

[12] https://tc.canada.ca/en/road-transportation/research-testing-vehicles-child-car-seats/research-publications#wb-auto-13 [available on request]

of Vehicle Regulations (WP.29). This foundational work is required before regulations to require ADS technologies on new transit buses can be developed.

Human factors and road users outside the bus

Transport Canada undertook a research project to examine the issue of drivers' visibility in transit buses, as well as the interaction between VRUs and large vehicles, to improve the likelihood of detecting VRUs and reduce the risk of injuries and fatalities. The research focused on developing methods to quantify driver "blind spots" and the ability of transit buses to detect pedestrians and cyclists, with the objective of developing new digital 3D tools to enable the benchmarking of visibility in a wide selection of vehicles. This included creating field of view diagrams, defining distortion zone limits, measuring object size in the display, qualitative assessment of image distortion using a single-plane checkerboard pattern, qualitative assessment of image distortion using simple and complex shape targets, and evaluating visibility in darkness. The results of this research were presented at the June 2023 meeting of the Canadian Association of Road Safety Professionals and highlighted the importance of including image quality measurements in a complete safety assessment of existing surround view camera systems. In addition to blind zone definition and object size requirements, evaluating geometric distortion can help identify potential safety risks and guide improvements in camera system and display design. Moving forward, findings from this research suggest the need for improved digital processing algorithms and camera characteristics to reduce distortion and mitigate collisions with VRUs.

Transport Canada also contributed a chapter on the federal approach to fatigue management in the 2023 publication of the *Handbook of Fatigue Management in Transportation: Waking Up to the Challenge*, which contains 40 chapters from leading international experts. The department presented the chapter at the Annual Conference of the Human Factors and Ergonomic Society, Washington, D.C. in October 2023.

Conclusion

Taken together, the comprehensive program undertaken by Transport Canada is creating the conditions under which the very small risk of injury and death associated with transit bus collisions can be further reduced. It is expected that as collision avoidance technologies mature and are integrated into transit buses they will reduce the number of collisions overall, thereby protecting passengers inside the bus and those outside the bus from injury and death.

February 2024: TSB assessment of the response (Satisfactory in Part)

Transport Canada (TC) indicated that it undertook multi-year research activities to address the TSB recommendation on crashworthiness standards for commercial passenger buses. TC has concluded that there is no clear path to safely develop crashworthiness standards. Therefore, TC continued to take steps to implement a comprehensive, multi-pronged approach to transit bus safety, stating that efforts to address the risk of injury to passengers and road users must

extend beyond the structure of the bus. In particular, TC focused on 4 key areas: structural crashworthiness, crash avoidance, human factors (the driver), and road users outside the bus.

For structural crashworthiness, TC examined the effects of structural stiffness and energy management on the protection of transit bus drivers and passengers during frontal crashes. The results of this research were published at the International Research Council on Biomechanics of Injury (IRCOBI) in September 2023. It was concluded that, while the addition of structural reinforcement to the front of the bus could mitigate certain injury responses for the driver, current crash test dummy technologies were not sufficiently representative of humans to adequately determine injury mechanisms for the passengers seated in the transit bus. TC indicated that, before guidelines or regulations can be proposed, tools like digital dummies and human body models need to be developed to ensure the potential for injury can be predicted through repeatable crashworthiness testing. TC will establish a collaborative graduate research program with the University of Waterloo to introduce the use of the human body model as a tool to evaluate occupant protection, and will conduct a scan of compatible research initiatives with international partners to identify opportunities for collaboration.

As for crash avoidance, TC believes that its crash avoidance work will lead to an overall reduction in residual risk for all road users, including transit buses. In May 2023, a comprehensive literature review focusing on crash avoidance measures for transit buses was published by National Research Council Canada for TC. The review summarized the potential for emerging technologies such as crash avoidance systems to mitigate these types of accidents, in combination with infrastructure upgrades and driver training. At the international level, there is an increasing focus on the integration of crash avoidance technologies within the transit bus sector to prevent fatalities and serious injuries. TC worked with the University of Warwick on a study on the qualification of virtual testing tools for automated driving systems (ADS). In 2023, TC also initiated research on safety-critical driving scenarios for validating ADS, which will examine how scenario generation methodologies for all vehicle types can be adapted and applied to Canada's driving environment using Canadian data sources. At the end of this research, a catalogue of scenarios specific to the Canadian driving environment will be developed. According to TC, this work is required before regulations can be developed to require ADS technologies on new transit buses.

Concerning human factors and road users outside the bus, TC undertook a research project focused on developing methods to quantify driver "blind spots" and the ability of transit buses to detect pedestrians and cyclists. The results of this research were presented at the June 2023 meeting of the Canadian Association of Road Safety Professionals and highlighted the importance of including image quality measurements in a complete safety assessment of existing surround view camera systems. TC also contributed a chapter on the federal approach to fatigue management in the 2023 publication of the *Handbook of Fatigue Management in Transportation: Waking Up to the Challenge*. In October 2023, TC presented the chapter at the Annual Conference of the Human Factors and Ergonomic Society in Washington, D.C.

TC believes that its comprehensive program is creating the conditions to further reduce the low risk of injury and death associated with transit bus collisions. TC also expects that the collision

avoidance technologies, once mature and integrated into transit buses, will reduce the number of collisions overall, thereby protecting passengers inside the bus and those outside the bus from injury and death.

The Board recognizes TC's efforts toward improving overall commercial passenger bus safety. While TC has indicated that it will not pursue the development of crashworthiness standards, the Board is encouraged with TC's plan to develop a comprehensive multi-pronged approach to transit bus safety that is expected to contribute to further reducing the risk of injury and death associated with transit bus collisions. The Board considers the response to Recommendation R15-02 to be **Satisfactory in Part**.

File status

The TSB will monitor the initiatives TC is planning to take and the work to continue researching ADS technologies for potential future implementation on new transit buses. Given the timelines associated with such complex research and the drafting and implementation of any possible resultant safety measures, the Board will periodically review TC's progress in the future.

This deficiency file is **Dormant**.