Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada

RAILWAY INVESTIGATION REPORT R13T0192

CROSSING COLLISION

VIA RAIL CANADA INC. PASSENGER TRAIN NO. 51
OC TRANSPO DOUBLE-DECKER BUS NO. 8017
MILE 3.30, SMITHS FALLS SUBDIVISION
OTTAWA, ONTARIO
18 SEPTEMBER 2013

Canada

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Ottawa, Ontario
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Summary

On 18 September 2013, at about 0832 Eastern Daylight Time, westward VIA Rail Canada Inc. (VIA) passenger train No. 51 departed from the VIA Ottawa Station on time and proceeded en route to Toronto. 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.

Le présent rapport est également disponible en français.

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1.0 Factual information

OC Transpo is the municipal transit authority for the City of Ottawa, Ontario (the City), with a daily ridership of approximately 375 000 passengers. It provides transit services to the nearly one million people who live in the Ottawa area. OC Transpo maintains a dedicated 2-lane Transitway system (Transitway) for buses that run throughout Ottawa. The Transitway includes a number of OC Transpo stops and several “Park & Ride” terminals near the outskirts of the City. The Transitway is considered a private roadway with use restricted to OC Transpo and City emergency vehicles. In September 2013, OC Transpo‘s bus fleet of 937 buses comprised the following:

- Alexander Dennis Limited (ADL)[1] E500 42-foot-long double-decker buses built in 2012 / 2013 (75 buses);
- New Flyer D60LFR 60-foot-long articulated buses built between 2010 and 2011 (306 buses);
- New Flyer D60LF 60-foot-long articulated buses built between 2008 and 2010 (53 buses);
- Orion VII Hybrid 40-foot-long buses built in 2008 and 2009 (177 buses); and
- New Flyer Invero D40i 40-foot-long buses built between 2003 and 2007 (326 buses).

VIA Rail Canada Inc. (VIA) operates up to 503 trains weekly on 7767 miles (12 500 km) of track and serves 450 communities across the country. VIA carries an average of 4 million customers annually on its fleet of 396 passenger cars and 73 road locomotives. It operates 159 passenger stations, 4 maintenance facilities, and employs about 2600 people. While most of the track infrastructure VIA uses is owned and managed by freight railway companies, VIA does own 139 miles (223 km) of track, which includes the Smiths Falls Subdivision that traverses the west end of the City.

VIA passenger train No. 51 (VIA 51) operates daily (Monday to Friday) westward from Montréal, Quebec, to Toronto, Ontario, via Ottawa (Figure 1).

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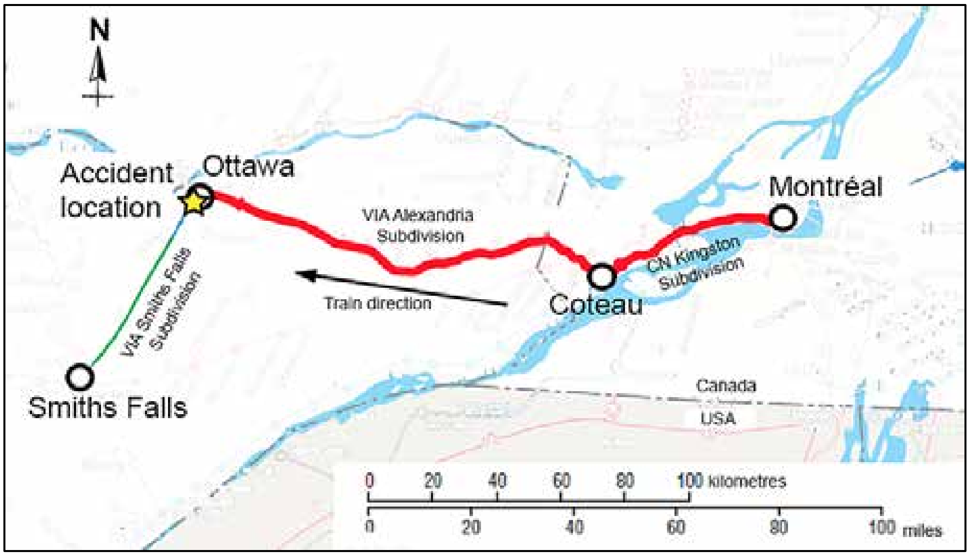
1 See Appendix M for abbreviations and acronyms.

Figure 1. Accident location (Source: Railway Association of Canada, *Canadian Railway Atlas*, with TSB annotations)



On 18 September 2013, VIA 51 was powered by a single General Electric (GE) Genesis locomotive, model EPa42 (VIA 915). The locomotive was located at the head end of the train. It was not equipped with an on-board forward-facing video camera, nor was it required to be. The remainder of the train was composed of 4 Light, Rapid, Comfortable (LRC) passenger cars (VIA 3455, VIA 3308, VIA 3331 and VIA 3353). The train weighed 312 tons and was 410 feet long. The rolling stock was in good condition. The train was last inspected at VIA's Montréal Central Station (Gare Centrale) on 18 September 2013, with no defects noted.

The train was operated by 2 qualified locomotive engineers located in the locomotive cab. The operating locomotive engineer (LE) was positioned at the controls on the right side of the locomotive cab while the in–charge locomotive engineer (ICLE) was positioned on the left side of the cab. The ICLE performed the duties of conductor. The LE and ICLE were both qualified for their positions and met fitness and rest standards. Each crew member had over 15 years of experience on the territory. VIA 51 was staffed by 4 VIA on-train service personnel and was transporting 108 passengers.

1.1 The accident

1.1.1 The train journey

On 18 September 2013, the train departed from the VIA Ottawa Station on time at 0831:57.[2, 3] The train's next stop was VIA Fallowfield Station, located at the west end of Ottawa at Mile 3.57 of the VIA Smiths Falls Subdivision. Prior to arriving at VIA Fallowfield Station,

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2 All times are Eastern Daylight Time, unless otherwise indicated.

3 Locomotive event recorder data are summarized in Appendix A.

westbound trains must pass through the level grade crossings at Woodroffe Avenue and the Transitway, located at Mile 3.28 and Mile 3.30 respectively.

As the train approached the crossings, its headlights were on full power and the ditch lights were illuminated. At 0847:13, approximately 1 mile (1.6 km) east of the crossings, the train was proceeding at 80 mph (128.7 km/h). In preparation for the stop at the VIA Fallowfield Station, the LE applied the locomotive dynamic brake as well as the train service brakes and began to slow the train. As the crossings were subject to a whistle ban between the hours of 2000 and 1200 (noon), the train horn was not sounded on the approach to the crossings.

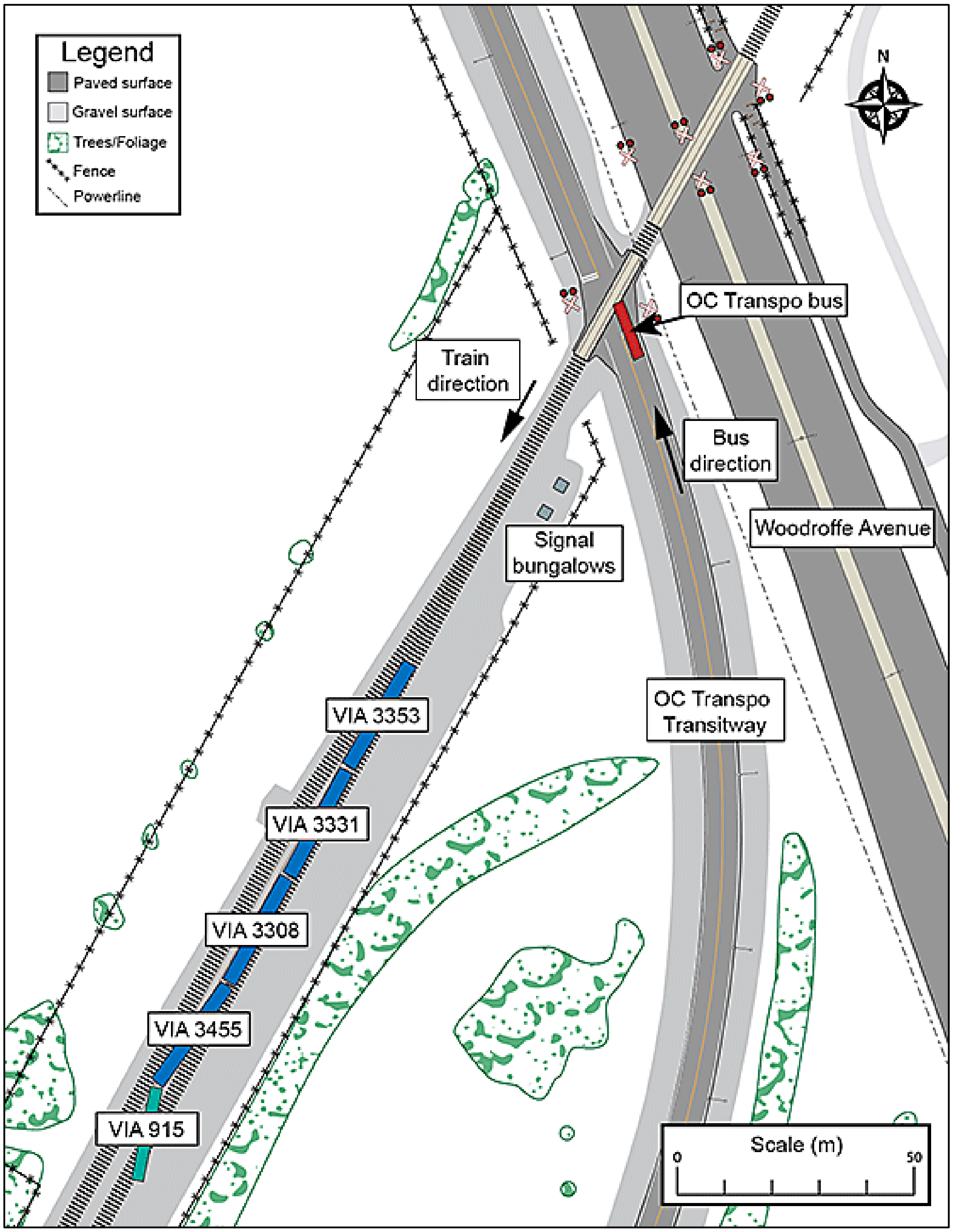
Prior to entering the crossings, the ICLE called the approach signal and began to document what the signal displayed. The LE was occupied with the task of slowing the train. The crew members first noticed the bus travelling northward toward the crossing when the train was approximately 600 feet (183 m) from the crossing. The crossing protection (i.e. lights, bells and gates) for both crossings were activated as required. Shortly thereafter, the train crew realized that the bus would not be able to stop in advance of the crossing.

At 0848:04, with the train travelling at 47 mph (75.6 km/h), the LE initiated emergency braking.

At 0848:06, with the train travelling at 43 mph (69.2 km/h), the bus collided with the left (south) side of the locomotive cab.

The train subsequently derailed and the locomotive came to a stop approximately 690 feet (210 m) west of the Transitway crossing, just east of the VIA Fallowfield Station (Figure 2).

Figure 2. Site diagram



1.1.2 *The bus journey*

The OC Transpo bus driver (the driver) worked as a regular spare. The driver would work different bus routes each day based on a 2-week schedule provided in advance. As a regular spare, the driver would primarily work "express" routes and work a split shift each workday. Split shifts comprised 2 distinct work periods, one during the 0600–0900 morning commute and the second during the 1500–1800 afternoon commute.

Generally, express routes operate from an OC Transpo garage to a City suburb, where passengers are picked up before proceeding downtown. A driver will typically work 2 or 3 of these routes per shift. Express routes generally operate on time, as there are not as many bus stops compared to regular routes. Drivers can get behind schedule when picking up passengers in a suburban area, but not normally to the extent that they would be concerned that they may miss the start time of their next route. A large part of an express route is typically operated on the Transitway between the suburbs and downtown Ottawa.

On the morning of the accident, the driver awoke just after 0500. At the Industrial Road OC Transpo garage, the driver picked up OC Transpo bus 8017, an ADL E500 double-decker bus. Departing from the garage at 0607, the bus deadheaded[4] to Orléans, a suburb in the east end of Ottawa.

At 0622, the driver started operating express route 35 from Orléans toward downtown Ottawa. At 0759, express route 35 terminated at the Lincoln Fields transit station. The bus then deadheaded toward Barrhaven, a suburb in the south end of Ottawa, and the bus route number was changed to express route 76. At 0828, from the intersection of Cobble Hill Road and Maravista Road, the driver started operating express route 76 and proceeded toward downtown Ottawa. The driver had driven express route 76 a total of 9 times in the previous 12 months.

At 0846:24,[5] arriving at the OC Transpo Fallowfield Station, the bus stopped just east of the south-side bus shelter at the stop sign. Passengers exited the bus and other passengers entered the bus from the front and side doors. A commuting cyclist loaded a bike onto the bike rack at the front of the bus.

At 0846:53, the side door of the bus was closed. Passengers, including the cyclist, continued to board the bus using the front door.

The driver asked a group of 3 or 4 passengers standing at the front of the bus to stand behind the yellow line on the floor. With the bus still stationary, the driver looked at the bus video monitor, located on a forward panel above the driver station and to the left of the driver seat. The video monitor display (6 inches [15.2 cm] wide by 3¾ inches [9.5 cm] high) was divided into 4 quadrants, each measuring 3 inches (7.6 cm) wide by 1⅞ inches (5 cm) high. Each quadrant displayed a view from 1 of 4 on-board video cameras. The bottom right quadrant displayed a rearward-facing view from the front of the upper deck.

The driver announced to the passengers that there were still seats available on the upper deck.[6] A passenger accessed the upper deck, but did not see any available seats. Since there

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4 Deadheading is defined as driving an empty bus to a location to commence or end a work shift.

5 The events were recorded from various sources including the train, the crossing signals, the bus and video cameras at the OC Transpo Fallowfield Station. Some event times for activities that occurred on board the bus have been approximated based on various witness accounts of what transpired. Event times have been normalized to coincide with the locomotive event recorder.

6 The upper deck of the bus had a seating capacity of 55 while the lower deck had a seating capacity of 27.

was no room below and the passenger knew that it would be difficult to reach the upper grab bars on the lower deck, the passenger remained on the upper deck, standing near the top of the stairs while holding on to a pole. A conversation ensued between the driver and the cyclist, who was standing on the lower deck near the driver, regarding seating availability on the upper deck.

Upon completion of passenger loading, the seating on the lower deck was full and there were at least 13 standing passengers, while the upper deck had 1 empty seat and 1 standing passenger.

At 0847:27, the bus departed from the OC Transpo Fallowfield Station, about 4 minutes behind the scheduled departure time. The bus immediately accessed the Transitway and continued northward.

Conversations ensued between some passengers standing near the front of the bus on the lower deck. The conversations focused on availability of seating on the upper deck and whether it was safe to go upstairs while the bus was moving. Passengers who were standing near the cyclist repositioned themselves, allowing the cyclist to move toward the front of the bus to monitor the bicycle.

At about 0847:57, the driver was busy negotiating the left–hand curve ahead as some passengers continued to look for seating and conversations continued. During this period, the driver looked upward and to the left toward the video monitor.

At 0847:59, the bus passed the point at which all of the red flashing lights at the Transitway crossing would have been fully visible, about 402 feet (122.5 m) from the south crossing gate.

At 0848:02, the bus was travelling at 42 mph[7] (67.6 km / h) with throttle (gas pedal) on. At about this time, some passengers on both decks began to shout “stop stop” and “look out”. Shortly thereafter, the driver released the throttle (gas pedal), refocused attention to the road ahead and began to apply the bus brakes.

At 0848:04, the bus had reduced speed to 35 mph (56.3 km / h) and, at 0848:05, the speed had further reduced to 25 mph (40.2 km / h) with no throttle on and the brakes applied.

At 0848:06, the bus speed had reduced to 4.8 mph (7.7 km / h) with no throttle on and the brakes applied as the bus collided with the south side of the train.

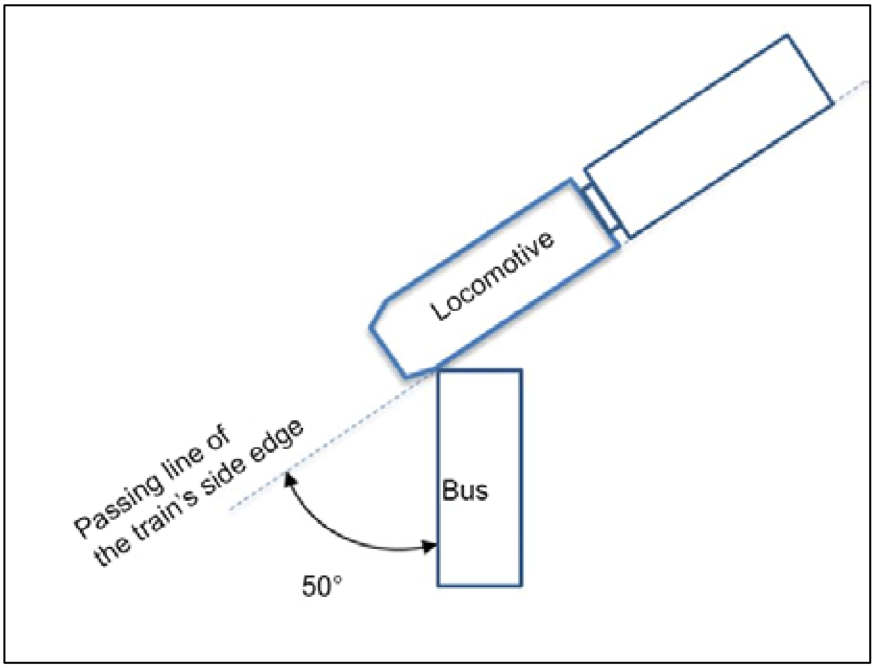
Shortly after the accident, 2 OC Transpo buses (a 60-foot-long articulated bus and a 40-foot-long single bus) stopped behind the occurrence bus at the crossing. A number of passengers from the trailing buses exited to assist.

[7] The bus engine control module records in miles per hour.

1.2 Site examination

At the railway crossing, the Transitway crosses the track at a 50-degree angle. The relative orientation of the bus and the locomotive just prior to impact is depicted in Figure 3.

Figure 3. Orientation of the bus and train just prior to impact



1.2.1 Bus examination

The front of the bus body was collapsed and torn off. The bus debris primarily came to rest on the west side of the roadway and along the railway right-of-way for about 100 feet (30.5 m) down the track in the direction of train movement.

The right side wall of the bus had little damage, except for the panel located above the front door, which was bent to the left, in the direction of train movement. The right front corner pillar, which serves as the foremost vertical beam for the front door frame, was deformed and disconnected from the chassis at its lower end. Most of the front dome glazing (window) was missing, except for a small portion hanging from the right top corner. The remaining glazing was about 30 inches (76 cm) wide at the bottom. The contour of the remaining glazing was consistent with that of VIA 915's bodywork (Photo 1), as this was the last portion of the bus that contacted the train.

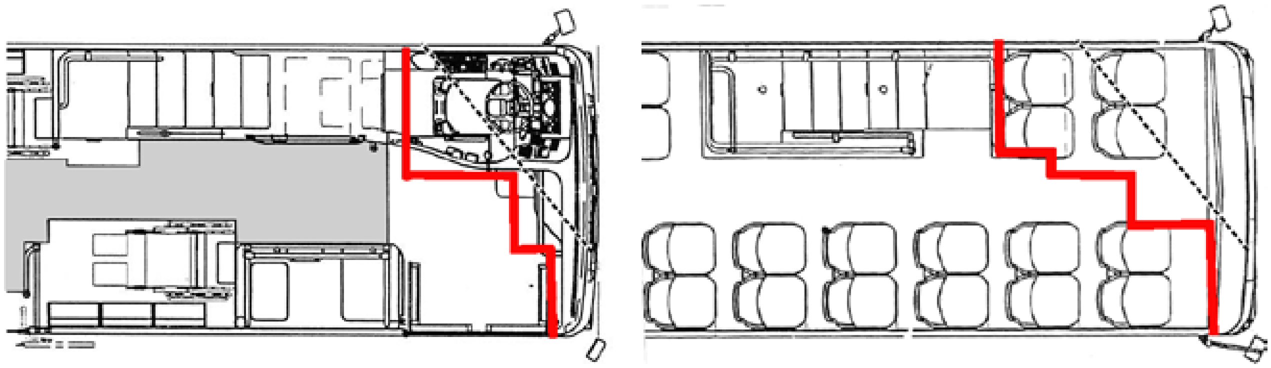
Photo 1. Right side view of the bus (the dotted line represents contour of locomotive VIA 915)

Photo 2. Front view of the bus

The front portion of the chassis was deformed to the left. The lower and upper front-end framing had separated from the bus and were found adjacent to the main wreckage. The remainder of the separated front structure was extensively broken up (Photo 2).

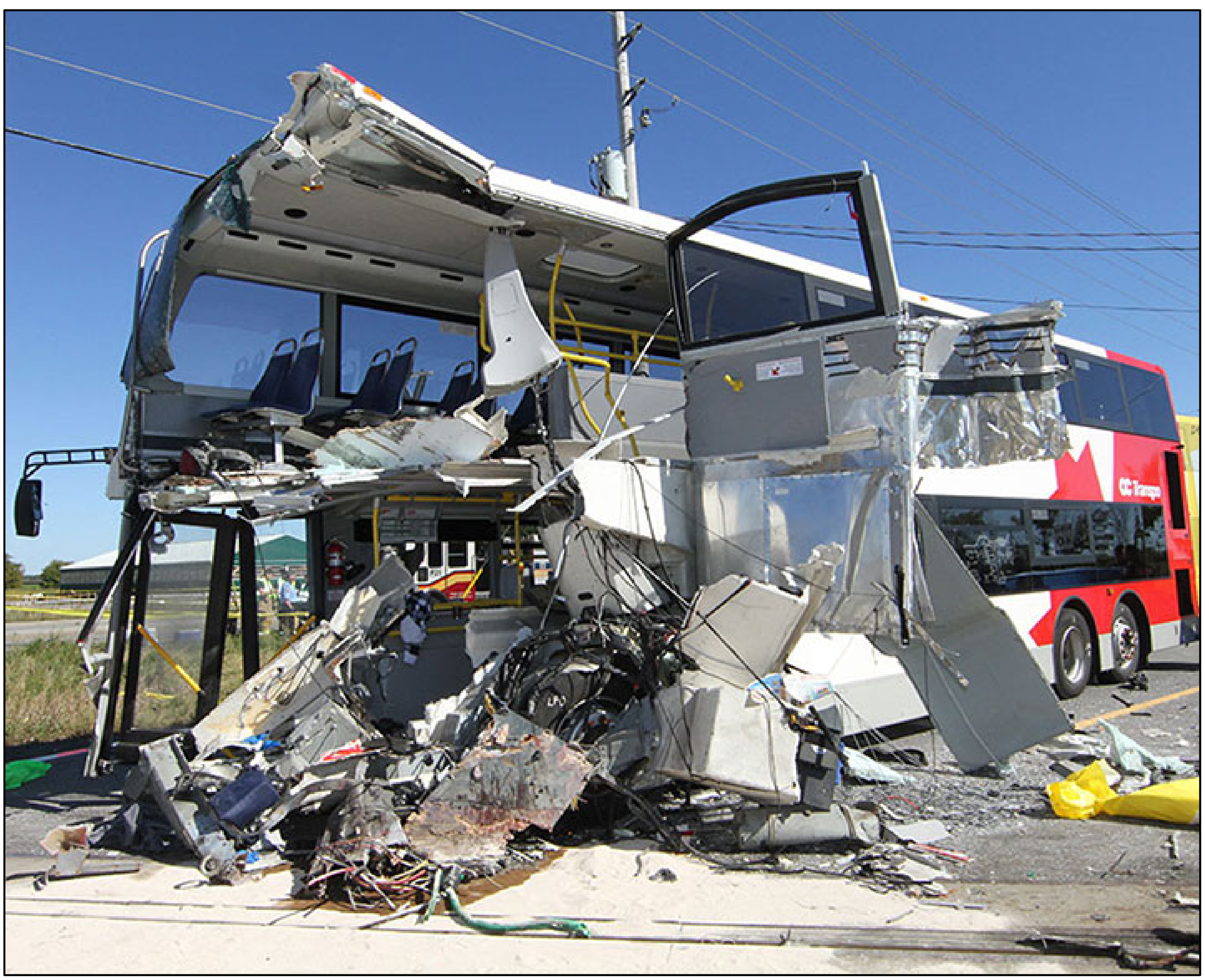
The driver's seat and the 4 seats on the 2 foremost rows of passenger seats on the left side of the upper deck were torn from the bus along with their supporting floor structure (Figure 4), coming to rest on the adjacent roadway west of the bus. The frame of these passenger seats had no significant damage, as the seats had not been directly struck by the train, nor did the impact with the ground exceed the seat design strength.

Figure 4. Schematics illustrating floor separation (lower deck on left; upper deck on right). The solid lines outline the boundary of floor separation. The dotted lines show the estimated line of train movement.



A portion of the left side wall of the bus (approximately 10 feet [3 m] long), containing the 2 foremost panels of the upper and lower decks, had separated from the left front corner of the bus and was bent toward the left (Photo 3). The left front corner pillar was missing. The left front corner of the roof was deformed upward. The foremost left side wall at the lower deck (below the driver's side window) had separated completely.

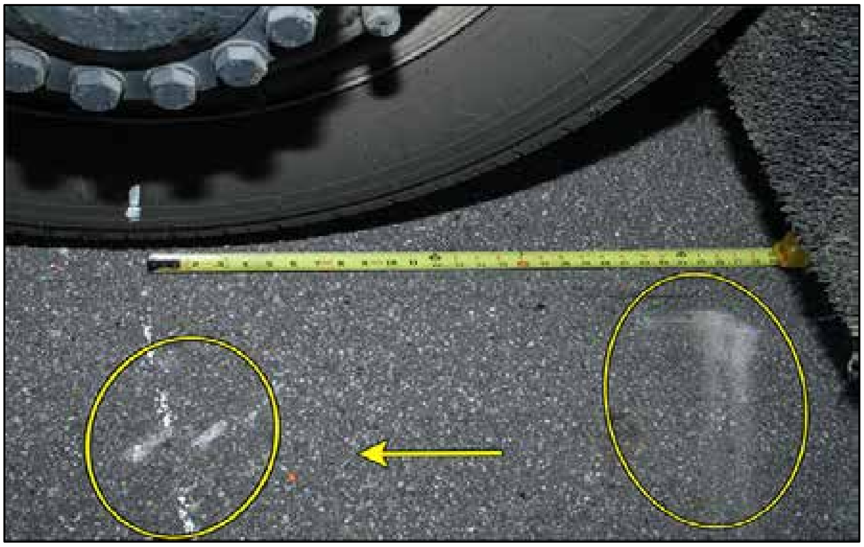
Photo 3. Left side of OC Transpo double-decker bus 8017



Although the stairwell within the bus was damaged, passengers on the upper deck were able to use it to evacuate.

Short skid marks (about 3 inches (7.6 cm] long) were present on the Transitway extending southward under the rear tires of the bus (Photo 4).

Photo 4. Skid marks on Transitway under rear drive tires



The bus was examined in situ. The bus batteries were disconnected to preserve any data that may have been recorded on various electronic modules. The memory card was removed from the Intelligent Vehicle Network (IVN).

The tires were marked to identify their location on the pavement, and then removed so that the treads and brake components could be examined in detail. All wheels were replaced with substitute wheels prior to transporting the bus to a secure facility for further detailed examination.

1.2.2 Train and track damage

VIA 915 (Photo 5) and all 4 passenger cars derailed, but remained upright.

No impact marks were present on the front of VIA 915's hood. The left side of VIA 915's short hood exhibited a vertical dent consistent with the contour of the left front corner of the bus, as the bus left front corner was just inside the line of movement of VIA 915 when the collision occurred.

The bottom portion of VIA 915's diagonal sheeting that transitions from the front to the side of the locomotive[8] was made of ¼-inch-thick (6.4 mm) steel with a 1.5-inch (38.1 mm) flange along the trailing edge secured to the frame by a gusset. There were signs of impact at this location, but there were no dents or deformation (Photo 5).

8 This area is referred to as the "skirt behind the pilot" or snow plow on the front of the locomotive.

Photo 5. Damage on locomotive VIA 915

Horizontal lines of denting and scoring extended on the left side of VIA 915's bodywork and onto the first 20 feet (6.1 m) of the first passenger car (VIA 3455), as the bus had kept moving forward after the initial impact until it stopped. There was shallow denting along the body side sheets of VIA 915, but the frame of VIA 915 was not deformed.

The bottom portion of the skirt behind the pilot of VIA 915 was 20 inches (51 cm) above the ground level at the point of collision. The side panel was 44 inches (112 cm) above the ground. The chassis of the ADL E500 bus, which was about 17 inches (43 cm) above ground level, had passed beneath the bottom portion of the skirt behind the pilot and side panel of VIA 915.

Impact marks were present on the left rear truck of VIA 915, just behind the underframe-mounted battery box (Photo 6). The battery box had separated. The electrical wiring providing power to VIA 915 was severed, and the locomotive event recorder (LER) had stopped recording. The rear truck of VIA 915 had derailed to the north side of the rails, on the crossing.

Photo 6. Impact mark on locomotive VIA 915's rear truck side frame (arrow) and separated battery box

The south crossing gate had broken away. Train wheel flange marks were present, extending westward from near the middle of the Transitway to past the west end (Photo 7) of the crossing. From that point, wheel impact marks were observed on the track ties and ballast extending westward from the crossing onto the diverging VIA siding located just north of and adjacent to the main track.

Photo 7. Looking eastward from the west end of the crossing, train wheel flange marks were observed from the middle of the crossing extending westward

VIA 915 and the first passenger car (VIA 3455) had jackknifed and came to rest straddling the main and siding tracks. The front truck of VIA 915, the rear truck of VIA 3455 and the 3 other passenger cars came to rest on the main track. The rear truck of VIA 915 and front truck of VIA 3455 came to rest on the siding track. The locomotive and passenger car trucks sustained various degrees of damage as a result of the derailment.

The main and siding tracks were displaced by the jackknifed equipment (Photo 8), as the track gauge had spread and rail on both tracks had rolled to the field side.

Photo 8. Westward view of derailed cars and displaced track

Track damage was present on both the main and siding tracks extending westward for about 600 feet (183 m) from the east end of the siding. The combined track damage for the main track and the siding track was about 1200 feet (365.8 m). The main track No. 12 turnout containing the east-end siding switch was also damaged.

1.3 Injuries

On the VIA train, there were no injuries to crew members or passengers. Among the bus occupants, there were 6 fatalities, 9 serious injuries[9] and about 25 minor injuries. The location of the bus occupants who sustained fatal and serious injuries is depicted in Figure 5.

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[9] *TSB Regulations* define "serious injury" as

(a) a fracture of any bone, except simple fractures of fingers, toes or the nose;

(b) lacerations that cause severe hemorrhage or nerve, muscle or tendon damage;

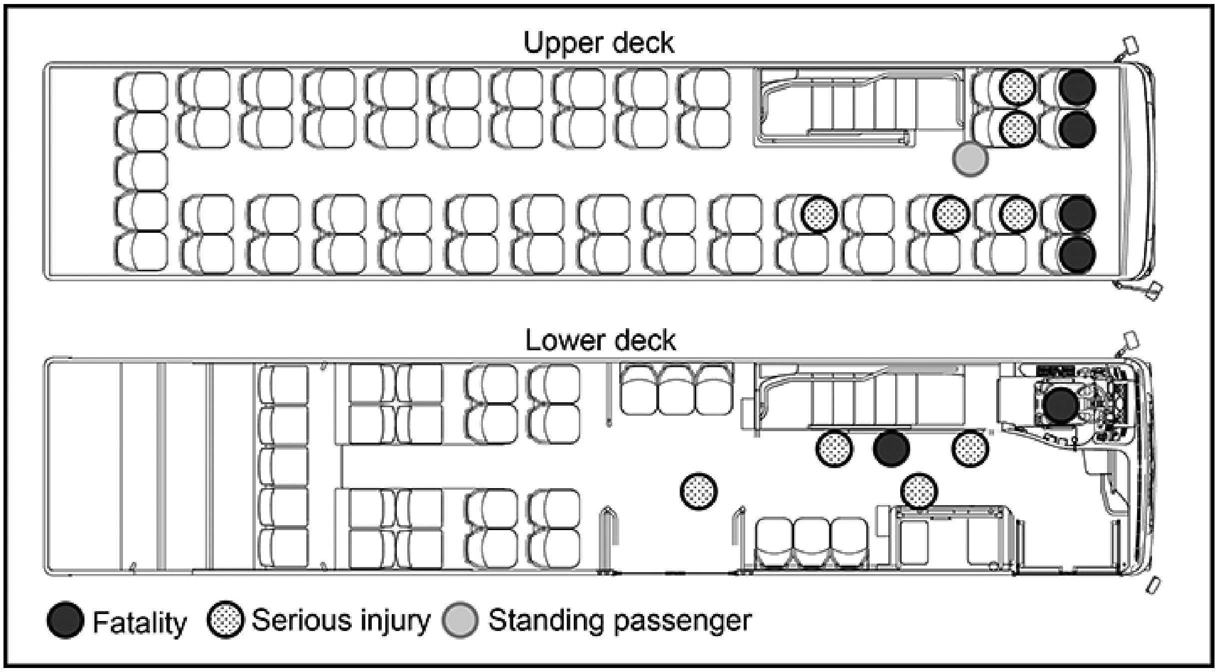
(c) an injury to an internal organ;

(d) second or third degree burns, or any burns affecting more than 5% of the body surface;

(e) a verified exposure to infectious substances or injurious radiation; or

(f) an injury that is likely to require hospitalization.

Figure 5. Double-decker bus layout with location of occupants who sustained fatal and serious injuries



The driver and the 4 passengers seated in the first row of the upper deck were ejected from the bus and sustained fatal injuries. An additional passenger on the lower deck was thrown to the front of the bus and later succumbed to fatal injuries.

Four passengers seated in rows 2 and 3 of the upper deck were also ejected from the bus. These 4 passengers and a 5th passenger in the 5th row of the upper deck as well as 4 passengers on the lower deck sustained serious injuries.

During the accident, many of the other passengers were ejected from or fell out of their seats. A total of 34 passengers were transported to hospital for various injuries.

The most common injuries included bruises, lacerations, broken bones and head, neck, shoulder, back and leg injuries. The injuries were primarily sustained by passengers being ejected from the bus, falling out of a seat, falling from a standing position, being struck by another passenger, being struck by other items or a combination of these. Seat restraints are not provided for transit buses, nor are they required by regulations.

1.4 Weather

At the time of the accident, it was sunny with clear visibility and the temperature was 14°C. The sun was positioned about 70 degrees southeast of the crossing at an elevation of 21 degrees.

1.5 Emergency response

The City maintains an Emergency Management Plan, which is based on an all-hazard and multi-departmental approach. The plan is designed to be used by all City services during planned and unplanned events. Each City service has a function to fulfill under the plan. Each City service also develops its own supporting emergency plan and corresponding response capability.

The City services responded immediately and coordinated their activities in accordance with the established emergency plans. About 350 personnel representing over 30 City departments, federal agencies, VIA staff and sub-contractors attended the site.

Following the accident, the City activated its Emergency Operations Centre. At 0926, senior management at the City and the City Council were notified of the accident. They were also updated on response activities as the information became available. As the response continued, the Emergency Operations Centre received information reports from the Traffic Incident Management Group, the Paramedic Service Command Centre, the Police Service Mobile Command, and OC Transpo.

1.5.1 Ottawa Police Service

Starting at 0848, the Ottawa Police Service (OPS) and Emergency Medical Services received numerous 911 calls regarding a collision involving an OC Transpo double-decker bus and a VIA passenger train at the Transitway crossing, adjacent to Woodroffe Avenue, near Fallowfield Road. Callers indicated that there were a number of injuries and possible fatalities. The OPS immediately dispatched patrol officers and a duty inspector. The Ottawa Fire Services and Ottawa Paramedic Service were also immediately notified and dispatched.

At 0851, the first police patrol officer arrived on scene. Initially, police officers assisted with first aid, maintained the safety of responders and secured ingress and egress routes for emergency vehicles. As these initial priorities were addressed, other emergency responders arrived and were directed toward establishing police perimeters, directing traffic and locating witnesses. Close proximity to the scene was initially hindered by vehicles blocking access to the Transitway. The OPS subsequently removed vehicles to allow site access to paramedic vehicles.

At 0940, a unified command was established to coordinate the emergency responder activities at the site. At 0957, the OPS command post arrived. Formal situation report meetings were established and maintained for the duration of the event. The OPS controlled and preserved the site and surrounding area until the site activities were completed at 1330 on 20 September 2013. During the response, about 200 OPS officers attended to various site tasks.

1.5.2 Ottawa Fire Services

At 0855, the Ottawa Fire Services arrived on site and assumed Incident Command. A Mass Casualty Incident was declared. Information on the number of injured passengers was gathered and disseminated. The Incident Commander surveyed the bus and spoke with VIA personnel to assess the condition of the train passengers and crew. The train was confirmed to be stable and locked in place. Ottawa Fire Services crews were assigned to assist paramedics with triage and first aid. Additional personnel were deployed as they arrived. The Ottawa Fire Services had a total of 46 personnel on scene throughout the response.

1.5.3 Ottawa Paramedic Service

Twenty paramedic units (40 paramedics in total) were dispatched to the accident site. At 0856, the first paramedics arrived on site and immediately commenced with on-site triage, assessment, treatment and transport of patients.

The most severely injured bus passengers were triaged and rapidly transported to local hospitals that had been notified in advance of the potential for casualties. By 0920, the most seriously injured passengers were transported to hospital. By 1050, the casualties had been removed from the site and transported to area hospitals. Over the course of the response, the paramedics had assessed and transported 34 patients and identified 5 fatalities.

1.6 Subdivision and track information

Prior to 2010, VIA owned a portion of the Smiths Falls Subdivision. In 2010, VIA purchased the remainder of the Smiths Falls Subdivision from Canadian National (CN). Following the purchase, VIA completed extensive infrastructure upgrades, which included equipping all public crossings with automatic warning device (AWD) protection that included flashing light-emitting diode (LED) lights (upgraded from incandescent), bells, gates and constant warning time (CWT) track circuits. As VIA does not have its own maintenance forces, RailTerm and other contractors were sub-contracted to maintain its signal system and track infrastructure on the Smiths Falls Subdivision.

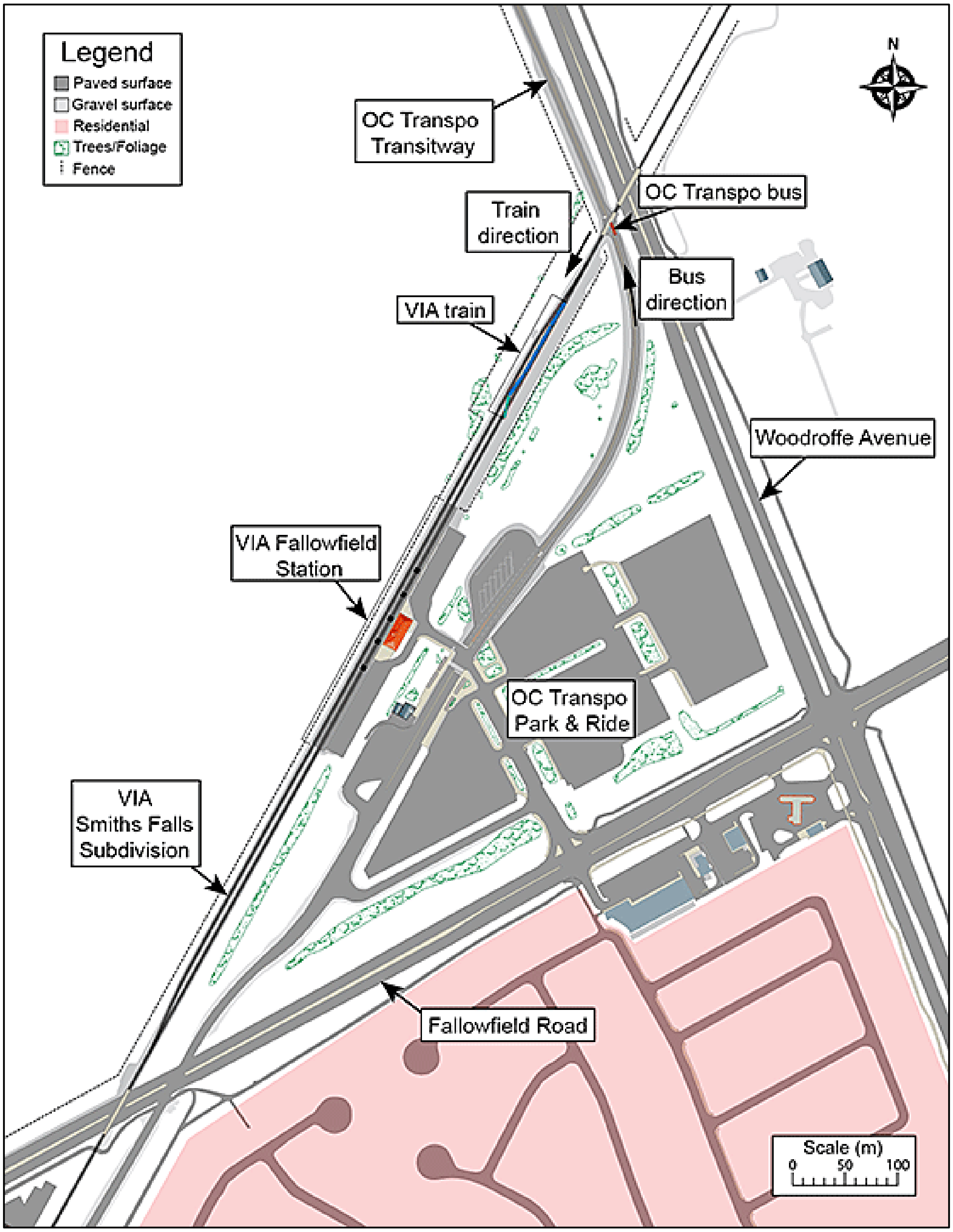
The VIA Smiths Falls Subdivision consists of a single main track that extends from Mile 0.0, located 6.0 miles (9.7 km) west of the VIA Ottawa Station, to Smiths Falls, Ontario (Mile 34.40). Train movements on the Smiths Falls Subdivision are governed by the centralized traffic control system, as authorized by the Transport Canada (TC)–approved *Canadian Rail Operating Rules* (CROR) and supervised and directed by a RailTerm rail traffic controller (RTC) located in Dorval, Quebec.

In the vicinity of the accident, there was a main track and a 2298-foot-long (700 m) siding, which is located just north of and parallel to the main track, between the Woodroffe Avenue (Mile 3.28) and the Transitway (Mile 3.30) crossings, and the Fallowfield Road (Mile 3.88) crossing. A number of VIA trains only traverse the Woodroffe Avenue / Transitway crossings as they either originate or terminate at the VIA Fallowfield Station. From Monday to Friday, up to 23 passenger trains and 2 freight trains operate over the Woodroffe Avenue / Transitway crossings each day. Similarly, up to 16 passenger trains and 2 freight trains operate over the Fallowfield Road crossing (Mile 3.88) each day (Appendix B).

The VIA Fallowfield Station (Mile 3.57) is located between the Transitway and Fallowfield Road crossings (Figure 6). This inter-city passenger railway station was built in 2002 to serve the developing Ottawa south community of Barrhaven. The station is a stop for all VIA trains operating between Montréal, Ottawa and Toronto. The station is located adjacent to the

OC Transpo Fallowfield bus station and the Park & Ride terminal, which provides direct access to local transit connections.

Figure 6. Roadway and track layout in vicinity of VIA Fallowfield Station



In the vicinity of the accident, the track is Class 5 track as defined in the TC–approved *Rules Respecting Track Safety* (Track Safety Rules). The track is authorized for speeds up to 100 mph (160.9 km) for passenger trains. To accommodate regulatory requirements for crossing AWD protection activation time (20 seconds), VIA trains depart from the VIA Fallowfield Station at a speed of 10 to 15 mph (16.1 to 24.1 km / h) in both directions. While VIA trains arriving at the station are slowing to prepare for a stop at the station, these trains can enter the

Woodroffe Avenue / Transitway crossings (westbound trains) and the Fallowfield Road crossing (eastbound trains) at speeds in the range of 40 to 50 mph (64.3 to 80.5 km / h).

The main track consisted of 115-pound RE continuous welded rail. The rails were laid on 14-inch double-shouldered tie plates secured to hardwood ties with 3 spikes per plate. The rail was box-anchored every tie. The cribs were full with crushed rock ballast and the drainage was good. The Transitway crossing was a concrete-panelled crossing.

The siding track was constructed with bolted 39-foot sections of 115-pound RE rail, laid on 11-inch double-shouldered tie plates and secured to hardwood ties with 3 spikes per plate. The rail was box-anchored every second tie. The cribs were full with crushed rock ballast and the drainage was good.

The tracks were visually inspected in accordance with regulatory and company requirements and were in good condition. The most recent track geometry test and ultrasonic rail test through the accident area had been conducted on the main track on 26 July 2013 and 14 August 2013 respectively, with no defects noted.

1.7 Recorded information

The locomotive was not equipped to record audio of in-cab conversations between crew members, nor was it required to be. There were no forward-facing or in-cab video recorders installed on the locomotive nor were there required to be. Neither the train crew nor the bus driver cell phones were in use at the time of the accident.

1.7.1 Locomotive event recorders

Part II, section 12, Event Recorders, of the TC–approved *Railway Locomotive Inspection and Safety Rules* requires that controlling locomotives be equipped with a crashworthy LER that meets specified minimum design criteria. Each LER records a minimum of 26 critical functions, which include, but are not limited to, date, time, train speed, distance travelled, throttle activation and position, air brake pipe pressure as well as the operation of all applicable brake systems.

For locomotives built prior to 01 January 2007, the rules require that an LER must record a minimum of 9 functions, which include, but are not limited to, time, distance, speed, brake pipe pressure, throttle position, emergency brake application, independent brake cylinder pressure, horn signal, and, where applicable, the reset safety control function. The LER on VIA 915, which was built in 2001, recorded 21 functions, including the required 9 functions.

Railway companies routinely use LER data in conjunction with operator proficiency testing to identify potential areas of improvement within the context of the company's safety management system (SMS).

A number of locomotives in the industry are also equipped with wireless communication technology that can transmit an LER download to a central location in real time. In the event of an emergency brake application, the information can be transmitted immediately for review. Similar technology could be adapted for the bus transit industry.

1.7.2 Crossing signal bungalows

The Woodroffe Avenue and the Transitway crossings each had their own control and monitoring circuitry, but the 2 crossings are linked to work in unison. As the clocks for each bungalow were independent, the recorded time stamps had to be manually synchronized between the 2 log files. The time stamp was synchronized to the Woodroffe Avenue crossing log, which was offset from the Transitway crossing log by about 2 seconds. Based on the known time of the collision, the signal logs were further synchronized to coincide with the LER timing.[10]

The rate at which the warning lights were flashing, as well as the current being drawn by the lights, fell within the design range. At the time of the accident, the lights were activated by the system, were on and functioning normally. The crossing protection for both the Woodroffe Avenue and Transitway crossings operated as designed with no malfunctions. The bells and lights of the Woodroffe Avenue and Transitway crossings were activated about 49 seconds before VIA 51 arrived. All of the crossing gates had been fully horizontal for at least 26 seconds before the accident.

1.7.3 Synchronized summary of events

Table 1 shows a summary of the events that occurred between the time the train left the VIA Ottawa Station and came to rest following the accident. The events were recorded from the LER, crossing signal bungalow downloads, closed circuit television (CCTV) at the OC Transpo Fallowfield Station, and the bus engine control module (ECM). All event times were normalized to coincide with the time log of the LER.

[10] For the broken gate alarm, the crossing bungalow recorded a time of 0859:46, which coincided with a locomotive event recorder recorded time of 0848:05. The Woodroffe Avenue crossing bungalow time stamp was adjusted by 11 minutes and 41 seconds to synchronize with the locomotive event recorder.

Table 1. Summary of events based on data from various recording devices

Time*	Event
0831:57	VIA 51 departed from the Ottawa Station.
0846:24	The bus arrived at the OC Transpo Fallowfield Station, south-side bus shelter. Passengers exited the bus and other passengers entered the bus from the front and side doors.
0846:36	A passenger (cyclist) secured a bike on the bike rack at the front of the bus.
0846:53	The side door of the bus closed and passengers continued to board at the front door.
0847:13	The train was proceeding at 80 mph (128.7 km / h) approximately 1 mile (1.6 km) east of the crossings. The LE applied the locomotive dynamic brake and train service brakes and began to slow the train in preparation for the stop at the VIA Fallowfield Station.
0847:17	The bells and lights at the Woodroffe Avenue and Transitway crossings were activated about 49 seconds before VIA 51 arrived.
0847:22	The train had slowed to 75 mph (120.7 km / h) approximately ¾ of a mile (1.2 km) east of the crossings with the locomotive dynamic brake and train service brakes applied.
0847:27	The bus departed from the OC Transpo Fallowfield Station.
0847:40	The Transitway crossing gates were fully down about 26 seconds before VIA 51 arrived at the crossing.
0848:02	The bus was travelling at 42 mph (67.6 km / h) with throttle (gas pedal) on.
0848:03	The bus was travelling at 42 mph (67.6 km / h) with no throttle (gas pedal) on.
0848:04	The bus speed reduced to 35 mph (56.3 km / h) with no throttle on and the brakes applied. The train was proceeding at 47 mph (75.6 km / h) with the locomotive dynamic brake and train service brakes applied. The LE activated the train emergency brakes and engine bell.
0848:05	The bus speed reduced to 25 mph (40.2 km / h) with no throttle on and the brakes applied. While travelling at 46 mph (74.0 km / h), the train arrived at the Transitway crossing. The bus struck the south crossing gate, initiating a broken gate alarm on the crossing signal log.
0848:06	The bus speed reduced to 5 mph (8.0 km / h) with no throttle on and the brakes applied. The bus collided with the south side of the train. The train slowed to 43 mph (69.2 km / h). The electrical wiring for VIA 915 was severed and the LER stopped recording.

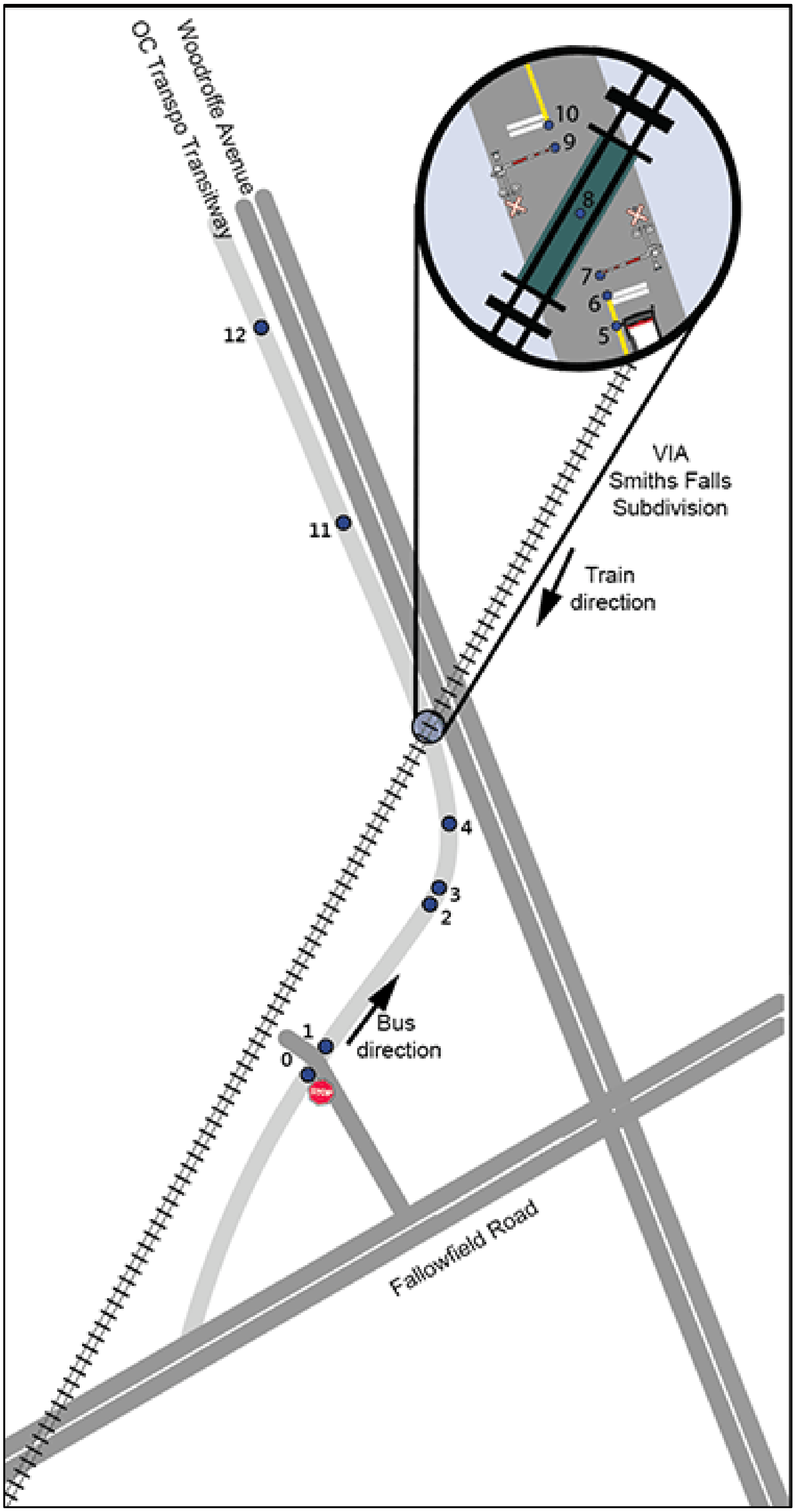
* All times are synchronized with the time log of the locomotive event recorder

1.8 TSB accident re-enactment

A re-enactment of the accident was conducted on the Transitway on 28 September 2013. The re-enactment was documented by photographs and video utilizing OC Transpo ADL E500 double-decker bus 8016 and from the bus driver’s position. The re-enactment was conducted at about the same time of day as the accident and under similar environmental conditions.

Timed runs and measurements were made with the bus travelling from the stop sign at OC Transpo Fallowfield Station up to and beyond the crossing on the Transitway (Figure 7 and Appendix C).

Figure 7. Locations of re-enactment measurements



The following observations were made during the re-enactment:

1. With the crossing gates inactive, it took between 35 and 40 seconds for the bus to travel from the stop sign to the crossing at the posted road speed of 60 km/h.

2. While proceeding northward from OC Transpo Fallowfield Station on the Transitway, approaching and into the curve, there were trees and brush that obstructed Woodroffe Avenue and the crossing from view until the bus exited the curve and began to proceed directly toward the crossing. The height of the trees between the Transitway and the rail tracks varied from 43 feet to 46 feet (13 m to 14 m) above ground level near the VIA Fallowfield Station to 36 feet to 39 feet (11 m to 12 m) above ground level near the Transitway crossing. The foliage was about 24 feet (7.4 m) thick along the tree-line over a length of 387 feet (118 m).

3. Advance warning of the crossing consisted of a sign along the northbound lane to indicate that there was a crossing ahead. There were no advance warning lights interconnected with the crossing AWDs to indicate that the crossing protection had activated and a train may be approaching.

4. The Woodroffe Avenue crossing lights were first visible from the Transitway when the bus was 748 feet (228 m) from the Transitway crossing (Photo 9).

Photo 9. Crossing lights on Woodroffe Avenue were first visible when the bus was 748 feet (228 m) from the Transitway crossing (see location 2 on Figure 7)

5. The Woodroffe Avenue crossing lights were fully visible from the Transitway when the bus was 694 feet (211.5 m) from the Transitway crossing (Photo 10).

Photo 10. Crossing lights on Woodroffe Avenue were fully visible when the bus was 694 feet (211.5 m) from the Transitway crossing (see location 3 on Figure 7)

6. The crossing lights on Woodroffe Avenue and on the Transitway were fully visible when the bus was 402 feet (122.5 m) from the Transitway crossing (Photo 11).

Photo 11. Crossing lights on Woodroffe Avenue and on the Transitway were fully visible when the bus was 402 feet (122.5 m) from the Transitway crossing (see location 4 on Figure 7)

7. There were 2 road signs installed on the west side of the Transitway that obscured the driver's view of the crossing back lights (short) on the left side of the crossing at different times on the approach (Photo 12 and Photo 13).

Photo 12. Traffic sign obscuring back lights

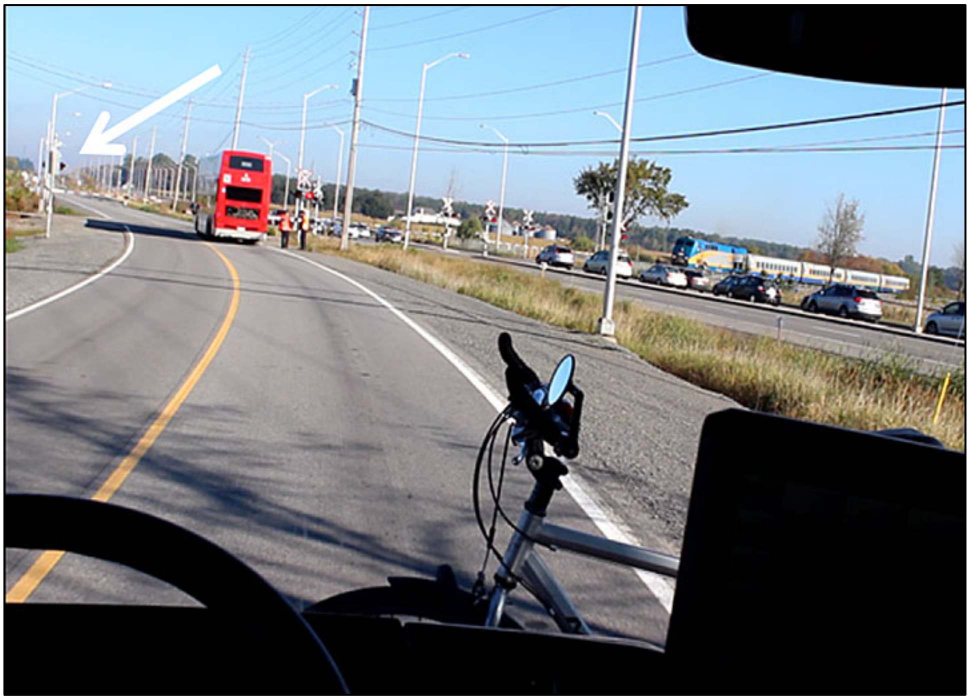


Photo 13. OC Transpo Fallowfield Station sign

8. From the driver's location stopped at the crossing, the bus window pillars and door structure obscured the driver's view of the train (Photo 14).

Photo 14. Wide angle view of approaching train from a bus stopped at the crossing

9. From inside the bus with the windows and doors closed and the bus idling, the locomotive's emergency horn was heard faintly as the train entered the Woodroffe Avenue crossing and was slightly louder as it entered the Transitway crossing.

10. Brake simulation tests were performed to determine stopping distance, time required to stop, tire condition and road surface marks with full braking force applied (Table 2).

Table 2. Empty ADL E500 double-decker bus stopping distances recorded*

Run	Speed	Stopping distance		Time to stop (seconds)
		Feet	Metres	
Run 1	60 km/h	71' 3"	21.73	2.7
Run 2	50 km/h	57' 3"	17.47	2.4
Run 3	50 km/h	53' 5"	16.31	2.3
Run 4	40 km/h	33' 1"	10.09	1.8

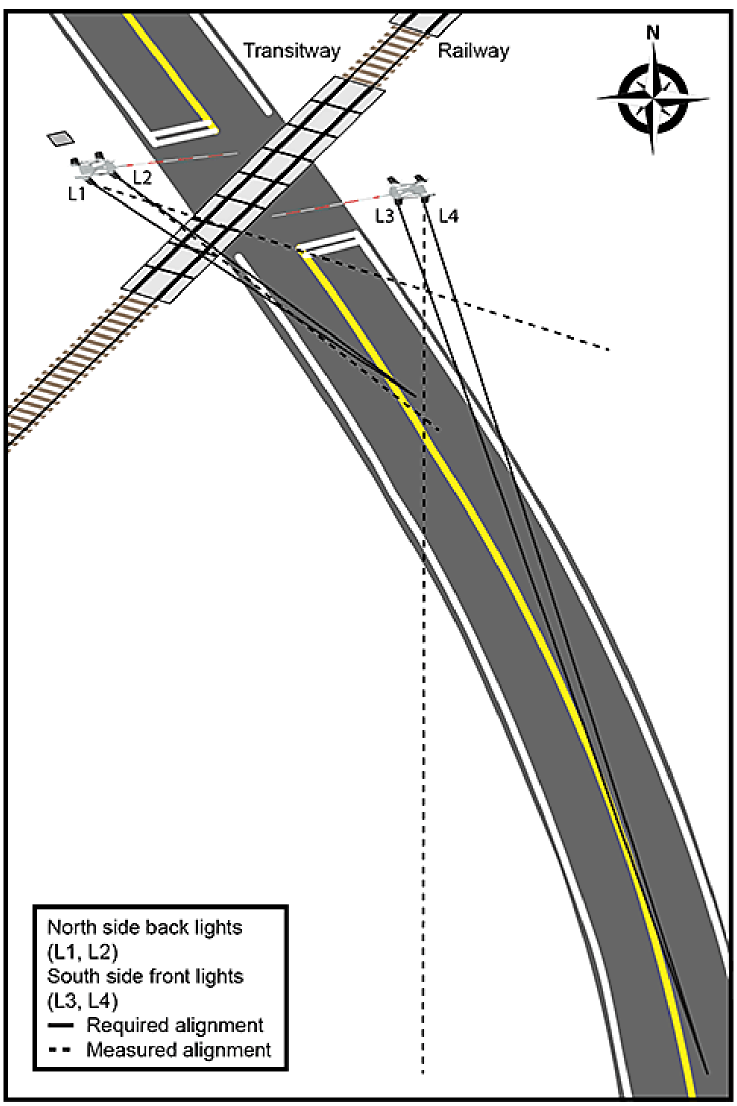
* Calculations for stopping distances of a loaded bus were also carried out by the TSB Engineering Laboratory.

Rubber abrasion was evident and consistent around the circumference of each tire. Abrasion was more pronounced on the front tires. Repositioning of the bus between test runs provided sufficient driving to produce a clean tire surface for the next run. Tire skid marks were evident on the road surface after the brake tests.

11. Although the crossing LED lights were clearly visible to roadway vehicles on the Transitway, the LED lights facing southward for the Transitway were misaligned. For a road speed of 60 km / h (i.e., Transitway speed limit at the time of the accident), the short lights (back lights located on the north stanchion – L1 and L2 in Figure 8) should have been aimed at a location 50 feet (15.2 m) south of the northbound lane stop line at the crossing, at the driver position, 5.2 feet (1.6 m) above the road surface. The long lights (front lights located on the south stanchion – L3 and L4 in Figure 8) should have been aimed at a location about 280 feet (85.3 m) south of the northbound lane stop line.

- For the north-side back lights (short), the east light (L2) was aimed at 62 feet (18.9 m) on the northbound lane while the west light (L1) was aligned about 50 feet (15.2 m) to the east, 62 feet (18.9 m) from the south stop line.
- For the south-side front lights (long), the west light (L3) was aligned properly at 280 feet (85.3 m) while the east light (L4) was aimed about 50 feet (15.2 m) to the west, 280 feet (85.3 m) from the south stop line (Figure 8).

Figure 8. Transitway crossing light layout and alignment



12. The larger road sign also obscured the driver's view of the south-side front lights (long) earlier on in the approach.

1.9 Grade crossing regulations in force at time of the accident

On 15 September 1980, the Canadian Transport Commission (CTC), pursuant to section 46 of the *National Transportation Act* and sections 198 and 200 of the *Railway Act*, revoked the *Highway and Railway Crossing at Grade Regulations, C.R.C., c. 1184* made by General Order No. E-4, and implemented the *Railway-Highway Crossing at Grade Regulations, C.T.C. 1980-8 RAIL*. The Regulations applied to all crossings constructed after 14 January 1981. For crossings that were constructed prior to 1981, General Order No. E-4 applied. The 2 documents contained essentially the same requirements governing construction of railway crossings.

The original 2-lane Woodroffe Avenue and Fallowfield Road crossings were constructed in accordance with the regulatory requirements.

1.9.1 Highway Crossings Protective Devices Regulations

The *Highway Crossings Protective Devices Regulations, C.R.C., c. 1183* stipulate that protective devices of the flashing light type installed by railway companies subject to the jurisdiction of the CTC shall comply with the specifications contained in the Regulations for protective devices of the flashing light type, and shall be maintained and tested in accordance with these Regulations. In particular, Part I of the Regulations sets forth criteria required for flashing light type protection (with or without gates) and states in part:

> 9. Electric light units shall conform to the A.A.R. [Association of American Railroads] Signal Section Specification No. 190, or the equivalent; the proper roundel within such specification shall be used as determined by local conditions.
>
> 10. Electric light units shall be equipped with a lamp having a rating of at least 18 watts and operated within 10 per cent of rated voltage.
>
> [...]
>
> 12. (1) Signals shall operate for not less than 20 seconds before the crossing is entered by a train at a speed in excess of 10 m.p.h.; [...] signals shall continue to operate until the train has cleared the crossing.
>
> [...]
>
> 13. Where train speeds on a main track vary considerably, additional control circuits may be required with timing devices so arranged that a warning time [...] will be automatically adjusted.
>
> [...]
>
> 19. (1) All highway crossing protective devices shall be maintained by the company to operate as intended and shall be tested as follows: for all crossings protected by flashing light signals and bells, or by flashing light signals, bells and gates, the tests shall be made at least once in each calendar week.

The original 2-lane, and subsequently upgraded 4-lane, Woodroffe Avenue and Fallowfield Road crossings were equipped as required.

1.10 Crossing design and draft RTD 10

TC's draft technical document, entitled *Road/Railway Grade Crossings: Technical Standards and Inspection, Testing and Maintenance Requirements* (RTD 10), issued in 2002, was developed with the intention of providing technical guidance for new grade crossing regulations. While the new regulations were being developed, RTD 10 was widely distributed and used as the de facto standard by TC, the rail industry and road authorities.

RTD 10 set forth guidance relating to the minimum safety criteria for the construction, alteration, maintenance, inspection and testing of grade crossings, and of their road approaches. In addition to RTD 10, road authorities typically consulted the Transportation Association of Canada (TAC) *Geometric Design Guide for Canadian Roads*.[11]

RTD 10 also provided guidance for maintenance of other land adjoining the railway line that may contain features that could also affect the safety of the grade crossing. VIA had used the RTD 10 as its standard for constructing, testing and maintaining crossings on all its subdivisions, including the Smiths Falls Subdivision.

The RTD 10 guidance includes in part:

- **Section 3 - Grade Crossing Safety Assessments**

  3.1 A detailed safety assessment of a grade crossing shall include a review for compliance with the requirements of the Road Railway Grade Crossing Regulations, and an evaluation of all factors that may impact on the safety of the crossing.

- **Section 4 – Design Considerations**

  4.1 The design of a grade crossing and its approaches for vehicles depends significantly upon the design vehicle braking and acceleration characteristics, as well as the vehicle length. The design vehicle characteristics are very important, along with the road approach gradient and the length of the grade crossing clearance zone for determining safe stopping sight distances, sightline requirements along the rail line, and the advance warning time and gate descent time requirements of a grade crossing warning system.

  […]

  Stopping Sight Distance

  4.4 Stopping sight distance is the sum of the distance travelled during perception and reaction time and braking distance. Braking distance is the distance that it takes to stop the vehicle once the brakes have been applied.

---

11 Transportation Association of Canada, *Geometric Design Guide for Canadian Roads*, September 1999.

When braking, 2.5 seconds is generally accepted as a baseline for perception reaction time.

The recommended stopping sight distance (SSD) for a transit bus is the same as that for a large truck. RTD 10 values for a truck travelling at speeds between 40 km/h and 80 km/h (RTD 10 Table 4-5) are summarized in Table 3 below.

Table 3. Stopping sight distances for large trucks/buses

Posted speed limit km/h (mph)	Stopping sight distance – truck class metres (feet)
40 (24.9)	70 (229.7)
50 (31.1)	110 (360.9)
60 (37.3)	130 (426.5)
70 (43.5)	180 (590.6)
80 (49.7)	210 (689.0)

Vehicle Travel Distance

4.6 The total distance the design vehicle must travel to pass completely through the clearance distance [….]

Departure Time – 'Design Vehicle'

4.7 **[…]** It includes the time required for the driver to look in both directions along the rail line and to start the vehicle in motion, and to pass completely through the clearance distance.

The design vehicle departure time depends upon the clearance distance, the length of the design vehicle, and the vehicle acceleration.

[…]

Determination of Design Vehicle Departure Time

The design vehicle departure time (Tv) is given by the expression;

Tv = J + T

Where J = 2 seconds perception reaction time of the driver to look in both directions, shift gears if necessary, and prepare to start

T = the time for the design vehicle to travel completely through the clearance distance.

T may be obtained through direct measurement of time required for the selected design vehicle to travel through the grade crossing clearance distance [...] at the grade crossing [....]

For example, a loaded tractor-trailer can take over 20 seconds to clear a crossing.

- **Section 7 – Road Geometry (Grade Crossing and Road Approaches)**

> **7.6** A grade crossing where the maximum railway operating speed exceeds 15 mph shall be constructed as specified […] with the angle of intersection between the road and the track of:
>
> (a) not less than 70 nor greater than 110 degrees without a grade crossing warning system; or
>
> (b) not less than 45 nor greater than 135 degrees with a grade crossing warning system.

- **Section 8 - Sightlines**

> **Sightlines for grade crossings with a grade crossing warning system**
>
> **8.4 (a)** Sightlines at grade crossings <u>with a grade crossing warning system</u> shall be provided in accordance with [RTD 10] Figure 8-2.

RTD 10 Figure 8-2 states the following:

> Sightlines of a Railway Crossing Sign, and at least one set of front lights of the grade crossing warning system must not be obstructed within the SSD. Particular attention should be given to:
>
> 1. trees, brush, other vegetation, pole lines, signs, bus shelters or other roadside installations; and
> 2. parked vehicles, or buses loading or unloading passengers.

- **Section 13 – Flashing Light Units**

> **Number and Location of Light Units**
>
> […]
>
> **13.1 (b)** Sufficient light units shall be provided in a grade crossing warning system and located to ensure that while a driver is approaching the grade crossing within the distances specified for the primary set of light units in [RTD 10] Table 19-1, or from a road intersection or a property access:
>
> (i) flashing light units are located within, or as close as possible to, 5 degrees horizontally of the centreline of the road; and
>
> (ii) the approaching driver is within the effective distribution pattern of luminous intensity of a set of flashing light units;
>
> **(c)** Sufficient back lights shall be provided in a grade crossing warning system and located to ensure that all drivers stopped at the grade crossing are within the effective distribution pattern of luminous intensity of a set of back lights.

- **Section 14 – Prepare to Stop at Railway Crossing Sign**

> **14.1** A Prepare to Stop at Railway Crossing Sign as specified in the *Traffic Control Devices Manual*, shall be installed:

(a) on a road approach where at least one set of front light units on a warning signal or on a cantilever at the grade crossing cannot be seen clearly within the minimum distance specified in [RTD 10] Table 19-1; or

(b) on road approaches to a grade crossing on a freeway or an expressway, as defined in the *Geometric Design Guide*; or

(c) where adverse local environmental conditions which obscure grade crossing warning signal visibility frequently occur.

14.2 The Prepare to Stop at Railway Crossing Sign shall provide warning:

(a) <u>during the time of the operation of the flashing lights of the grade crossing warning system;</u>

(b) <u>in advance of the operation of the flashing lights of the grade crossing warning system</u> for the time required for a vehicle travelling at the maximum road operating speed to pass the Prepare to Stop at Railway Crossing Sign that is not activated and to:

i) clear the grade crossing in advance of the arrival of all trains where there is a grade crossing warning system without gates; or

ii) clear the grade crossing before the start of the descent of the gate arms where there is a grade crossing warning system with gates; and

(c) <u>following completion of the operation of the flashing lights of a grade crossing warning system</u> for the time required for vehicles queued for the grade crossing to resume the maximum road operating speed on all roads that meet the criteria for a “freeway” or “expressway” classification in the *Geometric Design Guide* and on any other road approach where visibility at a safe stopping sight distance of vehicles queued for the grade crossing is restricted.

- **Section 19 – Bells, Gates and Flashing Light Units**

Light Unit Alignment

19.4 The alignment point of the axes of the beams of sets of light units shall be appropriate for the conditions at each grade crossing. They shall be aligned for approaching drivers, taking into consideration the maximum road operating speed and the distance at which the light units first can be seen.

Alignment Height - Front and Back Lights

19.5 Light units shall be aligned so that the axis of the light units pass through a point 1.6 m above the road surface at the required distance.

Alignment Distance- Primary Front Light Units For Vehicles

19.6 (a) Grade crossing warning system light unit visibility distance is defined as the distance in advance of the stop line or vehicle stop position from which a set of light units must be continuously visible for various approach speeds.

Sets of primary front light units on the warning signal, and on a cantilever structure where provided, shall be aligned through the centre of the approaching traffic lane, or lanes, for which they are intended, at:

- the recommended distance, adjusted for gradient of the road, specified in [RTD 10] Table 19-1; or
- the point at which the light units are first clearly visible, if this point is less than the recommended distance specified in Table 19-1.

Relevant speeds and distances from RTD 10 Table 19-1 are summarized in Table 4 below.

Table 4. Minimum front light alignment distance for heavy trucks (buses)

Maximum road operating speed km/h (mph)	Minimum distance primary set of light units for heavy trucks metres (feet)
50 (31.1)	110 (360.9)
60 (37.3)	130 (426.5)
70 (43.5)	180 (590.6)
80 (49.7)	210 (689.0)

Alignment - Back Lights

19.9 At least one set of back lights shall be aligned through the centre of the approaching lanes, or separate traffic lanes for which they are intended, 15 m (50 ft) in advance of the crossing warning signal on the opposite approach.

The back lights are intended to provide warning for vehicles stopped at the crossing.

- **Section 21 - Grade Crossing Warning Systems**

21.2 Grade crossing warning systems shall be maintained, inspected and tested to ensure that they operate as intended.

Operation of crossing AWD protection is tested weekly. In addition, monthly inspections include checks for

- light units with obvious misalignment and for physical damage;
- cleanliness of light roundels;
- standby power operating voltage; and
- flashing light units, gates, and signs for operation, damage, cleanliness and visibility.

21.3 (a) [...] Local circumstances may require inspection and testing more frequently than the maximum intervals specified.

1.10.1 Crossing gates

Where 2 or more main tracks cross a section of highway or where there is heavy vehicular traffic, gate arms and gate mechanisms are commonly installed to supplement flashing lights. In these cases, the main purpose of installing gates is to discourage vehicular traffic from occupying the crossing after one train passes, if there is another train approaching on the second track.[12]

Crossing gates are covered with alternating strips of highly reflective red / white coating supplemented by 3 small 4-inch-diameter flashing lights on the top of the gate. The light nearest the tip of the gate is lit steadily while the other 2 lights are located to suit local conditions and flash alternately in unison with the crossing signal lights. When positioning the lights on the gate arm, the rightmost light must be in line with the edge of the roadway and the centre light should be placed between the 2 outer lights.

Crossing gates are intended as a barrier to cars within the immediate vicinity of the crossing. The lights on the gate arm are intended to identify the position of the gate in situations where there is inadequate light (e.g., dusk). Crossing gates are not intended to be conspicuous from a distance as the crossing signal lights serve that function.

For crossings equipped only with flashing lights and bells (no gates), crossing accidents sometimes occur when a trailing vehicle inadvertently follows another vehicle onto a crossing while the flashing lights and bells are activated. When these types of accidents occur, the crossing AWDs are often upgraded to include gates.[13] Gate deployment also minimizes the potential of a trailing vehicle entering the crossing when following another vehicle.

1.11 New grade crossing regulations

TC had been developing new grade crossing regulations for over 20 years. At the time of the accident, the new regulations were in the draft stage, but have since come into force on 27 November 2014. The previous *Railway-Highway Crossing at Grade Regulations* and the *Highway Crossings Protective Devices Regulations* have since been repealed.

The new regulations define a grade crossing as a road crossing **at grade**, or 2 or more road crossings **at grade** where the lines of railway are not separated by more than 30 m. The new *Grade Crossings Regulations* (GCR) and the accompanying *Grade Crossings Standards* technical manual provide more detail on crossing design, testing and maintenance as compared to the regulations in place at the time of the accident. While many of the RTD 10 requirements were incorporated into the new *Grade Crossings Standards*, the requirement to conduct detailed safety assessments of level crossings every 5 years was removed.

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12 The American Railway Engineering and Maintenance-of-Way Association, *Practical Guide to Railway Engineering*, Section 7.5.2, Crossing Gates.

13 TSB Railway Investigation Report R08W0181.

Part C, section 9, Warning Systems Specification, of the new *Grade Crossings Standards* states in part

> 9.1 The specifications for a public grade crossing at which a warning system without gates is required are as follows:
>
> a) where the forecast cross-product[14] is 2,000 or more;
>
> [...]
>
> 9.2 The specifications for a public grade crossing at which a warning system with gates is required are as follows:
>
> 9.2.1 a warning system is required under article 9.1 and;
>
> (a) the forecast cross-product is 50,000 or more […]

The new GCR and accompanying *Grade Crossings Standards* technical manual only apply to level crossings. While the GCR set forth criteria for when a grade crossing cannot be built, TC has no guidance as to when construction of a grade separation[15] should be considered.

1.12 Regulatory overview

Crossing safety is a responsibility shared by the public, TC, the infrastructure owner (railway) and the road authority.[16] Responsibilities under the *Railway Safety Act* include the following:

- TC is responsible for oversight of railway crossings under federal jurisdiction, which includes the following activities:
  - promote compliance with railway safety requirements developed under the authority of the *Railway Safety Act* and related regulations, rules, engineering standards as well as encourage adoption of guidelines and best practices;
  - monitor for compliance and safety through its national and regional oversight inspection programs for the crossings and signals functions; and
  - enforce non-compliances and mitigate threats to safety with respect to railway operations.
- Railways are responsible for maintaining crossing infrastructure and sightlines along the railway right-of-way (ROW).
- Road authorities are responsible for traffic control devices (traffic lights, road signs, etc.), maintenance of roadway approaches up to the railway ROW, sightlines on civic property, and ensuring that there is adequate SSD for vehicles approaching the crossing, based on road geometry.

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14 Cross-product is the number of trains per day multiplied by the number of vehicles that use a crossing per day.

15 A roadway underpass or overpass that physically separates roadway traffic from railway infrastructure.

16 The road authority is the federal, provincial, municipal or private party that is responsible for the roadway.

When a crossing is constructed or significantly upgraded, there is usually an agreement among the parties involved to share costs.

1.12.1 Risk assessment tool for grade crossings

TC uses the GradeX risk assessment tool to identify risk levels for the approximately 15 000 public and 9000 private level crossings in Canada. This risk ranking system can vary by region and is based on a mathematical model developed by the University of Waterloo in 2001.

Through GradeX, a series of crossing parameters are input into the system, a mathematical algorithm is applied, and the higher-risk locations are identified. The input parameters to GradeX include

- train and vehicular traffic volume;
- road and track posted speed;
- track configuration;
- sightline visibility and road approach configuration;
- collision history; and
- type of crossing and protection.

The resulting GradeX rankings may prompt an inspection, a referral to the Grade Crossing Improvement Program (GCIP), or both. While GradeX will rank level crossings based on risk, it does not specifically identify crossings that should be considered for grade separation.

1.12.2 Grade Crossing Improvement Program

The GCIP provides funds to upgrade and improve safety at selected federally regulated level crossings. In April 2013, the annual GCIP funding for Canada was 10.9 million dollars. The program funds up to 50% of eligible project costs to a maximum of 550 000 dollars per project.

TC uses the GradeX risk rankings to help determine which level crossings will receive funding. Eligible upgrades include

- upgrade of passive crossing protection to include AWDs;
- addition of gates or extra lights to existing AWD protection;
- replacement of incandescent lights with LED lights;
- interconnection of crossing signals to nearby roadway traffic signals;
- modification of operating circuits within automated warning systems; and
- improvement of existing roadway alignment and / or approach grades.

1.12.3 Grade separation

In 1989, the Government of Canada implemented a policy to no longer appropriate funds for grade separation projects pursuant to section 13 of the *Railway Safety Act*. Consequently, TC no longer provides funding for grade separation projects. Since 1989, railway companies and road authorities can apply for funding under Infrastructure Canada programs. For grade separations, road authorities are typically responsible for the planning of such installations as part of their road transportation network while the railways are involved in the detailed design of the structure to ensure safe railway operations. To assist in identifying potential grade separation projects in Canada, cross-product has always been one of the primary criteria used. Historically, a cross-product of 200 000 was the accepted benchmark used by TC and industry for a grade separation project to be considered. However, there is no record of when or why the 200 000 threshold was established.

TC records indicated that, for the approximately 15 000 public crossings across Canada, there are 43 level crossings protected by AWDs that have cross-products in excess of 400 000, and 15 of these have cross-products in excess of 600 000.

TC has no firm cross-product value that requires a grade separation to be built. In Canada, there are no regulations, standards or guidelines that identify when level crossings should be grade separated.

1.12.4 United States Department of Transportation Federal Highway Administration Railroad–Highway Grade Crossing Handbook

The United States Department of Transportation (DOT) Federal Highway Administration (FHA) *Railroad–Highway Grade Crossing Handbook* (2007) provides general information on rail crossings, including the characteristics of the crossing environment and the crossing users as well as physical and operational improvements that can be made to enhance crossing safety. The guidelines and improvements presented in the handbook have been accepted nationwide in the United States.

Chapter V of the handbook discusses methods for selecting crossing alternatives. Part A, Section 6 of this chapter, Grade Separation, states in part:

> b. Highway-rail grade crossings should be considered for grade separation across the railroad right of way whenever the cost of grade separation can be economically justified based on fully allocated life-cycle costs and one or more of the following conditions exist:
>
> i. The highway is a part of the designated National Highway System.
>
> ii. The highway is otherwise designed to have partial controlled access.
>
> iii. The posted highway speed exceeds 88 km / hr. (55 mph).
>
> iv. AADT [average annual daily traffic] exceeds 50,000 in urban areas or 25,000 in rural areas.
>
> v. Maximum authorized train speed exceeds 161 km / hr. (100 mph).
>
> vi. An average of 75 or more trains per day or 150 million gross tons per year.
>
> vii. An average of 50 or more passenger trains per day in urban areas or 12 or more passenger trains per day in rural areas.
>
> viii. Crossing exposure (the product of the number of trains per day and AADT) exceeds 500,000 in urban areas or 125,000 in rural areas; or

ix. Passenger train crossing exposure (the product of the number of passenger trains per day and AADT) exceeds 400,000 in urban areas or 100,000 in rural areas.

x. The expected accident frequency for active devices with gates, as calculated by the U.S. DOT Accident Prediction Formula including five-year accident history, exceeds 0.2.

xi. Vehicle delay exceeds 30 vehicle hours per day.

xii. An engineering study indicates that the absence of a grade separation structure would result in the highway facility performing at a level of service below its intended minimum design level 10 percent or more of the time.

c. Whenever a new grade separation is constructed, whether replacing an existing highway-rail grade crossing or otherwise, consideration should be given to the possibility of closing one or more adjacent grade crossings.

1.13 Grade crossing considerations at the City of Ottawa

In 1995, due to the planned and expected urban development in the area of what is now the south Ottawa suburb of Barrhaven, the city of Nepean, Ontario (prior to amalgamation with the City),[17] undertook 2 environmental assessments (EA). One EA was conducted for the southwest Transitway extension and the second was for the widening of Woodroffe Avenue and of Fallowfield Road from their 2-lane configuration to the present 4-lane configuration. At the time, the Smiths Falls Subdivision was owned by CN.

During the planning stage for Woodroffe Avenue, the Transitway, and Fallowfield Road, the need for grade separations was examined due to the expected population growth and the ongoing development of the road and Transitway system. In 1997, the southwest Transitway extension EA considered several alternative alignments. One proposal considered constructing the Transitway on the east side of Woodroffe Avenue, which would provide a longer, straighter approach to the crossing, but it was not recommended. This EA also included various grade separation options for Woodroffe Avenue, the Transitway, and Fallowfield Road.

During public consultation, there was local opposition to any roadway overpass proposal due primarily to the perceived adverse aesthetic, noise and environmental impacts on properties. Some of the farmland adjacent to the proposed projects was owned by the National Capital Commission (NCC). The NCC, which was also consulted, supported the public position and also preferred the underpass alternatives given that the views of the Greenbelt would be preserved, which was the NCC's primary planning interest in the matter. Once the underpass alternative was selected as the preferred option, the EAs only

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17 The *City of Ottawa Act, 1999* created the City of Ottawa. The Act was passed in 1999 to provide for the 01 January 2001 amalgamation of the former Municipality of Ottawa-Carleton, the former cities of Ottawa, Nepean, Kanata, Gloucester, Vanier and Cumberland, the former townships of West Carleton, Goulbourn, Rideau, and Osgoode, and the former village of Rockcliffe Park into the new City of Ottawa.

considered this option. Any future consideration for roadway overpass alternatives would have required reopening the EAs. Upon completion of the EA process, the EAs recommended the present alignment of the Transitway, which was later refined during the detail design phase.

1.13.1 Geotechnical studies

In 2001, the City contracted Delcan Corporation (Delcan) to manage the proposed grade separation projects for Woodroffe Avenue, the Transitway, and Fallowfield Road. Delcan sub-contracted Golder Associates Limited (Golder) for a number of geotechnical studies in order to establish preliminary engineering guidelines and construction considerations related to the geotechnical aspects of the projects. In late 2001, Golder conducted preliminary geotechnical testing at the 2 proposed underpass locations to determine the general soil and groundwater conditions.

A letter from CN to the City dated 08 May 2001, stated the following:

> CN would not permit permanent at-grade crossings at Fallowfield Road and Woodroffe Avenue due to the projected rail - road cross product, which is in excess of 200,000, and the current and future safety concerns, which justify the need for grade separated structures. Further justification is provided by VIA Rail’s plan to add two daily trains and increase train speed. In addition, train volumes are expected to increase with plans for future commuter service.

In July 2002, Golder conducted additional geotechnical testing to assess the hydrogeological properties of the bedrock, to estimate the pumping rates required to enable construction to take place, and to establish the potential impacts and design mitigation measures should they be required.

In October 2002, VIA completed construction of the VIA Fallowfield Station and commenced with passenger service at this location. Since that time, all VIA trains along this route stopped at the station. However, due to the signal circuitry in place at that time, the crossing protection on Woodroffe Avenue and Fallowfield Road, both of which were 2-lane roads at the time, remained activated while the trains were stopped.

In November and December 2002, Golder submitted 2 reports,[18, 19] indicating that the preferred design option at each location was to have a roadway underpass. This design option would involve significant open-cuts for the roadway, related storm sewers for drainage, utility relocation and temporary detours for both vehicular and train traffic during construction. The open-cuts would be about 8 m (26.2 feet) below the structures. The structures would be 105 m to 115 m (344.5 feet to 377.3 feet) long, supported by 4 piers and

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18 Golder Associates Limited, Report, Preliminary Geotechnical Investigation, Proposed Grade Separations, Fallowfield Road and Woodroffe Avenue at CN Rail, Ottawa, Ontario, Report No. 011-2012-5400, November 2002, presented to Delcan Corporation.

19 Golder Associates Limited, Report, Geotechnical Investigation, Proposed CN Rail Grade Separation Alternatives at Fallowfield Road, Ottawa, Ontario, Report No. 011-2012-5600, December 2002, presented to Delcan Corporation.

2 abutments at Woodroffe Avenue and a the Transitway, and 3 piers and 2 abutments at Fallowfield Road.

In January 2003, Golder submitted another report[20] summarizing the additional geotechnical testing performed in July 2002. The report indicated that the roadway underpass option would likely involve the pumping / recharging of large quantities of groundwater during construction and potentially throughout the life of the underpass. This option presented risks and significantly increased the cost of the projects from the original estimate of 40 million dollars to over 100 million dollars. The Golder report further indicated the following:

- Once excavation of the permanently open-cut option is completed, the pumping would have to be maintained in order to prevent bottom heave and / or filling of the lower portion of the underpass.
- Mitigation measures should be taken to reduce the effects of water depletion of the soils in the areas where buildings are present, due to the potential damage that could result from the consequent settlement.
- The impacts of depressurization of the bedrock evaluated from the results of the pumping test and of the modelling are significant. The possible mitigating options and alternatives for grade separation included
    - bedrock grouting and / or installation of recharge wells for temporary depressurization of the bedrock in conjunction with a watertight underpass structure;
    - raising the grades related to the grade separation; and
    - construction of a roadway overpass in conjunction with a potential lowering of the railway.
- It should be possible to adapt the design of the pumping and recharging to the site and maintain adequate groundwater conditions.
- For a raised roadway underpass or a lowered railway grade option, any grade raise over 2 m (6.6 feet) required the use of lightweight fill to prevent overloading the grey clay on site.
- A roadway overpass could be considered provided that lightweight fill would be used to construct the 9.2 m-high (30.2 feet) embankment approaches.

In February 2003, Golder further indicated[21] that, with the open-cut underpass option, if a pumping interruption should occur at the site, the water table would rise rapidly in the bedrock and would result in slope instability and / or bottom heave of the road in the lower portion of the cut, which would also fill with water. Slope instability and bottom heave would begin to occur within minutes of the interruption.

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[20] Golder Associates Limited, Report, Additional Geotechnical Investigation, Proposed CN Rail Grade Separation Alternatives at Woodroffe Avenue / Transitway and Impact of Simultaneous Depressurizing at the Fallowfield Road and Woodroffe Avenue Sites, Ottawa, Ontario, Report No. 011-2012-5700, January 2003, presented to Delcan Corporation.

[21] Letter from Golder Associates Limited to Delcan Corporation, dated 18 February 2003.

Following the Golder comments, Delcan indicated[22] to the City that, because significant groundwater dewatering was required during the construction stage, if a pumping interruption was to occur, the risks could be potentially catastrophic and could include

- loss of all infrastructure constructed up to the time of a pumping interruption causing the slope instability and/or bottom heave;
- loss of utilities in the side slopes (water mains, gas main, hydro lines);
- loss of the rail line;
- loss of the roadway detours;
- loss of residential and commercial property south of Fallowfield Road; and
- potential loss of life.

Due to the risks identified, it was recommended that the open-cut option should not be pursued and that it was necessary to consider other alternatives.

1.13.2 Other alternative options

A number of roadway overpass alternatives were initially considered. Roadway overpasses could have been constructed using light approach fills and multiple bridge spans. However, the previous public and NCC consultation identified the preferred option to be a roadway underpass. Consequently, the EAs did not consider overpass alternatives. The time required to reopen the EAs to reconsider roadway overpass options would have made completion of the projects within the time constraints imposed through the Government of Canada Millennium project funding (end of March 2006) difficult. This would likely have resulted in the loss of the Millennium funding, which accounted for approximately 70% of the original estimated project cost. The additional costs associated with the remaining grade separation options, the potential loss of the Millennium funding and the position of both the public and NCC related to any roadway overpass alternative limited the options considered by the City in 2004.

In January 2004, after considering the projected increase in the cost of grade separation for Woodroffe Avenue, the Transitway, and Fallowfield Road, and since passenger trains at this location were now slowing down to stop at the VIA Fallowfield Station, the City and CN agreed to reconsider the level grade crossing options. Subsequently, the City contracted Jock Valley Engineering Limited (Jock Valley) to conduct a detailed safety assessment (DSA) for level crossing upgrades in consideration of the proposed widening of Woodroffe Avenue and the construction of the Transitway.[23] Jock Valley was also contracted to conduct a DSA for the proposed widening of Fallowfield Road and construction of the southwest Transitway extension.[24]

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22 Letter from Delcan Corporation to the City of Ottawa, dated 19 February 2003.

23 R.J. Fish, P. Eng., Jock Valley Engineering Limited, Woodroffe Avenue Detailed Safety Assessment Final Report - Detailed Safety Assessment of the proposed widening of Woodroffe Avenue over the CN tracks at mileage 3.28 of Smiths Falls Subdivision in Ottawa, Canada, 28 October 2004.

24 R.J. Fish, P. Eng., Jock Valley Engineering Limited, Fallowfield Road Detailed Safety Assessment Final Report - Final Report - Detailed Safety Assessment of the proposed widening of Fallowfield

On 20 June 2004, VIA sent a letter to the City of Ottawa regarding the proposed changes to Woodroffe Avenue and Fallowfield Road level crossings. VIA acknowledged that, at that time, CN was the owner of the rail infrastructure and, as such, had full control over the proposed expansion of the affected level crossings. However, as the maintainer and primary user of the crossings at the time, VIA had some safety-related concerns as summarized below:

- The Woodroffe Avenue crossing will basically triple in size from the original configuration (from 2 to 6 traffic lanes), which would increase the exposure of public road users to rail traffic at this point.
- The Fallowfield Road crossing, combined with the proposed new extension of the OC Transpo Transitway in close vicinity to the level crossing, would increase the complexity of the level crossing.
- The addition of dedicated cycle paths and recreational walkways outside the confines of crossing warning gates could put users at risk.
- The Woodroffe Avenue and Fallowfield Road AADTs at the time were 22 000 and 20 000 vehicles respectively. This will likely increase as the population grows, which will also increase the risk exposure at both crossings.

VIA also indicated that the expansion of the level crossings would place additional ongoing operational constraints on the railway as summarized below:

- All trains will be required to stop at the VIA Fallowfield Station.
- The Transitway would run adjacent to the Fallowfield Road level crossing and required the pre-emption of the related traffic signals. As a result, all westbound VIA trains would incur a delay departing from the VIA Fallowfield Station.
- The proposed number of traffic lanes and the anticipated AADT at each of the crossings will eliminate any opportunity for the expansion of passenger rail service (i.e., installation of double track through this area) without first replacing the crossings with grade separations.

VIA also asked the following questions:

1. Has any consideration been given to having the road pass over the railway?
2. Would it be feasible to construct only 1 of the 2 grade separations (i.e., Woodroffe Avenue or Fallowfield Road) with the second to be completed in the future?
3. Would it be feasible to reroute Fallowfield Road along the north side of the CN ROW on the existing NCC vacant lands such that the Fallowfield Road level crossing could be eliminated?

On 22 July 2004, the City responded to VIA's letter and provided answers to VIA's questions as summarized below:

Road over the CN tracks at mileage 3.89 of their Smiths Falls Subdivision in Ottawa, Canada, 29 April 2005.

1. Multiple overpass scenarios were investigated during the preliminary engineering phase of the project.

   In each case, it was recognized that overpass alternatives would require reopening both the southwest Transitway extension and the Fallowfield Road EAs undertaken earlier and subsequently approved by the City of Ottawa and the Ontario Ministry of the Environment. The public input that had been received as part of both EAs indicated widespread and vigorous opposition by the residents to any overpass alternative due to the adverse aesthetic, noise and other environmental impacts on their properties. The farmland adjacent to the project is owned by the NCC, which was similarly opposed with a clear preference for the underpass alternatives.

   Therefore, the excessive cost of an overpass structure in conjunction with the loss of Millennium-funded subsidy and the opposition of both the public and NCC effectively eliminated the overpass options.
2. The surficial soils in the area have very limited load-bearing capacity. Either structure, including utility, road and rail detours, storm water requirements and outlets as well as ongoing pumping requirements, far exceeded the available budget.
3. Multiple alternative geometric configurations were investigated to see if there were other less conventional alternatives that could reduce costs but still operate effectively. However, the alternative alignments would have been subject to EAs, again resulting in lost subsidy. Furthermore, it was inevitable that they would undergo opposition from both the public and NCC.

The end result was that the City proceeded with its preferred option of expanding the level crossings for Woodroffe Avenue, the Transitway, and Fallowfield Road.

On 25 August 2004, an update on the Woodroffe Avenue, Transitway, and Fallowfield Road grade separation projects was provided to City Council.[25] It was recommended that the open-cut underpass option be abandoned. It was further recommended to transfer the 2004 spending authority, the pre-commitment of the 2005 capital budget, and the associated Millennium-funded subsidy from the Woodroffe Avenue, Transitway, and Fallowfield Road grade separation projects to a number of other projects throughout the City. This left the grade crossing issues related to the widening of Woodroffe Avenue and Fallowfield Road unresolved. The City had indicated that the construction of grade separation for Woodroffe Avenue, the Transitway, and Fallowfield Road was not possible due to geotechnical issues.

1.13.3 Woodroffe Avenue and Transitway detailed safety assessments – 2004

The final report for the Woodroffe Avenue and Transitway DSA was submitted to the City on 28 October 2004. The report noted that Barrhaven had experienced tremendous growth and was expected to reach a population of 105 000 by 2021. Road and transit facilities had to be expanded in order to serve the public.

[25] Woodroffe / Fallowfield Grade Separation Reallocation of Millennium Funding, Committee Recommendations, presented to Ottawa City Council 25 August 2004.

The DSA had been conducted using the draft *Canadian Road/Railway Grade Crossing Detailed Safety Assessment Field Guide*. This guide had been produced in conjunction with RTD 10 dated 24 October 2002. The DSA was based on the proposal to widen Woodroffe Avenue from a 2-lane road to a 4–lane road and to construct a new north-south 2-lane bus Transitway running parallel to and just west of Woodroffe Avenue. In conjunction with the project, new level grade crossings would have to be constructed for Woodroffe Avenue and the Transitway.

The DSA indicated the following:

- Rail traffic at this location consisted of 5 passenger trains and 1 freight train in each direction for a total of 12 trains per day. While no increase in the number of freight trains was foreseen, the number of passenger trains could increase by 2 trains in each direction within the foreseeable future for a forecasted total traffic of 16 trains per day.
- The City conducted a traffic survey at the Woodroffe Avenue crossing in May 2004. At the time, daily roadway traffic was approximately 21 000 vehicles. Using a growth factor of 2.8%, the traffic volume on Woodroffe Avenue was predicted to increase to about 24 000 vehicles by 2009.
- Prior to any construction or alteration of the original crossings, all passenger trains stopped at the VIA Fallowfield Station. However, freight trains were not required to stop. The maximum speed on this section of track was 60 mph (96.6 km/h) for freight trains and 95 mph (152.9 km/h) for passenger trains. A temporary speed restriction of 20 mph (32.2 km/h) was put in place for all trains to eliminate unnecessary operation of the crossing signals at the Woodroffe Avenue and Fallowfield Road crossings. This speed restriction remained in place until 2010.
- The design of the proposed crossing circuit was based on the assumption that all passenger trains would continue to stop at the VIA Fallowfield Station. When trains were ready to depart, the locomotive engineer would activate the crossing warning system from the cab of the locomotive using a radio code transmitted on channel 1 of the locomotive radio. When the desired warning time had elapsed, the locomotive engineer would receive a signal (white strobe light) to indicate that the crossing warning system had been activated and that it was safe to proceed.
- To ensure that the crossing warning system would not be activated by movements stopping at the VIA Fallowfield Station, the CWT for the eastward approach to Woodroffe Avenue was extended to the edge of the VIA Fallowfield Station platform. This extension would also provide the required warning time to allow through freight movements at a maximum speed of 20 mph (32.2 km/h).
- Passenger trains would continue to approach the Woodroffe Avenue crossing from the east at 95 mph (152.9 km/h), but would enter the crossing at a substantially slower speed as they were required to stop at the VIA Fallowfield Station.
- All crossing surfaces would be constructed in accordance with the requirements of section 6 of RTD 10 and would be designed in consultation with CN.

- The horizontal alignment of Woodroffe Avenue was within the safe SSD as the road was straight in both directions with the exception of slight lane shifts to accommodate the introduction of a median in the vicinity of the crossing.
- The design speed for this section of Woodroffe Avenue was 100 km / h (62.1 mph) with a posted speed limit of 80 km / h (49.7 mph).
- The horizontal alignment of the Transitway within the SSD was straight on the north approach with a slight shift to bring it closer to the road through the crossing. The south approach included a 250 m (820 feet) radius curve with a straight portion of about 20 m (66 feet) before the crossing. The design speed for the Transitway in the vicinity of the crossing was 80 km / h (49.7 mph) with a posted speed of 60 km / h (37.3 mph).
- The maximum size vehicle to regularly use the Transitway was a 60-foot-long articulated bus (i.e., design vehicle). For a design speed of 80 km / h, the SSD for the design vehicle was 210 m (689 feet). For the posted speed limit of 60 km / h, the recommended SSD was 130 m (427 feet).
- The vehicle travel distance for the Transitway was 46.6 m (153 feet).
- The vehicle departure time for an articulated bus on the Transitway was 14 seconds, which was within the time provided by the grade crossing warning system.
- For vehicles stopped at either the Woodroffe crossing or the Transitway crossing, the existing sightlines were adequate.
- As the reconstructed crossings were to be designed to meet the requirements of section 16 of RTD 10, there was no necessity to continue train whistling during daylight hours once the crossings were reconstructed.

The DSA recommendations included the following:

- The traffic signals at the entrance to OC Transpo‘s Fallowfield Station located 270 m (886 feet) south of the Woodroffe Avenue crossing must be removed. The intersection must be removed completely and the road in this area must be reconstructed to provide a smooth approach to the crossing.
- The next DSA should be conducted in 5 years (2009 / 2010) unless required earlier by some other event.

The DSA concluded that the proposed crossing reconstruction would include a number of improvements over the existing crossing, including the following:

- The introduction of a median would discourage motorists from driving around lowered crossing gates.
- The problem of unnecessary operation of the crossing warning devices as a result of trains stopping at the VIA Fallowfield Station would be resolved.

The proposed widened crossing would have a high level of safety, exceeding that of the existing level crossing.

1.13.4 Fallowfield Road and Transitway detailed safety assessment – 2005

The final report for the Fallowfield Road and Transitway DSA was submitted to the City on 29 April 2005. The DSA contained much of the same background, rail traffic volume and operation information as outlined in the Woodroffe Avenue and Transitway DSA, and requirements for the crossing to be constructed in accordance with RTD 10.

The DSA was based on the proposal to widen Fallowfield Road from a 2-lane road to a 4–lane road and to construct a new north-south 2-lane bus Transitway running parallel to the rail line in the vicinity of Fallowfield Road. In conjunction with the project, a new level grade crossing would have to be constructed for Fallowfield Road.

The DSA indicated the following:

- The proposed level grade crossing would be complex and would push the limit for normal design in a number of areas, including the close proximity of the Fallowfield Road / Transitway intersection, the crossing angle, traffic volumes and high driver workload. Subsequently, the City engaged Delphi-MRC to conduct a "road safety oriented" peer review of the preliminary crossing design. The peer review detailed the following:
    - The design option for Fallowfield Road provided a workable solution to a difficult situation in which substantive constraints and impediments existed. The option provided a reasonable basis for handling anticipated train and traffic volumes, but would also require careful long-term management and monitoring.
    - A number of formal recommendations and endorsements of actions were planned, but not clearly indicated in the preliminary drawings.
    - A number of suggestions were made relating to the risk management of the ongoing maintenance and operation of the crossing. While these were not formally identified as recommendations, given the complexity of this crossing, the peer review recommended that they also be implemented. For example, the peer review strongly recommended investigating the potential for improving the various warning and traffic control measures associated with the crossing using the driver simulation laboratory at the University of Calgary.
- The City conducted a traffic survey at the Fallowfield Road crossing in May 2004. At the time, daily roadway traffic comprised approximately 20 000 vehicles. Using a growth factor of 2.8%, the traffic volume on Fallowfield Road was predicted to increase to about 23 000 vehicles within 5 years (2009).
- In the future, an intersection between Fallowfield Road and the southwest Transitway would be constructed immediately east of the proposed crossing. No turns to or from the Transitway would be permitted from Fallowfield Road.
- The horizontal alignment of Fallowfield Road was within the SSD as the road was straight in both directions.
- The maximum size vehicle permitted to operate on Ontario roads was a B-train double (BTD) otherwise known as a semi-tractor hauling 2 trailers. As BTDs hauling gasoline regularly used Fallowfield Road, a BTD with a length of 25 m (82 feet) was selected as the design vehicle.

- Based on the Fallowfield Road design speed of 80 km / h, the SSD for trucks (and buses) was 210 m (689 feet). For the posted speed limit of 60 km / h, the recommended SSD was 130 m (427 feet).
- The vehicle travel distance for the Fallowfield Road crossing was 57 m (187 feet).
- The vehicle departure time for the design vehicle on the Fallowfield crossing was 17.5 seconds and was within the time provided by the grade crossing warning system.
- For a vehicle stopped at the crossing, the existing sightlines were adequate.
- The construction of the 4-lane section of Fallowfield Road over the crossing will reduce driver workload, particularly for the approach for eastbound traffic, which currently reduces from 2 lanes to 1 lane immediately west of the crossing.
- The rail crossing was at an acute angle of 33 degrees, which was less than the minimum 45 degrees specified in RTD 10 for new construction. Options to realign Fallowfield Road to produce a more favourable angle were explored, but were deemed to be unfeasible. As a result of the crossing angle, the grade crossing clearance distance was greater than usual. The acute angle required motorists to look back over their right shoulders in order to view any trains approaching from behind and to the right.
- The proposed Transitway intersection, adjacent to the crossing, would also be at an angle less than standard for new construction, resulting in a combined length of about 100 m (328 feet) for motorists to traverse both the Transitway and the crossing.
- A single roadway stop line for the crossing, in conjunction with a traffic pre-signal interconnected with crossing AWDs, would reduce confusion for eastbound traffic. When a pre-signal is activated, westbound traffic and eastbound traffic would receive an amber traffic signal light followed by a red traffic signal with a minimum 13-second duration prior to the activation of the crossing AWDs. This redundancy would reduce driver workload as all vehicles would either be stopped or clear of the crossing when the crossing lights are activated.

The DSA recommendations included:

- The risk management recommendations identified by the peer review relating to the ongoing monitoring and maintenance of the crossing should be implemented.
- The next DSA should be conducted in 5 years (2009 / 2010) unless required earlier by some other event.

The DSA concluded that safety could not be guaranteed. However, if the recommendations contained in the peer review and the DSA were implemented, and the detailed design was carried out in accordance with RTD 10, the crossing would have a high level of safety.

1.13.5 Road and crossing construction

In May 2005, construction commenced for the Woodroffe Avenue twinning between Fallowfield Road and the Nepean Sportsplex, for the Transitway from the OC Transpo Fallowfield Station to the Nepean Sportsplex and for the Fallowfield Road twinning between

Woodroffe Avenue and Greenbank Road. The road construction was conducted in accordance with City guidelines and the 1999 TAC *Geometric Design Guide for Canadian Roads*.

On 25 July 2005, the City contracted CN to install level grade crossings at Woodroffe Avenue (Mile 3.28), at the Transitway (Mile 3.30) and at Fallowfield Road (Mile 3.88). The crossing construction was conducted in accordance with the DSAs, RTD 10 and established railway engineering standards and practices. Construction of the crossings and the roadways was completed by December 2005.

The design speed for the straight portion of the Transitway was 90 km / h. The design speed for the curved portion of the Transitway just south of the crossing was 80 km / h. The curved portion of the Transitway was assigned a posted speed limit of 60 km / h. According to the TAC, the SSD for a bus (or truck) on a road with a design speed of 80 km / h is 210 m (689 feet) and 130 m (427 feet) for a design speed of 60 km / h.

1.13.6 Crossing positive guidance analysis

The City contracted Delphi-MRC in conjunction with the University of Calgary to conduct a crossing positive guidance analysis for the Fallowfield Road railway crossing and southwest Transitway roadway crossing. A detailed evaluation of driver behaviour and performance using a driving simulator was conducted. The information and observations were used to develop a positive guidance plan for road users of the Transitway roadway crossing and the VIA railway crossing that traversed Fallowfield Road.

In January 2007, the *Fallowfield Road at Grade Railway/Transitway Crossing Positive Guidance Analysis Final Report* was submitted. The report contained a guidance plan for the placement of signs and warning devices to assist roadway users with safely negotiating the crossings. The City committed to implementing the recommendations. In July 2009, construction commenced on the Transitway and extended south from the OC Transpo Fallowfield Station. This construction was completed in April 2011.

1.13.7 Engineering Review of Smiths Falls Subdivision – October 2010

In 2010, after VIA purchased the Smiths Falls Subdivision from CN, it contracted AECOM to undertake an engineering review of the planned speed improvements on the VIA Smiths Falls Subdivision. The engineering review included DSAs for all crossings on the Smiths Falls Subdivision.[26]

The review focused on safety, track, bridges, crossings, and signals. VIA had planned to increase passenger train speed up to 95–100 mph (153-161 km / h) wherever the infrastructure was found to be adequate. Where the infrastructure was not suitable for these speeds, the necessary next steps required to achieve the proposed speed increases were to be identified. The AECOM engineering review assessed each crossing to the RTD 10 standards and

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[26] AECOM, *Engineering Review of Planned VIA Speed Improvements on Smiths Falls Subdivision*, 18 October 2010.

requirements. The DSAs for the Woodroffe Avenue, Transitway, and Fallowfield Road crossings were completed by 11 September 2010. The results were generally similar to the DSAs conducted in 2004.

The AECOM report highlighted that the need for a grade separation is typically based on cross-product and that a cross-product greater than 200 000 generally warrants consideration for a grade separation. The report noted that

- the Woodroffe Avenue crossing (Mile 3.28) had a cross-product of 236 599 (11 trains X 21 509 vehicles);
- no vehicle data were available for the Transitway crossing (Mile 3.30); and
- the Fallowfield Road crossing (Mile 3.88) had a cross-product of 166 111 (11 trains X 15 101 vehicles).

The report suggested that VIA re-evaluate the information for Woodroffe Avenue with the City to confirm the cross-product as it was in the range requiring grade separation, yet the crossing met TC requirements. The report also recommended that VIA approach the City regarding potential plans for grade separation for Woodroffe Avenue.

1.13.8 Pre- and post-opening audits for the Fallowfield Road railway crossing and the Transitway roadway crossing

The City contracted Delphi-MRC to conduct audits of the Fallowfield Road / Transitway in November 2011 (pre-opening) and June 2012 (post-opening).[27, 28] Both audit reports indicated that the Fallowfield Road / Transitway crossing was a very unusual crossing. The pre-opening audit identified a number of measures that had been put in place and concluded that additional items may be accommodated after the opening. The pre-opening audit report also indicated that, when risks exist, interim mitigating measures should be considered. The post-opening audit concluded that, while most of issues identified had been dealt with, a number of issues still remained. The report recommended that the outstanding issues be dealt with, and the City subsequently mitigated the issues.

1.13.9 Risk assessment for train speed at Woodroffe Avenue, Transitway, and Fallowfield Road crossings

In 2012, the City received notification from VIA that it intended to move from the designated and required low-speed train operations through the Woodroffe Avenue, Transitway, and Fallowfield Road crossings to higher speed operations of up to 100 mph (160.9 km / h) for some of its trains. This increase in speed for some VIA trains represented a significant change in train operations at the crossings, raising concerns regarding the risk environment and the potential impact on safety at the crossings.

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27 Delphi-MRC in conjunction with Flood Murray International Incorporated, *Fallowfield Road-Transitway Crossing Pre-Opening Audit: Final Report*, 04 May 2011.

28 Delphi-MRC in conjunction with Flood Murray International Incorporated, *Fallowfield Road-Transitway Crossing Post-Opening Audit: Final Report*, 15 June 2012.

The City contracted Delphi-MRC to conduct a risk assessment for the increase in train speed.[29] The final report concluded in part:

- The Fallowfield Road grade crossing was already an exceptional crossing as the cross-product exceeded the 200 000 threshold typically used to trigger an examination of grade separation. The ultimate decision to proceed with the grade crossing at this location had been obtained primarily as a result of the City's technical review based on the assumption that trains would either stop at the VIA Fallowfield Station or slow down to 10 mph (16 km / h) as they travelled through the station.
- Planned growth in the Barrhaven area was expected to result in significant increases in traffic volume on Fallowfield Road. These forecasted traffic volumes would result in a cross-product that would be 2 to 3 times greater than the 200 000 threshold. This indicated that there would be a significant increase in risk at this level grade crossing.
- The Fallowfield Road crossing was a key link in the active transportation network for Barrhaven. Field observations indicated that young children were regular users of this crossing, warranting particular concern. Undesirable pedestrian and cyclist behaviours had been observed during field reviews, raising concerns regarding the safety of the level grade crossing when high-speed rail operations are present.

1.13.10 Draft detailed safety assessment for the Fallowfield Road Crossing – 2013

In 2013, VIA commissioned a DSA for the Fallowfield Road crossing.[30] This was triggered by a proposal to operate express trains daily that would not stop at the VIA Fallowfield Station, with an associated increase in the maximum train speed to 100 mph (160.9 km / h) over the crossing. The draft DSA noted that a number of changes had taken place since the previous DSA (2005). These changes included the construction of a siding between the Woodroffe Avenue and Fallowfield Road crossings and an increase in the posted speed limit on Fallowfield Road from 60 km / h to 80 km / h.

The DSA indicated the following:

- In March 2013, the City had conducted a traffic survey at the Fallowfield Road crossing. The results indicated that the AADT was 26 646. Using a 2.8% growth factor, the AADT on Fallowfield Road was predicted to increase to 30 600 within 5 years.
- The rail traffic at this location consisted of an average of 88 passenger trains per week and 4 freight trains per week for an average of 13 trains per day. There was a possible increase of 2 passenger trains in each direction within the next 5 years, which would bring the total number of trains to 17 per day.
- Based on an AADT of 26 646 and an average of 13 trains per day, the cross-product is 346 400. This is forecasted to increase to 520 200 within the next 5 years.

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[29] Delphi-MRC in conjunction with Flood Murray International Incorporated, *Fallowfield Road Crossing: Speed Increase Risk Assessment, Final Report*, October 2012.

[30] R. J. Fish, P. Eng., Jock Valley Engineering Ltd., Draft – Detailed Safety Assessment of the Fallowfield Road Crossing over the VIA Rail tracks at mileage 3.88 of their Smiths Falls Subdivision in Ottawa, Canada, 14 May 2013.

The DSA concluded that quantifying the level of risk for individual changes (increase in train speed) within a complex system such as the Fallowfield Road crossing with any degree of accuracy is difficult. However, in this situation, the increase in train speed could be done safely.

1.13.11 Other City of Ottawa planned grade separation projects

As of May 2015, the City had an active project to widen Greenbank Road (Mile 5.10, Smiths Falls Subdivision) and a project to widen Strandherd Drive (Mile 6.81, Smiths Falls Subdivision), which was on hold. The Greenbank Road project included a roadway underpass while the Strandherd Drive project included a roadway overpass.

Preliminary design for the Strandherd Drive overpass had begun in 2006. The City had forecasted that the 2013 AADT for Strandherd Drive would be 31 600 vehicles. With an estimate of 14 trains per day, the cross-product would be 442 400.

In 2013, the detailed design for the Greenbank Road underpass was being finalized and the project was scheduled to proceed to construction. The City had forecasted that the 2013 AADT for Greenbank Road would be 22 100 vehicles. With an estimate of 14 trains per day, the cross-product would be 309 400.

1.14 Present roadway and crossing information

In November 2011, VIA updated the crossings in the vicinity of the VIA Fallowfield Station. These improvements included upgraded signal circuitry and the replacement of the crossing incandescent lights (signal and gates) with LED lights.[31] LED signal light technology provides improved conspicuity of active signal lights.[32] LED lights have a much higher light output, are brighter and have a wider dispersion pattern, which makes them more visible than incandescent lights.[33] Both LED and incandescent bulb technologies continue to be acceptable for use in railway signal systems. Neither LED nor incandescent lights are polarized.[34]

1.14.1 Woodroffe Avenue and Transitway

The main track traverses the level grade crossings at Woodroffe Avenue (Mile 3.28) and the Transitway (Mile 3.30) at an angle of 50 degrees. The roadway approaches to both crossings have a grade of about 1%. Both crossings are equipped with AWD protection that includes flashing LED lights, bells, gates (FLBG) and CWT track circuits. Although listed as 2 separate crossings, by design, the crossing AWD protection functions as a single crossing.

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31 Many crossing signal lamps still use 18-watt incandescent bulbs. However, in Canada, LED lamp units have been increasingly used at signalized crossings.

32 TSB Railway Investigation Report R09V0219.

33 TSB Railway Investigation Report R08M0002.

34 Light may be polarized by reflection or by passing it through polarizing filters, such as certain crystals, that transmit light primarily in one plane.

Woodroffe Avenue is a 4-lane arterial municipal asphalt road that runs predominantly north / south and has a posted speed limit of 80 km / h. In the vicinity of the railway crossings, the roadway approaches are straight in each direction with approximately 2297 feet (700 m) of relatively clear view of the crossing AWDs. In 2013, the vehicle traffic on Woodroffe Avenue was recorded[35] to be an average of 30 396 vehicles per day.

The Transitway is a private 2-lane asphalt roadway. In 2013, the Transitway traffic averaged 1007 buses per weekday.[36] From the OC Transpo Fallowfield Station, the Transitway extends for 812 feet (247.5 m) eastward toward Woodroffe Avenue. From that point, the Transitway transitions into a significant left-hand curve (in the direction of travel) that turns sharply northward where it runs parallel to Woodroffe Avenue. At the time of the accident, from the stop sign at the station, the roadway speed limit was 60 km / h up to just north of the crossing, where the speed limit changed to 90 km / h. A standard advance warning sign was posted, warning vehicle drivers of the railway crossing ahead. There was no active advance warning light for northbound buses approaching the curve or for southbound buses approaching the crossing.

A 3.0 m-wide (10 feet) pedestrian / cyclist pathway is located parallel to Woodroffe Avenue, on the east side. The pathway is protected by cross bucks and crossing lights positioned beside the pathway and are visible to pedestrians. Barriers have been installed on the pathway on each side of the crossing to slow pedestrians and cyclists, as there are no gates protecting it.

1.14.2 Fallowfield Road and Transitway

Fallowfield Road is a 4-lane arterial municipal road that runs predominantly east / west and has an average traffic volume count of 25 412 vehicles per weekday.[37] The Fallowfield Road crossing is equipped with AWD protection that includes flashing LED lights, bells, gates and CWT track circuits.

The Transitway runs parallel to the railway tracks about 138 feet (42 m) east of the railway crossing.

Fallowfield Road has a posted speed limit of 80 km / h. In the vicinity of the crossing, the roadway approaches are straight in each direction with an estimated 2297 feet (700 m) of relatively clear view of crossing AWDs. The main track traverses the crossing at an angle of 33 degrees. The roadway approach to the Fallowfield Road crossing has a grade of about 1%.

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35 The TSB conducted a vehicle count survey between 30 September 2013 and 07 October 2013.

36 Idem.

37 Idem.

Photo 15. Fallowfield Road looking east (Source: Jock Valley Engineering)

The crossing (Photo 15) AWD protection is interconnected with the traffic lights at the crossing and with the signalized intersection of Fallowfield Road and the Transitway. The interconnection is equipped with a pre-emption circuit. Once the railway AWD sequence is initiated, the roadway traffic lights at the Transitway turn green to allow traffic in the vicinity of the crossing to clear the crossing. The traffic lights then turn amber for several seconds followed by red displayed for a minimum of 13 seconds after which the crossing AWDs activate and the lights begin to flash for about 12 seconds before the gates begin to descend. All vehicles should be stopped in advance of the crossing stop line on the road and clear of the crossing when the lights on the crossing warning system start to flash. The Fallowfield Road / Transitway traffic lights cannot be seen from the roadway stop line for the crossing, but are visible to drivers if their vehicle is beyond the stop line.

A 3.0 m-wide (10 feet) multi-use recreational pathway is located on the south side of Fallowfield Road. The pathway crossing is equipped with flashing lights, gates and a bell. The approaches to the pathway crossing are fenced to deter people from going around the gates. Gaps between the gates and the fence ensure proper clearance to the ROW, but do allow pathway users to bypass the gates.

At the time of the accident, the Fallowfield Road crossing AWDs were not activated nor were they required to be.

1.14.3 Signal circuitry and operation

When trains are stopped at the VIA Fallowfield Station, the signal circuitry was designed to not activate the crossing protection. In 2011, the circuit timing was shortened and train speeds were reduced to ensure that a train leaving the station in either direction would activate the AWDs and the Transitway roadway traffic pre-emption’s for the appropriate amount of time (minimum of 20 seconds).

CWT track circuits measure train speed for all trains approaching the station from either west of Fallowfield Road or east of Woodroffe Avenue. Based on the train speed, the system predicts the arrival time of the train at the crossing and activates the crossing AWDs accordingly to ensure that adequate warning time is provided.

With the crossing approaches equipped with CWT track circuits, there were no speed restrictions for trains arriving at the VIA Fallowfield Station. VIA trains that were slowing to stop at the station would still have been travelling between 40 and 50 mph (64 and 80 km / h) as they entered the crossings.

All AWD events involving lights, bells and gates were monitored, identified, recorded and time stamped in the crossing signal log files. Two independent devices (an analog and a digital system) would monitor the input signals, which provided redundancy for the system. The light flash repetition rate and the lamp current were also monitored to ensure that they fell within the design values.

Once activated, a crossing gate unlocks from its “up” position and begins to descend. The gate does not fall freely but is powered down from the “up” position. The system records when a gate descends past the 86-degree position referenced from the horizontal (90 degrees is fully upright and 0 degree is horizontal). Once a gate descends past the 10-degree position, the system records a gate as fully “down”.

The system also detects and records when a train enters and exits the island circuit.[38] Once a train exits the island circuit, the gates are commanded to rise. The system then records when a gate rises above the 10-degree position and above the 86-degree position, which is recorded as the “up” position. Once fully upright (90-degree position), the gate locks in position to prevent it from descending without a command and the crossing lights turn off.

Throughout this process, the system continues to monitor for a broken crossing gate using a loop of wiring that runs to the first light connector on the gate. If the loop is broken, the signal cannot pass back to the system, indicating that the gate is broken. Once a gate is indicated as being broken, the power down is released and the bracket assembly, which includes the gate and a counterweight, moves freely to the 45-degree position and then slowly returns to the fully upright position.

1.14.4 Train movements in the vicinity of the VIA Fallowfield Station

Eastbound movements on the main track, including eastbound trains departing from a station stop, were not authorized to exceed 15 mph (24 km / h) between the VIA Fallowfield Station (Mile 3.57) and the Woodroffe Avenue / Transitway public crossings at Mile 3.28 and Mile 3.30 until the crossings were occupied.

Westbound movements on the main track were not authorized to exceed 10 mph (16 km / h) between the VIA Fallowfield Station (Mile 3.57) and the Fallowfield Road crossing (Mile 3.88) until the crossing was occupied.

Eastbound movements stopped at Signal 34S (main track) and eastbound movements leaving the siding at Fallowfield East must transmit a code from the locomotive radio to

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38 The island circuit is the portion of the track circuit that is within the roadway and usually extends about 50 feet beyond the edge of the road or sidewalk.

activate the Woodroffe Avenue / Transitway crossing AWDs. A strobe light on the crossing signal bungalow adjacent the track would flash, indicating that the correct code had been entered. The crossing AWDs would start 33 seconds after. Movements could proceed as soon as the crossing AWDs were activated. The movement must have travelled past the controlled signal within 45 seconds of the activation. A similar process was in place for westbound movements that stopped at either signal (39N or 39S) at the west end of the VIA Fallowfield Station.

1.14.5 Inspection of crossing automatic warning devices

Prior to the accident, the most recent detailed inspection of the Woodroffe Avenue / Transitway crossings by a TC inspector had been conducted on 26 April 2012. This crossing inspection was also attended by a RailTerm signal supervisor and a signal maintainer. The inspection noted that the back short lights intended for vehicles stopped in the vicinity of the crossings were not aligned to the 49-foot (15 m) location on both the north and south side of the crossings. While the results of the inspection were provided verbally at the time, there was no record that TC provided written notification regarding this condition to either RailTerm or VIA. Similarly, there was no written record that the condition was subsequently corrected.

The crossing lights had been aligned upon installation of the LED lights on 03 November 2011. The crossing lights were again aligned on 28 September 2013 following the accident. Before the accident, RailTerm had been inspecting the crossing circuitry monthly and crossing activation was being tested weekly in accordance with regulatory requirements. No anomalies had been noted at these crossings.

1.15 Urban development in South Ottawa

Population estimates were obtained for the area bounded to the west by provincial Highway 416, to the north by Hunt Club Road, to the east by Bank Street and to the south by the City limits (Table 5).

Table 5. Population estimates (Source: City of Ottawa)

Area	2004	2010	2013	2020
Urban area only	75 945	103 389	116 761	142 000
Entire area	100 358	130 537	145 062	171 000

1.16 Traffic studies and cross-products

For a comprehensive understanding of railway and roadway traffic in the vicinity of the VIA Fallowfield Station, a review of the train information and the roadway information for Woodroffe Avenue, the Transitway, and Fallowfield Road was conducted. VIA train information (since 2004) is presented in Table 6.

Table 6. VIA historical number of trains

Location	2004 - Trains		2007 - Trains		2010 - Trains	
	Weekly	Avg/day	Weekly	Avg/day	Weekly	Avg/day
Woodroffe Avenue	67	10	102	15	102	15
Transitway	67	10	102	15	102	15
Fallowfield Road	67	10	67	10	67	10

For 2014, the average number of trains per week for the Woodroffe Avenue / Transitway crossings was 133 and for the Fallowfield Road crossing, it was 100 trains. However, between Monday and Friday each week, these crossings recorded up to 23 and 16 trains per day respectively, while weekend traffic comprised 12 trains per day.

1.16.1 Historical traffic for Woodroffe Avenue, the Transitway, and Fallowfield Road

Historical road traffic count surveys for Woodroffe Avenue, the Transitway, and Fallowfield Road in the vicinity of the VIA rail crossings was compiled. The average annual daily traffic (AADT) values were derived using the City of Ottawa expansion / AADT factors (Table 7).

Table 7. Historical traffic for Woodroffe Avenue, Transitway, and Fallowfield Road

Location	Day	Date	12-hour count	Average annual daily traffic
Woodroffe Avenue	Wednesday	19 May 2004	15 405	18 163
	Wednesday	16 May 2007	18 944	22 335
	Wednesday	16 June 2010	21 335	25 154
Transitway	Wednesday	16 June 2010	372	390
Fallowfield Road	Monday	19 July 2004	10 327 (8-hour count)	18 795
	Friday	18 May 2007	11 498 (8-hour count)	16 787
	Friday	23 July 2010	11 821 (8-hour count)	19 387

1.16.2 Post-accident traffic study

Following the accident, at the request of the TSB, the City conducted a traffic study for Woodroffe Avenue, the Transitway, and Fallowfield Road. The study was conducted between 30 September 2013 and 07 October 2013. An estimate of the average number of occupants per vehicle was also obtained. This information is summarized in Table 8.

Table 8. Average number of vehicles in October 2013, by location

Location	Mon. 24 hr	Tues. 24 hr	Wed. 24 hr	Thurs. 24 hr	Fri. 24 hr	Sat. 24 hr	Sun. 24 hr	Mon.–Fri. Average	7-day average
Woodroffe Avenue	28 898	30 795	30 528	30 933	30 828	28 217	21 775	30 396	28 853
Transitway	1 009	989	1 003	1 018	1 016	449	422	1 007	844
Fallowfield Road	24 693	25 496	25 494	25 994	25 385	20 419	15 156	25 412	23 234

Data source:
Post-accident traffic study (daily vehicle counts)

Based on the cross-product and the average number of vehicle occupants, an "occupant cross-product"[39] was calculated for each crossing (Table 9).

Table 9. Crossing, vehicle and occupant cross-product results

Location	Number of trains 2014	Mon.-Fri. Average number of vehicles	Cross-product (trains x vehicles)	Average number of vehicle occupants	Occupant cross-product (trains x vehicles x occupants)
Woodroffe Avenue	23	30 396	699 108	1.08	755 036
Transitway	23	1 007	23 161	32	532 703
Fallowfield Road	16	25 412	406 592	1.08	439 119

1.17 *Ontario Regulations and the* Ontario Highway Traffic Act

In the Province of Ontario, buses and other public vehicles are required to stop at level grade crossings that are not protected by AWDs, while school buses must stop at all railway crossings. Ontario Regulation 339/94 outlines the demerit point system while the *Ontario Highway Traffic Act* (OHTA) sets forth the rules of the road and the penalties for non-compliance when operating a vehicle on public roadways in Ontario. However, the OHTA does not apply to vehicles operating on private roads such as the Transitway.

1.17.1 Section 8 – Ontario Regulation 339/94 (demerit point system)

Section 8 of Ontario Regulation 339/94 states in part

> (1) If a person who is a fully licensed driver in Ontario in one or more licence classes or a person who is not a resident of Ontario has 9, 10, 11, 12, 13 or 14 accumulated demerit points, the Registrar may require the person to attend an interview before a Ministry official and to provide information or other evidence to show cause why his or her driver's licence should not be suspended. O. Reg. 339/94, s. 8 (1).

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39 Although not commonly used in the industry, an occupant cross-product can be used to more precisely identify risk and exposure.

> (2) The Minister may suspend or cancel the person's driver's licence,
>
> (a) if the person fails to attend the required interview; or
>
> (b) if the person does not comply with the Ministry's requirements as a result of the interview; or
>
> (c) if, in the Minister's opinion, the person has not shown cause at the interview why the licence should not be suspended. O. Reg. 339/94, s. 8 (2); O. Reg. 204/10, s. 4.

1.17.2 Section 78 – Distracted driving

In an effort to reduce instances of distracted driving, the Province of Ontario enacted distracted driving legislation on 26 October 2009 that banned the use of display screens and hand-held devices while driving. The law made it illegal for drivers to talk, text, type, dial or email using hand-held cell phones and other hand-held communications and entertainment devices. The law also prohibited drivers from viewing display screens unrelated to the driving task, such as laptops or DVD players, while driving.

Section 78 of the OHTA states in part

> (1) No person shall drive a motor vehicle on a highway if the display screen of a television, computer or other device in the motor vehicle is visible to the driver.
>
> Exceptions
>
> (2) Subsection (1) does not apply in respect of the display screen of,
>
> (a) a global positioning system navigation device while being used to provide navigation information;
>
> (b) a hand-held wireless communication device or a device that is prescribed for the purpose of subsection 78.1 (1);
>
> (c) a logistical transportation tracking system device used for commercial purposes to track vehicle location, driver status or the delivery of packages or other goods;
>
> (d) a collision avoidance system device that has no other function than to deliver a collision avoidance system; or
>
> (e) an instrument, gauge or system that is used to provide information to the driver regarding the status of various systems of the motor vehicle.

The law permits exemptions for drivers of certain commercial vehicles, which includes bus drivers, provided that the video screen is securely mounted in the vehicle and its use is considered to be essential for the operation of the vehicle.

All provinces have some form of distracted driving legislation in place. With the rapid development of technology and in-vehicle displays, distracted driving is an emerging safety issue. For example, the Ontario Provincial Police (OPP) notes that distracted driving is the number one killer on roads. Statistics show that more people in Ontario died in distracted driving-related crashes in 2013 than in any other type of crash. The OPP said that, for roads patrolled by the force, there were

- 78 fatalities related to distracted driving;
- 57 fatalities related to impaired driving; and
- 44 fatalities related to speed.[40]

The OPP states that

> Distracted Driving continues to be a serious issue on our roads and is a danger to all road users. Distracted driving qualifies as talking on a cell phone, texting, reading (e.g., books, maps, and newspapers), using a GPS, watching videos or movies, eating / drinking, smoking, personal grooming, adjusting the radio / CD and playing extremely loud music. Even talking to passengers and driving while fatigued (mentally and / or physically) can be forms of distracted driving.[41]

1.17.3 Section 128 – Rate of speed

Section 128 of the OHTA states in part

> (1) No person shall drive a motor vehicle at a rate of speed greater than,
>
> [...]
>
> (d) the rate of speed prescribed for motor vehicles on a highway in accordance with subsection (2), (5), (6), (6.1) or (7);
>
> [...]
>
> Rate of speed by by-law
>
> (2) The council of a municipality may, for motor vehicles driven on a highway or portion of a highway under its jurisdiction, by by-law prescribe a rate of speed different from the rate set out in subsection (1) that is not greater than 100 kilometres per hour and may prescribe different rates of speed for different times of day.

Under these requirements, the City sets speed limits for municipal public roadways within City limits that can be enforced under the OHTA.

1.17.4 Section 163 – Vehicles required to stop at railway crossing signal

Section 163 of the OHTA states

> (1) When the driver of a vehicle is approaching a railway crossing at a time when a clearly visible electrical or mechanical signal device or a flagman is

[40] CBCnews (on line), *OPP calls distracted driving 'number one killer on roads'*, March 2014, available at: http://www.cbc.ca/news/canada/kitchener-waterloo/opp-calls-distracted-driving-number-one-killer-on-roads-1.2557892 (last accessed 28 September 2015).

[41] Ontario Provincial Police website, *Distracted Driving*, available at: http://www.opp.ca/ecms/index.php?id=545 (last accessed 28 September 2015).

> giving warning of the approach of a railway train, he or she shall stop the vehicle not less than 5 metres from the nearest rail of the railway and shall not proceed until he or she can do so safely. R.S.O. 1990, c. H.8, s. 163.
>
> Stop signs at railway crossings
>
> (2) Every driver of a vehicle approaching a stop sign at a railway crossing shall, unless otherwise directed by a flagman, stop the vehicle at the marked stop line or, if none, then not less than five metres from the nearest rail of the railway, and shall not proceed until he or she can do so safely. 2002, c. 18, Sched. P, s. 30.

1.17.5 Section 164 – Driving of vehicles under crossing gates prohibited

Section 164 of the OHTA states

> No person shall drive a vehicle through, around or under a crossing gate or barrier at a railway crossing while the gate is closed or is being open or closed.

1.18 *Ministry of Transportation of Ontario* Official Driver's Handbook

The Ministry of Transportation of Ontario (MTO) *Official Driver's Handbook* contains guidance related to railway crossing safety that is summarized below:

- Railway crossings on public roads in Ontario are marked with red and white "X" signs. Drivers should watch for these signs and be prepared to stop. There are also yellow advance warning signs and the pavement is marked with a large X on approaches to railway crossings.
- Some crossings have flashing signal lights while some use gates or barriers to keep drivers from crossing the tracks when a train is coming. Buses and other public vehicles are required to stop at railway crossings that do not have AWD protection such as barriers and signal lights.
- School buses must stop at all railway crossings whether or not they have AWDs. Drivers must be prepared to stop behind these vehicles and obey all signs and signals.
- Drivers should remember that it can take up to 2 km for a train to stop under full emergency braking.
- Approaching a railway crossing, drivers should consider the following:
    - Slow down, listen and look both ways to make sure the way is clear before crossing the track.
    - Stop at least 5 m (16.4 feet) from the nearest rail or gate if a train is coming. Do not cross the track until it is certain that the train or trains have passed.
    - Never race a train to a crossing.
    - If there are signal lights, wait until they stop flashing and, if the crossing has a gate or barrier, wait until it rises, before crossing the tracks.
    - Never drive around, under, or through a railway gate or barrier while it is down, being lowered, or being raised. It is illegal and dangerous.

- Never stop in the middle of railway tracks. For example, in heavy traffic, make sure to have enough room to cross the tracks completely before beginning to cross.
- Do not shift gears while crossing tracks.
- If the vehicle gets trapped on a crossing, immediately get everyone out and away from it. Move to a safe place and then contact authorities.

Drivers are trained to observe the roadway signage and take appropriate action as required. Among the primary roadway signs are regulatory signs, which include the STOP, YIELD and RAILWAY CROSSING signs (Figure 9, Figure 10 and Figure 11). The railway crossing sign is X-shaped. With its white background and red outline, it has similar colouring to a yield sign and means essentially the same thing. As outlined in the MTO *Official Driver's Handbook*, the railway crossing sign warns that railway tracks cross the road and drivers should **slow down when approaching a crossing**, be prepared to stop and yield the right-of-way to a train.

Figure 9. Stop sign

Figure 10. Yield sign

Figure 11. Crossing sign

Drivers convicted of driving-related offences receive demerit points on their driving records that stay there for 2 years from the date of the offence. The aim of the demerit point system is to encourage drivers to improve their driving performance and to protect other road users from unsafe drivers. If drivers accumulate 15 demerit points, regardless of the vehicle type driven, their licence will be suspended. School bus drivers in the Province of Ontario (Class B and E licence holders) may have no more than 8 demerit points. Once school bus drivers accumulate 9 demerit points or more, their licence is downgraded and they are no longer permitted to drive a school bus.

1.19 City of Ottawa by-laws

1.19.1 By-law 2007-268 – Public Transit

The operation of vehicles on the Transitway is governed by the City of Ottawa By-law 2007-268 respecting public transit enacted 13 June 2007. The by-law permits enforcement of speed limits on the Transitway by police officers, special constables or municipal law enforcement officers. However, in practice, the Ottawa Police Service does not enforce speeds on the Transitway because it is a private road and as such is not enforceable under the OHTA. Enforcement on the Transitway generally falls to OC Transpo special constables. Speeding on the Transitway is considered a by-law infraction and does not result in demerit points being added to a driver's licence.

The by-law contains no provisions for the following situations:

- stopping at a railway crossing when the crossing signals are activated;
- driving through, around or under a crossing gate; and
- using hand-held communications and entertainment devices or viewing video display screens unrelated to the driving task.

1.19.2 Anti-whistling by-law

On 06 November 1987, the CTC approved an application from the City of Nepean (now a suburb of Ottawa) to prohibit the sounding of a locomotive horn at the 6 crossings in Barrhaven. The following instruction has been in place in VIA timetables since that time:

> Except to prevent an accident or in case of emergency, the sounding of whistle is prohibited at the following crossings at grade:
>
> - Mile 1.63 - Merivale Road
> - Mile 3.28 - Woodroffe Avenue*
> - Mile 3.88 - Fallowfield Road
> - Mile 5.10 - Greenbank Road
> - Mile 5.73 - Jockvale Road
> - Mile 6.81 - Strandherd Road
>
> * only from the hours of 20:01 to 11:59

1.20 Operation Lifesaver

Operation Lifesaver (OL) is a national public awareness program aimed at educating Canadians about the hazards surrounding rail property and trains. Its main goal is to prevent collisions between trains and motor vehicles and to prevent trespassing incidents that lead to serious injury or death. OL responds to individual requests and makes over 500 presentations per year to a variety of interested parties. In Canada, OL has contributed to the reduction in railway crossing accidents.

In 2007, the Advisory Panel for the *Railway Safety Act* Review acknowledged that an educational component was an integral part of a multi-faceted approach to rail safety. The committee stated that “more than 50 per cent of crossing accidents occur at crossings equipped with active warning systems,” and therefore, “technology by itself is obviously not sufficient to solve existing crossing safety problems, but must be coupled with robust outreach and public education programs, and an understanding of human behaviour.”

OL publishes tips for drivers to improve safety in the vicinity of railway crossings. A module has been developed specifically for school bus drivers and could be modified for transit drivers. The tips include advice that they turn off audio equipment and fans, silence passengers, open the driver’s window and service door, and look and listen for an approaching train before deciding whether to cross railway tracks. Drivers are reminded to be especially careful at crossings without gates, flashing lights or bells.

OL indicates that opportunities for improving crossing safety include: education for vehicle drivers on risks associated with railway crossings, engineering to improve crossing protection, and enforcement of crossing violations to reinforce safe driving habits. A weakness in one or more of these elements at a crossing may increase the risk of a crossing accident.

OC Transpo was aware of OL, but had neither received nor sought any targeted railway safety education before the accident.

1.21 Bus driver licensing requirements

To drive a bus in the Province of Ontario, a driver must possess a valid Ontario Class "C" (commercial) driver's licence with "Z" (air brake) endorsement (C/Z). Commercial drivers (e.g., bus) are also required to meet more stringent medical standards than regular drivers for visual acuity, horizontal visual field and hearing. The requirements of the MTO commercial driver's licence medical exam are based on Canadian Council of Motor Transport Administrators (CCMTA) national medical standards.[42] These standards were developed by medical advisors and administrators from Canadian provincial driver licensing bodies. Many of the standards are adapted from the Canadian Medical Association (CMA) *Determining Medical Fitness to Operate Motor Vehicles*.[43] Commercial drivers under the age of 46 are required to submit a medical report every 5 years. Drivers aged 46 to 64 are required to submit a medical report every 3 years. Drivers aged 65 and older are required to submit a medical report annually.

At the time of the accident, OC Transpo required that, upon hire, all new bus drivers have at least a Class G (general) driver's licence, with no demerit points received in the preceding 3-year period. Prior to being trained to operate OC Transpo buses, new drivers who did not already hold a commercial vehicle licence were required to obtain a temporary Class C vehicle licence before being given instruction and testing to assist them in obtaining a full MTO Class C/Z licence. All drivers were required to maintain their Class C/Z licence to remain employed. OC Transpo also required all candidate bus drivers to undergo a pre-employment physical exam by a physician. No subsequent medical exams were required, other than those required by provincial commercial driver licensing requirements.

Section 1.2 of the CCMTA Medical Standards for Drivers states that "colour [vision] deficiency has not proven to be an important driving hazard however all drivers must should [*sic]* be able to discriminate between the different traffic lights."[44] OC Transpo and

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42 Canadian Council of Motor Transport Administrators (CCMTA), *CCMTA Medical Standards for Drivers*, March 2009, available at: http://static1.1.sqspcdn.com/static/f/365523/10268843/1295286504923/medical_standard_2009.pdf?token=WJdZ6lSz3hKhWLJu79PJamUd3D8%3D (last accessed 28 September 2015).

43 Canadian Medical Association (CMA), *CMA's Driver's Guide: Determining Medical Fitness to Operate Motor Vehicles, 8th edition*, 2013, available at: https://www.cma.ca/En/Pages/drivers-guide.aspx (last accessed 28 September 2015).

44 Canadian Council of Motor Transport Administrators (CCMTA), *Determining Driver Fitness in Canada*, Part 2: CCMTA Medical Standards for Drivers, August 2011 edition.

MTO commercial driver's licence requirements did not specify that a driver must have normal colour vision.

1.22 OC Transpo driver training

When the occurrence driver was hired in 2005, OC Transpo provided a 6-week (30-day) New Bus Operator Training (NBOT) program that included a Canada Safety Council defensive driving course, a driver's licence written exam, as well as information, procedures and practice with braking on a bus, followed up by performance observations and daily progress reports. The NBOT defensive driving training consisted of lessons in accident prevention, driver fatigue and stress, negotiating intersections (including railway crossing procedures), passing, and consideration of other road users. Drivers were advised to adopt a minimum eye-lead time[45] of 12 to 15 seconds for urban areas and a minimum eye-lead time of 20 seconds, or as far as possible, for rural areas and highway driving. Daily road training trips throughout the City were also conducted in a bus during the course. These trips were coached, observed and evaluated by an on-board instructor. The NBOT training has been expanded since 2005 to include some additional crossing information.

Drivers were coached to begin braking far enough ahead of the planned stop so that smooth braking would be possible. They were instructed that one single braking action was required (not several small brake applications, which would make the braking jerky) to the point of almost stopping, at which time the driver should "ease off the brake pedal slightly in order to avoid the bump" at the end of the brake application. The normal brake application was then completed by a final depression of the brake pedal.

Although various points related to crossing safety were discussed and practised during training, the crossing safety curriculum was not as comprehensive as that available through OL.

1.22.1 OC Transpo driver recurrent training and qualification

In addition to the NBOT, a recurrent training program (Pro-in-Motion) was a 3-day refresher course that drivers were required to attend every 3 years. This course included facilitated sessions with guest speakers and transit training instructors on driver improvement. Pro-in-Motion also incorporated the SmartDRIVER program (1 day) that focused on efficient, safe driving techniques linked to previously learned defensive driving skills with an emphasis on smooth braking to enhance passenger comfort and safety as a key principle.

During Pro-in-Motion training, OC Transpo drivers were instructed to "hover" their foot over the brake pedal as they approached a level crossing (until the point at which the driver felt that they could no longer stop safely), scan the tracks and, if it was safe to cross, depress the accelerator pedal to clear the tracks. Drivers were evaluated by trainers during the driving portion of Pro-in-Motion training.

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45 Eye-lead time is a time measurement of how far a person scans the roadway ahead when driving in order to safely react to any hazards that may arise.

The driver had completed on-road coaching sessions in 2006 and in 2009. The driver had also completed the Pro-in-Motion training in May 2013. No exceptions were noted during the coaching sessions and training.

1.22.2 OC Transpo double-decker bus training

In September 2012, when OC Transpo introduced the ADL E500 double-decker bus to its fleet, OC Transpo drivers were provided with a full-day, in-class / on-road training session to familiarize themselves with the new bus. The training included components related to

- bus specifications and braking system;
- vehicle start-up and shut-down;
- overhang and undercarriage clearance;
- vehicle driver console, including the various warning lights and switches;
- use of rear-view mirror affixed to the front windshield to monitor the bus interior on the lower deck; and
- service stop requirements and use of the video monitor.

Unlike the rest of the OC Transpo bus fleet, ADL E500 double-decker buses were equipped with a video monitor that provided the driver with interior views and exterior views of the bus. OC Transpo provided drivers with the following guidance relating to the use of these monitors:

- Drivers were instructed not to stare at the video monitor while driving.
- While the bus was in motion or stopped, passengers could move throughout the bus without restriction.[46]
- Drivers were required to view the monitor before departing from a station stop to ensure that exits were clear and upper deck passengers were seated.
- While in service, drivers were to ensure that passengers were seated or standing on the bus as follows:
    - upper deck: seated load only, no standees;
    - lower deck: seated load, standees can safely and reasonably occupy available floor space.[47]
- If passengers were seen to be standing on the upper deck, drivers were required to make an announcement on the bus public address (PA) system informing the passengers that standing was not permitted on the upper deck or in the stairwell.[48, 49] However, the guidance provided did not clearly state whether the PA announcement had to be made while the bus was stopped or in motion. Some drivers were under the

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46 OC Transpo, OC Transpo Double-Decker Buses – Regular Operational Procedures, Standard Operating Procedure TOPC-Q080-02-SOP, dated 16 November 2012, Section 4.0.2.

47 Ibid., Section 4.1.1.

48 Ibid., Section 4.0.4.

49 OC Transpo, OC Transpo Driver Training Sign-Off Sheet, dated 19 September 2012.

impression that an announcement had to be made whenever a passenger was observed standing on the upper deck or in the stairwell.

During the on-road portion of this training, each driver was evaluated by a trainer. The drivers were required to make at least 3 service stops, during which the trainer verified that the drivers viewed the video monitor before departing from each stop. At one of the stops, drivers were required to make an announcement on the PA system informing passengers that standing on the upper deck or in the stairwell was not permitted while the bus was in motion.

The on-road training also covered emergency braking. At a slow speed, each driver was required to stop the bus using the parking brake, which could also be used as a functioning emergency brake to bring the bus to a stop in the event that other braking systems malfunctioned.

1.23 The driver

In April 2005, the driver had undergone a pre-employment physical exam and was certified as medically fit. When hired in May 2005, the driver had met all OC Transpo pre-employment requirements. In June 2005, the driver passed the OC Transpo NBOT final exam. In September 2005, the driver completed the training by obtaining an MTO Class C / Z licence and had been driving for OC Transpo since that time. At the time of the accident, the driver was 45 years old, met all medical requirements and held a valid MTO Class C / Z licence.

On 19 September 2012, the driver completed the ADL E500 bus training. The driver was evaluated as having carried out each required task successfully.

The driver had not accumulated any more than 4 demerit points within a 2-year period since receiving his Class C / Z driver's licence. The number of demerit points and the number of incidents reported to OC Transpo for this driver was considered typical as compared to other OC Transpo drivers.

Between 01 September 2012 and the day of the accident, the driver had worked a total of 407 shifts, 67 (16%) of which were driving the ADL E500 bus.

In the 12-month period preceding the accident, the driver had driven various routes southward over the Transitway crossing 16 times and northward over it 44 times. During these bus trips, it is not known how many times the driver had encountered a train at the crossing, but it is likely that these encounters would have rarely occurred.

1.23.1 Colour vision defect

The driver had a congenital, red-green colour vision defect that had been identified during the 2005 OC Transpo pre-employment medical exam. Although the OC Transpo exam screened prospective drivers for colour vision deficits, neither OC Transpo nor the MTO require drivers to have normal colour vision.

Red-green colour vision defects are the most common type of congenital colour vision deficiency, and are found in approximately 8% of the male Caucasian population.[50] The label "red-green" is used because these individuals have difficulty in discriminating between hues in the red-green region of the hue circle. Within the red-green colour deficiency group, there are 2 subtypes that can vary in severity: deutan and protan colour vision defects.

1.23.1.1 Deutan colour vision defect

For drivers with a deutan colour vision defect, research has shown that the mean visual range and brightness sensitivity for red traffic lights is between 90% and 95% that of drivers with normal colour vision.[51]

1.23.1.2 Protan colour vision defect

Drivers with a protan colour vision defect represent approximately 1% of Caucasian males. These drivers not only confuse certain coloured lights but also have decreased brightness sensitivity to red lights by as much as 60%.[52] Red lights appear much dimmer to drivers that have a protan colour vision defect when compared to drivers that have a deutan colour vision defect or normal colour vision.

The decreased brightness sensitivity to red lights among drivers with the protan colour vision defect can result in shorter sighting distances and slower reaction times to red lights.[53] To some extent, the design of traffic lights has compensated for the decreased sensitivity by making the red lights brighter and standardizing their location in the top position of the light arrangement. However, the reaction time of drivers with the protan colour vision will still be slightly slower.[54]

Based on the vision screening test results, there was a greater than 90% probability that the driver had a deutan colour vision defect.[55]

1.23.2 Driver's sunglasses

At the time of the accident, the driver was wearing polarized sunglasses with a dark vermillion (reddish-brown) tint. This type of sunglasses is promoted for drivers because of

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50 J. Birch, "Worldwide prevalence of red-green color deficiency", *Journal of the Optical Society of America*, Volume 29, Issue 3, 01 March 2012, pp. 313-320.

51 B.L. Cole, "Protan colour vision deficiency and road accidents", *Clinical and Experimental Optometry*, Volume 85, Issue 4, July 2002, pp. 246-253.

52 Ibid.

53 G. Verriest, O. Neubauer, et al., "New investigations concerning the relationships between congenital colour vision defects and road traffic security", *International Ophthalmology*, Volume 2, Issue 2, 1980, pp. 87-99.

54 B.L. Cole, "Protan colour vision deficiency and road accidents", *Clinical and Experimental Optometry*, Volume 85, Issue 4, July 2002, pp. 246-253.

55 J. Birch, "Efficiency of the Ishihara test for identifying red-green colour deficiency", *Ophthalmic and Physiological Optics*, Volume 17, Issue 5, September 1997, pp. 403-408.

its ability to reduce glare reflected from horizontal surfaces such as the roadway and other vehicles, and for its contrast enhancement. The dark vermillion tint of the sunglasses would absorb more light in the green region of the visible spectrum, followed by the light absorbed in the blue region. The least amount of light would be absorbed in the red region, which would make the red light appear relatively brighter.

1.23.3 Previous neck injury

In July 2007, the driver had sustained a neck injury, which at the time caused significant pain and some restriction in neck motion. Since the injury did not limit the driver's ability to steer a bus or apply the brakes, OC Transpo accommodated this injury by allowing the driver to work part time. In January 2009, OC Transpo assessed the driver as being medically fit for full-time work duties. In January 2012, following a mild flare-up of the injury, the driver saw a doctor. Since that time, there had been no subsequent problems or visits to a doctor for the injury.

1.23.4 Diabetes

The driver had Type 2 diabetes, which had been reported to the MTO on the driver's most recent (March 2010) medical report. The report indicated that the diabetes was being treated with diet alone and that the driver had never experienced hypoglycemia or loss of consciousness due to hypoglycemia. Since the last medical, the driver had been prescribed medication (metformin) to help manage the diabetes.

Diabetes is a disease in which blood glucose (sugar) levels are not kept in a normal range. The body of a diabetic either does not produce enough insulin or cannot use its own insulin as well as it should. This causes sugar to build up in the blood. Type 2, or "adult-onset", diabetes can affect people at any age. Treatment for Type 2 diabetes includes making healthy food choices, being physically active, controlling one's blood pressure and cholesterol levels, and using diabetes medicines.[56]

According to the CCMTA Medical Standards for Drivers, individuals with diabetes are at risk for the development of neurological, cardiovascular and ophthalmologic complications that can interfere with driving ability. Yet, diabetic individuals must meet the same standards in these areas as all other drivers. The major concern in diabetes and driving is that a driver may experience an episode of hypoglycemia, or low blood sugar, which could cause a driver to become incapacitated or unconscious.

The CCMTA also advises that diabetics who are treated by either diet or a single oral diabetes medication are not at an elevated risk of being involved in a collision. In the Province of Ontario (and elsewhere in Canada), drivers with diabetes who are treated with diet alone, or oral medication provided they are not subject to hypoglycemia, can be

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[56] National Institute of Diabetes and Digestive and Kidney Diseases, *Your Guide to Diabetes: Type 1 and Type 2*, 12 February 2014, available at: http://www.diabetes.niddk.nih.gov/dm/pubs/type1and2/index.aspx (last accessed 28 September 2015).

considered for any class of driver's licence, provided there are no disqualifying complications that adversely affect driving ability.

1.23.5 Toxicology testing and other related examinations

Toxicology testing and other related examinations determined that there was

- no medical illness involved in the driver's death;
- no evidence of hyperglycemia;
- no medical evidence that the driver suffered an episode of hypoglycemia before the collision;
- no trace of diabetes medication in the driver's system, suggesting that the driver's blood sugar had been stable in the days preceding the accident; and
- no trace of drugs or alcohol in the driver's system.

1.24 Fatigue

Performance decrements associated with fatigue are established as significant risk factors and predictors of occupational accidents and injuries.[57] These risk factors can include, for example, slowed (or no) reaction time, reduced vigilance, impaired decision-making ability, inability to concentrate, poor judgment, poor memory, distraction, and loss of awareness in critical situations.[58] These risk factors can be influenced by fatigue.

Normal healthy adults need between 6 and 9 hours of sleep each night to feel well rested and to be able to maintain vigilance throughout the day, with the average being between 7 and 8 hours per night.[59] Anything less can result in a sleep debt and potentially lead to fatigue. Long-term sleep debt can manifest itself as chronic fatigue.

Time of day has a strong effect on alertness and performance due to changes in body physiology known as circadian rhythm. This 24-hour physiological rhythm allows the body to gear itself for action during the day and for recuperation at night. The body is physiologically ready for sleep at night, and the best quality and longest sleep is obtained at night.[60]

For tasks that are monotonous but continually demanding of attention, such as highway driving, performance closely follows that of the body temperature rhythm. Because of

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57 D. Dawson, Y.I. Noy, et al., "Modelling fatigue and the use of fatigue models in work settings", *Accident Analysis & Prevention*, Volume 43, Issue 2, March 2011, pp. 549-564.

58 S.E. Lerman, E. Eskin, et al., "Fatigue risk management in the workplace", *Journal of Occupational and Environmental Medicine*, Volume 54, Issue 2, February 2012, pp. 231-258.

59 A. Anch; C. Browman, et al. (Editors), *Sleep: A Scientific Perspective*, Prentice Hall, New Jersey, 1988.

60 E. Grandjean, *Fitting the Task to the Man: An Ergonomic Approach*, Taylor and Francis Ltd., London, 1982.

circadian rhythm, performance on vigilance tasks is poorest in the early morning hours between 0200 and 0600, with a secondary low point after lunch.

Optimal human performance occurs when all the circadian rhythms are synchronized to each other and to external time cues. These time cues include the light–dark cycle, meal times and socializing periods. People working shifts with irregular patterns usually have to adjust their sleep-wake patterns quickly to keep up with the changing shifts. Changing sleep-wake patterns too quickly can cause circadian rhythms to desynchronize, which can also lead to performance impairments.

1.24.1 Driver's work/rest history

The driver did not have any sleep difficulties, finding it easy to fall asleep and to sleep in on a day off. The driver would often come home and take naps, and often napped between shifts on Wednesday, Thursday and Friday. The driver was neither a "morning" nor an "evening" person in particular and would typically sleep in on holidays. On weekends, the driver would typically sleep in late and was occasionally up until 11:00 p.m. Before bed, the driver would usually drink chai tea, which contains caffeine (about 28 to 34 mg per cup). The driver was sometimes concerned about the effectiveness of the wakeup alarm and would occasionally awake during the night to check the time. Although these two factors could affect quality of sleep, the driver's sleeping habits and environment were generally good.

On the morning of 14 September 2013, the driver had called in sick with a cold. The driver went back to bed and slept late. The driver took some cold medication, and the cold did not affect his sleep that day.

The driver's estimated work-rest schedule for the 7-day period preceding the accident is summarized in Table 10.

Table 10. Driver's estimated work/rest schedule for 7 days preceding the accident

Date	Bedtime previous night	Hours of sleep	Wake up	Bus pick-up	Start shift	Total hours awake
12 Sep. 2013	2230	6.1	0432	0532	0547	18.0
13 Sep. 2013	2230	5.9	0421	0521	0536	18.2
14 Sep. 2013	2230	12.0	1030	-	SICK	12.0
15 Sep. 2013	2230	12.0	1030	-	OFF	12.0
16 Sep. 2013	2230	7.5	0600	0700	0715	16.5
17 Sep. 2013	2230	6.2	0442	0542	0557	17.8
18 Sep. 2013	2230	6.6	0507	0607	0622	3.7

1.24.2 Fatigue analysis results

To test for the existence of fatigue, there is no rigid formula that can be applied to the fatigue factors. Both the number of risk factors and the magnitude must be considered. The following factors are known to influence fatigue and alertness:

- acute sleep disruption;
- chronic sleep disruption;
- continuous wakefulness;
- circadian rhythm effects;
- individual factors (morningness / eveningness, ability to nap);
- medical and psychological conditions, illnesses and drugs;
- nature of the work;
- schedule type (split shifts); and
- sleep disorders.

In this occurrence, while the driver worked split shifts with changing start and end times, these shifts were during daytime hours. As most of the driver's sleep occurred at night, major changes in sleep-wake patterns were not required.

Based on qualitative and quantitative factors, fatigue risk factors for the driver at the time of the accident may have existed for acute sleep disruption and chronic sleep disruption. The acute sleep disruption concern was noted due to the fact that

- the driver had a shortened sleep (6.6 and 6.2 hours of sleep) on 2 of 3 consecutive nights preceding the accident; and
- the quality of the sleep on those nights may have been reduced because he usually drank chai tea, which contained caffeine, before bed and the driver may have occasionally awakened during the night.

The chronic sleep disruption concern was noted due to the fact that

- the driver had a small sleep debt (estimated at -1.3 hours) at the time of the accident; and
- the potential factor of the quality of the sleep.

Further qualitative analyses concluded that the acute and chronic disruptions in the driver's sleep would not have been sufficiently large to have a significant effect on performance.

It was determined that the driver was not likely affected by the following fatigue risk factors:

- continuous wakefulness;
- circadian rhythm effects;
- individual factors (morningness / eveningness, ability to nap);
- medical and psychological conditions, illnesses and drugs;
- nature of the work;
- schedule type (split shifts); and

- sleep disorders.

A quantitative analysis of the driver's work / rest history carried out using the Fatigue Avoidance Scheduling Tool (FAST)[61] software predicted that the driver's performance would be expected to be in the average range of a well-rested person.

1.25 Human information processing related to driving

To effectively process incoming information and navigate the road traffic environment, a driver must attend to and use information selectively. As human information processing takes place constantly and there is so much information available in the driving environment, a driver must filter out the less important information. While humans can switch their attention rapidly from one information source to another, they can only attend well to one information source at a time,[62] especially when driving. For drivers to interrupt what they are doing, a condition or stimulus would need to be perceived as sufficiently important to require immediate action. This characteristic is referred to as the object's "conspicuity" or "salience".

1.25.1 Attention

Attention is defined as the set of cognitive processes that allow the brain to select specific types of information for further processing. Internal attention allows for the voluntary selection of objects to attend to, while external attention occurs when objects involuntarily capture attention. Attention can be further divided into the following sub-categories:

1. Alertness and arousal are the most basic elements of attention.
2. Sustained attention is the ability to maintain a state of readiness to detect events.
3. Divided attention refers to the distribution of attention to 2 or more tasks.
4. Selective attention is the selection of task-appropriate information from available information.

While these 4 types of attention can occur in isolation, during driving, they work together. The operation of a vehicle requires a driver to be alert and to constantly monitor and process environmental information. Sustained attention is what gets a driver through an entire journey. Drivers can also experience divided attention, such as talking to a passenger while still attending to critical information needed for driving. Driving also requires selective attention to filter out non-driving-related information from other information that is relevant to the driving task.

Human attention and the capacity to process information are limited. These limitations can create difficulties because driving requires that attention be divided among

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[61] FAST is a software analysis package that allows scientists, planners and schedulers to quantify the effects of various work-rest schedules on human performance.

[62] P.L. Olson, R. Dewar, and E. Farber, "Vision, audition, vibration and processing of information", *Forensic Aspects of Driver Perception and Response*, 3rd edition, Lawyers & Judges Publishing Company, Inc., Tucson, Arizona, 01 January 2010.

- control tasks such as staying in the lane or maintaining the vehicle speed;
- guidance tasks such as merging with other vehicles; and
- navigational tasks such as looking for street name signs or monitoring a global positioning system (GPS).

1.25.2 Driver expectation and faulty activation of schema

Expectation and knowledge about a given situation are often referred to as schemas or mental shortcuts. Based on their driving experience, drivers develop schemas over time. Perceiving and thinking based on schemas allows humans to filter, organize and act on large amounts of information quickly and efficiently. However, situational awareness can be impaired when a schema and situation do not match.[63] For example, when drivers receive information that they expect to receive, such as a red traffic light displayed following an amber light, they tend to react quickly and error-free. However, when drivers receive information contrary to their expectations, their performance tends to be slow or inappropriate.[64]

Research into driver expectations has determined the following:

- When a driver becomes familiar with a particular level crossing or with a particular type of level crossing, and where the driver has never, or seldom, encountered an approaching train at the level crossing, the driver will tend to have a “no trains” expectation at the crossing.[65]
- Many drivers have developed a negative expectancy at level crossings, whereby they come to expect the absence, rather than the presence of trains because of the infrequency of previous train encounters.[66]
- Drivers who are familiar with a crossing, especially one associated with low train volumes, look less—and are less likely to reduce their approach speed—than drivers who are unfamiliar with a crossing.[67, 68, 69]

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63 K. Smith and P.A. Hancock, “Situation awareness is adaptive, externally directed consciousness”, *Human Factors*, Volume 37, Issue 1, 1995, pp. 137-148.

64 G.J. Alexander and H. Lunenfeld, *Driver Expectancy in Highway Design and Traffic Operations*, report number FHWA-TO-86-1, United States Department of Transportation, May 1986.

65 R.E. Dewar and P.L. Olson, “Railroad grade crossing accidents”, *Human Factors in Traffic Safety*, Lawyers & Judges Publishing Company, Inc., Tucson, Arizona, 2002, pp. 507–523.

66 R.W. Eck, “A context-sensitive approach to improving safety at passive crossings”, Proceedings of the 7th International Conference on Railroad-Highway Grade Crossing Research and Safety: Getting Active at Passive Crossings, Melbourne, Australia, 20–21 February 2002.

67 J.H. Sanders, *Driver Performance in Countermeasure Development at Railroad-highway Grade Crossings*, BioTechnology, Inc., 1975, pp. 28–37.

68 M. Yeh and J. Multer, *Driver Behavior at Highway-Railroad Grade Crossings: A Literature Review from 1990–2006*, report number DOT/FRA/ORD-08/03, United States Department of Transportation, Federal Railroad Administration, Office of Research and Development, October 2008, available at: http://www.fra.dot.gov/eLib/Details/L01598 (last accessed 28 September 2015).

69 E.C. Wigglesworth, “Human factors in level crossing accidents”, *Accident Analysis & Prevention*, Volume 10, Issue 3, September 1978, pp. 229-240.

- Heavy-vehicle drivers do not look in either direction on approach to level crossings equipped with AWDs between 35% of the time (for crossings equipped with FLBG) and 65% (for crossings equipped with FLB only).[70]

1.25.3 Driver distraction

Driver distraction is "the diversion of attention away from activities critical for safe driving toward a competing activity."[71] Distractions can divert drivers' attention during periods in which they must be making, or have made, a decision regarding a level crossing.[72] Driver distraction has been identified in several studies as a contributory factor to accidents at level crossings.[73, 74]

There is ample evidence that driver distraction impairs driving performance and is a significant cause of all types of motor vehicle accidents worldwide.[75]

There are 4 potential sources of driver distraction:

1. Visual distraction occurs when a driver looks away from the road at a non-driving-related object or person.
2. Auditory distraction occurs when listening to a passenger or a ringing cell phone.
3. Physical distraction occurs when a driver dials a cell phone, tunes a radio or adjusts the temperature control in a vehicle.
4. Cognitive distraction occurs when a driver's attention is withdrawn from the processing of information necessary for the safe operation of a vehicle and applied instead to a non-driving-related activity.[76]

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70 T. Ngamdung and M. daSilva, *Driver Behavior Analysis at Highway-Rail Grade Crossings Using Field Operational Test Data – Heavy Trucks*, report number DOT/FRA/ORD-12/22, United States Department of Transportation, Federal Railroad Administration, Office of Research and Development, December 2012, available at: http://ntl.bts.gov/lib/46000/46600/46647/DOT-VNTSC-FRA-12-01.pdf (last accessed 28 September 2015).

71 J.D. Lee, K.L. Young and M.A. Regan, "Defining driver distraction", *Driver Distraction: Theory, Effects and Mitigation*, CRC Press, Boca Raton, 2009, pp. 31-40.

72 R.W. Eck, "A context-sensitive approach to improving safety at passive crossings", Proceedings of the 7th International Conference on Railroad-Highway Grade Crossing Research and Safety: Getting Active at Passive Crossings, Melbourne, Australia, 20–21 February 2002.

73 J.K. Caird, J.I. Creaser, et al., *A Human Factors Analysis of Highway-Railway Grade Crossing Accidents in Canada*, report TP 13938E, prepared for the Transportation Development Centre, Transport Canada, by the Cognitive Ergonomics Research Laboratory, Department of Psychology, University of Calgary, September 2002.

74 United States National Transportation Safety Board (NTSB), *Safety Study: Safety at passive grade crossings, Volume 1: Analysis*, NTSB/SS-98/02 1998, available at: http://images.spinics.net/rail/SS9802.pdf (last accessed 28 September 2015).

75 World Health Organization, *Mobile Phone Use: A Growing Problem of Driver Distraction*, 2011, available at: http://www.who.int/violence_injury_prevention/publications/road_traffic/distracted_driving_en.pdf (last accessed 28 September 2015).

Each of these potential sources of distraction, either individually or in combination, can impair driver performance. Many in-vehicle activities involve more than one source of distraction. For example, talking on a cell phone while driving can involve hearing a call come in, looking at the display to see who is calling, pressing a button to answer the call, and thinking about the conversation both during and after the call.

With regards to driver visual distraction, research conducted under "naturalistic" conditions, where everyday drivers operate their own vehicles while a range of video and vehicle performance data are recorded and later analysed, has consistently found that driver eye glances away from the forward visual scene, especially those lasting 2 seconds or longer, are significantly associated with crashes and near-crash events.[77]

With regards to driver cognitive distraction, studies have identified the following detrimental effects:

- Cognitive distraction slows driver reaction time and increases the likelihood that a driver will miss critical visual stimuli in the visual field and roadway ahead.[78]
- Cognitive distraction can impair a driver's attention to safety-critical visual stimuli (such as activated level crossing AWDs) to such an extent that they do not even perceive the stimuli.
- Cognitively distracted drivers are less likely to visually search for approaching traffic at intersections,[79] and make fewer anticipatory glances when entering a roadway curve.[80]
- Cognitive distraction has significant detrimental effects on visual scanning horizontally and vertically.[81]
- Cognitive distraction that does not involve verbal (talking) or visual (looking) elements is described as "driving without awareness", "mind-off-the-road" or being

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[76] D.L. Strayer, J.M. Cooper, et al., *Measuring Cognitive Distraction in the Automobile*, Washington, D.C., AAA Foundation for Traffic Safety, June 2013, available at: https://www.aaafoundation.org/sites/default/files/MeasuringCognitiveDistractions.pdf (last accessed 28 September 2015).

[77] S.G. Klauer, T.A. Dingus, et al., *The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data*, report number DOT HS 810 594, United States Department of Transportation, National Highway Traffic Safety Administration, April 2006.

[78] D.L. Strayer and W.A. Johnston, "Driven to distraction: Dual-task studies of simulated driving and conversing on a cellular phone", *Psychological Science*, Volume 12, Issue 6, November 2001, pp. 462-466.

[79] L. Gruzdaitis, J. Karola, et al., "Mental load and visual search at street crossings", Proceedings of the 3rd International Conference on Traffic and Transport Psychology, Nottingham, United Kingdom, 2004.

[80] E. Lehtonen, O. Lappi and H. Summala, "Anticipatory eye movements when approaching a curve on a rural road depend on working memory load", *Transportation Research Part F: Traffic Psychology and Behaviour*, Volume 15, Issue 3, 2012, pp. 369-377.

[81] M.A. Recarte and L.M. Nunes, "Effects of verbal and spatial-imagery tasks on eye fixations while driving", *Journal of Experimental Psychology: Applied*, Volume 6, Issue 1, 2000, pp. 31-43.

"lost in thought" in a number of studies.[82, 83, 84] Drivers in this state do not adequately visually scan and monitor the driving environment, with the cognitive distraction causing relevant information to be noticed either too late or not at all.

1.25.4 Inattentional blindness

Inattentional blindness occurs when a driver mistakenly filters out important information that is available to the senses.[85] For inattentional blindness, engagement in one task can result in a driver missing, or being "blind" to a second simultaneous event. Inattentional blindness can be caused by cognitive distraction. Errors that occur as a consequence of driver inattentional blindness are referred to as "looked-but-failed-to-see" (LBFTS) errors.

Inattentional blindness has been identified as a contributing factor in accidents at level crossings equipped with flashing lights and bells. In a crossing accident that occurred in Kerang, Australia, a truck weighing about 40 tonnes and travelling at about 100 km/h (62.1 mph) struck a train. The approach to the crossing was straight and the truck drove into the side of the train. The AWD crossing protection was activated at the time, but the truck driver did not respond to the activated crossing protection. The primary cause of the driver not responding was deemed to be a LBFTS error driven by a "faulty activation of schema". Once the driver's "non-activated" (or "no trains") level crossing schema was initiated on approach to the crossing, it was likely further reinforced by the presence of trees and the truck's A-pillar, both of which obstructed the driver's view of the tracks and the approaching train.[86]

1.25.5 Driving while negotiating a curve

Driving while negotiating a curve increases driver mental workload when compared to straight road driving,[87] and influences where a driver will look in the forward visual scene.

When on a straight road, drivers maintain lane position and heading by looking straight ahead and relying on streaming in the peripheral visual field to guide steering inputs. In a

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82 J.S. Kerr, "Driving without attention mode (DWAM): A formalization of inattentive states in driving", in A.G. Gale et al. (Editors), *Vision in Vehicles III*, 1st edition, Elsevier, North Holland, 1991, pp. 473-479.

83 M. Green, "'How long does it take to stop?' Methodological analysis of driver vision-brake times", *Transportation Human Factors*, Volume 2, Issue 3, 2000, pp. 195-216.

84 M. Martens and R.F.T. Brouwer, "Measuring being lost in thought: An exploratory driving simulator study", *Transportation Research Part F: Traffic Psychology and Behaviour*, Volume 20, September 2013, pp. 17-28.

85 A. Mack and I. Rock, *Inattentional Blindness*, The MIT Press, Cambridge, Massachusetts, March 1998.

86 P.M. Salmon, G.J. Read, et al., "The crash at Kerang: Investigating systemic and psychological factors leading to unintentional non-compliance at rail level crossings", *Accident Analysis & Prevention*, Volume 50, January 2013, pp. 1278-1288.

87 L.B. McDonald and N.C. Ellis, "Driver workload for various turn radii and speeds", Transportation Research Record 530, 1975, pp. 18-29.

curve, the vehicle's current and future positions in the lane are visually separate, so a driver must look intermittently toward both locations, effectively doubling visual demand.[88]

Studies measuring driver eye movements when negotiating curves found that, during daytime driving without a lead vehicle present, eye fixations tend to be directed toward the direction that the vehicle would be turning.[89]

When drivers negotiate a curve, they visually rely on the "tangent point" on the inside of the curve, with their gaze being directed toward this point 1 to 2 seconds before entering a curve and returning to it throughout the curve.[90] Research using eye tracking[91] has shown that the time that drivers look ahead is about 0.9 second. For a driver travelling at 60 km/h (37.3 mph), this would translate to approximately 15 m (49.2 feet).[92]

Drivers also direct anticipatory glances toward the occlusion point, or the nearest point where the view of the road ahead is blocked.[93] Speed and distance also influence where a driver negotiating a curve will look.

In this occurrence, while negotiating the Transitway curve on the approach to the crossing, the driver would have generally gazed toward the centreline of the road to scan the forward lane and make anticipatory glances toward the occlusion point (Photo 16).

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88 D. Shinar, E. McDowell and T.H. Rockwell, "Eye movements in curve negotiation", *Human Factors: The Journal of the Human Factors and Ergonomics Society*, Volume 19, Issue 1, February 1977, pp. 63-71.

89 P.L. Olson, D.S. Battle and T. Aoki, *Driver Eye Fixations Under Different Operating Conditions*, report number UMTRI-89-3, The University of Michigan Transportation Research Institute, Ann Arbor, Michigan, February 1989, available at: http://deepblue.lib.umich.edu/handle/2027.42/62169 (last accessed 28 September 2015).

90 M.F. Land and D.N. Lee, "Where we look when we steer", *Nature*, Volume 369, 30 June 1994, pp. 742-744.

91 M.F. And and J. Horwood, "How speed affects the way visual information is used in steering", in A.G. Gale et al. (Editors), *Vision in Vehicles VI*, Amsterdam, Elsevier, 1998, pp. 43-50.

92 i.e. 16.67 m/s x 0.9

93 E. Lehtonen, O. Lappi and H. Summala, "Anticipatory eye movements when approaching a curve on a rural road depend on working memory load", *Transportation Research Part F: Traffic Psychology and Behaviour*, Volume 15, Issue 3, May 2012, pp. 369-377.

Photo 16. View of Transitway on approach to the crossing (TSB re-enactment 28 September 2013). The arrow identifies the tangent point of the curve. The circle identifies the occlusion point toward which drivers would make anticipatory glances. Note the large sign within occlusion point.

1.26 *Crossing characteristics and active warnings*

A driver's attention will likely be attracted to areas that contain a great deal of auditory and visual information, such as:

- concentrations of lights;
- signs and people;
- objects that differ greatly from their backgrounds in terms of brightness, colour and texture;
- flickering or flashing stimuli;
- objects of large size; and
- objects that are moving.

On the morning of the accident, there were a number of stimuli in the vicinity of the Transitway crossing that could have acted as warnings of the approaching train and the need to stop. These included

- red flashing crossing lights on stanchions;
- red flashing lights on crossing gates;
- vehicles stopped at the crossing on the adjacent road (Woodroffe Avenue);
- passengers' shouts to stop the bus;

- the approaching train;
- bells at the crossing; and
- locomotive horn.

1.26.1 Red flashing crossing lights on stanchions

The northbound approach to the crossing on the Transitway consisted of 4 red LED flashing warning lights on stanchions located to the north and south of the crossing (2 lights on each stanchion), and 2 crossing gates each equipped with 3 flashing LED lights. The flashing lights and bells were activated by the approach of a train and were operative at the time of the accident.

1.26.2 Red flashing lights on crossing gates

The 3 lights affixed to each crossing gate were 4-inch LED fixtures, with maximum luminous intensity readings of approximately 160 candelas (cd) at 60 feet (18.3 m). During the accident re-enactment, when the gates were in the activated “down” position, the horizontal gate and flashing gate lights were positioned directly in line with the horizon beyond the crossing. It was observed that the crossing gate lights were not conspicuous and the gate blended into the background.

1.26.3 Stopped vehicles on roadways

Stimuli other than designated warnings can act as cues to drivers that indicate expected, or appropriate, behaviour. The AWDs for both the Woodroffe Avenue and the Transitway crossings had been activated for 49 seconds prior to the arrival of the bus at the crossing. Northbound and southbound vehicles were stopped at the Woodroffe Avenue crossing for the activated crossing AWDs prior to the bus arriving at the Transitway crossing.

There were no other buses on the Transitway travelling in either direction in the immediate vicinity of the bus before the accident.

1.26.4 Passengers’ shouts to stop the bus

In the seconds immediately preceding the accident, with the bus travelling at 42 mph (67.6 km/h) and the throttle (gas pedal) on, passengers on both the upper and lower decks began to shout to warn the driver of the approaching train and the need to stop the bus. The background noise within the bus on approach to the crossing was estimated to have been at least 65 dB(A).[94]

There are 3 levels of audibility of a sound stimulus. First, a sound is detected but no other characteristics of the sound may be known. Recognition of the sound occurs at some point above the threshold of detection, normally at a level between 3 and 8 dB(A) above the threshold. The alerting level of an auditory stimulus – the point at which a driver would

[94] TSB Railway Investigation Report R13W0083.

become aware and "alerted" to its presence – typically occurs when the sound rises at least 9 to 10 dB(A) above any background noise level.[95]

The loudness of male speech ranges from approximately 52 dB(A)[96] for casual speech to 89 dB(A) for shouted speech when measured 1 m (3.28 feet) from the speaker. The intelligibility of shouted speech decreases linearly with distance. For speech to be understood against background noise, it must be at least 6 dB(A) above the background noise. Even at this signal-to-noise ratio, listeners will report difficulty hearing the message. Sound levels drop at a rate of 6 dB(A) per doubling of distance from the source of the sound.

For a male passenger on the upper deck, located 7.3 m (24 feet) from the driver, the loudness of shouting in the seconds before impact would have been limited to about 60 dB(A), which would have been inaudible to the driver. Shouts that were audible to the driver would have come from passengers located on the lower deck in the general vicinity of the driver.

1.26.5 The approaching train

For a northbound driver looking ahead toward the tangent point (the inside) of the road as the bus exited the left-hand curve of the Transitway toward the crossing, a train approaching from the east would be in the driver's peripheral vision.

1.26.6 Bells at the crossing

The primary purpose of crossing bells is to warn pedestrians and other non-vehicle road users of an approaching train. The crossing bells at the crossing were active at the time of the accident, and were activated at the same time as the crossing warning lights.

1.26.7 Locomotive horn

The crossing was subject to an anti-whistling by-law between 2000 and 1200 (noon) daily; therefore, the locomotive horn was not required to be activated on approach to the crossing.

1.27 Locomotive horn information

CROR Rule 14 governs the use of locomotive horn signals. Section (l) indicates that the train horn must be blown using 2 long, 1 short, and 1 long succession of sounds at every whistle post. Trains exceeding 44 mph (70.8 km / h) must sound the whistle signal starting from ¼ mile (402 m) before the crossing, and be prolonged or repeated until the crossing is fully occupied.

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95 S. Fidell, "Effectiveness of audible warning signals for emergency vehicles", *Human Factors: The Journal of the Human Factors and Ergonomics Society*, Volume 20, Issue 1, February 1978, pp. 19-26.

96 The decibel (dB) is a logarithmic unit used to express the ratio between two values, usually measured in units of power or intensity. The decibel is also commonly used as a measure of sound (gain or attenuation) displayed as dB(A).

Section 11 of TC's *Railway Locomotive Inspection and Safety Rules* governs audible signals and states in part:

> 11.1 PASSENGER LOCOMOTIVES
>
> 11.1.1 Passenger locomotives must be equipped or retrofitted with horns capable of producing a high and a low level sound, as per the following schedule:
>
> a) new locomotives ordered after January 1st, 2007 and delivered after January 1st 2008;
>
> b) locomotives in a controlling or lead position on trains in passenger service, traveling at speeds exceeding 105 km (65MPH), must be retrofitted before January 1st, 2012.
>
> […]
>
> 11.1.4 DESIGN TYPES
>
> Locomotives shall be equipped with:
>
> (a) one single five flute horn capable of producing two different sound levels-low level mode or high level mode; or
>
> (b) two separate horns:
>
> i. one three or five flute horn that produces the low level mode; and
>
> ii. one five flute horn that produces the high level mode;
>
> 11.1.5 COMPLIANCE
>
> (a) When tested in an anechoic chamber meeting the requirements of ISO 3745 (18-22 deg C, 45%-65% rel. hum., 990-1025 millibars), the horn shall produce a minimum sound pressure level of 143 dB(A) at one meter from the front of the horn.
>
> […]
>
> 11.2 FREIGHT LOCOMOTIVES
>
> All locomotives other than in designated service operating in a controlling position shall be equipped with a horn that is tuned in chords of not less than three tones meeting the following design criteria:
>
> (a) a horn capable of producing a minimum sound level of 96 (db)A at any location on an arc of 30 meters (100 feet) radius subtended forward of the locomotive by angles 45 degrees to the left and to the right of the centerline of the track in the direction of travel [….]

For the high-level emergency horn on passenger locomotives, the minimum sound pressure level of 143 dB(A) 1 m (3.3 feet) in front of the horn equates to a minimum sound level of 110 dB(A), at any location on an arc of a radius of 30 m (98.4 feet).

Train horns are often described as a secondary alerting system because their effectiveness is affected by other factors.[97] A number of TSB investigations[98] have concluded that the effectiveness of the horn can be compromised due to speed of the train, the dampening of sound through the road vehicle shell and the ambient noise within the vehicle.

A TC Transportation Development Centre (TDC) study[99] evaluating locomotive horn effectiveness determined that

- audible warnings should be at least 10 dB(A) above ambient noise to be recognizable as an auditory danger signal; and
- studies cited in the TC report recommend using 30 dB(A) as the typical sound loss offered by a vehicle shell with the windows and doors closed.

Having the bus door open could increase the perceived loudness of an activated train horn by between 20 and 30 dB(A).[100]

In this occurrence, the bus windows and doors were closed, which would have resulted in a loss of 30 dB(A) for a locomotive horn. The background noise within the bus consisted of passenger conversation and vehicle noise associated with the bus travelling at 42 mph (67.6 km / h) on an asphalt road. Based on other TSB investigations,[101] the sound level within the bus was estimated to be in the range of 65 dB(A).

Based on these values, for a train located 100 feet (30.5 m) from the bus, the signal-to-noise ratio (SNR) of a high-level emergency passenger locomotive horn would be

Train horn dB(A) - Vehicle shell loss dB(A) – Background noise in bus = Train horn SNR

110 dB(A) - 30 dB(A) - 65 dB(A) = 15 dB(A)

Under similar circumstances, the SNR of a freight locomotive horn would be

96 dB(A) - 30 dB(A) - 65 dB(A) = 1 dB(A)

For each halving of distance between a locomotive horn and a bus, the SNR will increase by 6 dB(A). For example,

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97 G.W. English, F.A. Russo, et al., *Locomotive Horn Evaluation: Effectiveness at Operating Speeds*, TP 14103E, prepared for the Transportation Development Centre, Transport Canada, by TransSys Research Ltd., June 2003.

98 TSB railway investigation reports R13D0001, R13W0083, R12W0182, R11T0175, R10W0123, R08M0002, R04H0014, and R02W0063.

99 *Project Summary – Locomotive Horn Evaluation: Effectiveness at Operating Speeds*, TP 14163E, prepared for the Transportation Development Centre, Transport Canada, by Trans Sys Research Ltd., January 2004.

100 G.W. English, F.A. Russo, et al., *Locomotive Horn Evaluation: Effectiveness at Operating Speeds*, TP 14103E, prepared for the Transportation Development Centre, Transport Canada, by TransSys Research Ltd., June 2003.

101 TSB railway investigation reports R12W0182 and R13W0083.

- at 50 feet (15.2 m), the SNR of a high-level emergency passenger locomotive horn would have been 21 dB(A);
- at 50 feet (15.2 m), the SNR of a freight locomotive horn would have been 7 dB(A).

1.28 Canada Motor Vehicle Safety Standards

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 *Canada Motor Vehicle Safety Standards* (CMVSS)[102] and are governed by the *Canada Motor Vehicle Safety Act* and *the Motor Vehicle Transport Act* through the *Motor Vehicle Safety Regulations*.[103]

The *Motor Vehicle Safety Regulations* specify the requirements respecting safety for motor vehicles and motor vehicle components. Pursuant to the regulations, the CMVSS identify the prescribed tests required for the certification of various weight categories of vehicles.

CMVSS crashworthiness standards have evolved over time, and performance standards were developed to improve the safety of automobiles which, historically, have posed the greatest risk of injury in the event of an accident. Once these were completed, attention turned to addressing larger vehicles and school buses. Given that vehicles in the heaviest weight category (gross vehicle weight rating [GVWR] of 11 793 kg or 26 000 pounds) are perceived as the lowest risk based on their accident history and because they are usually one of the largest vehicles on the road, very few of the CMVSS crashworthiness standards apply to vehicles in this weight category.

CMVSS requirements vary according to the weight and type of vehicle:

- All school buses and passenger vehicles with a GVWR[104] of up to 4536 kg (10 000 pounds) are subject to safety standards in both Canada and the United States. The Canadian standards include the following:
    - CMVSS Standard 201 - Occupant Protection
    - CMVSS Standard 203 - Driver Impact Protection and Steering Control System
    - CMVSS Standard 204 - Steering Column Rearward Displacement
    - CMVSS Standard 208 - Occupant Protection in Frontal Impacts
    - CMVSS Standard 214 - Side Door Strength
    - CMVSS Standard 216 - Roof Crush Resistance
    - CMVSS Standard 220 - Rollover Protection
    - CMVSS Standard 221 - School Bus Body Joint Strength
    - CMVSS Standard 222 - School Bus Passenger Seating and Crash Protection

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102 Department of Justice, *Motor Vehicle Safety Regulations* (C.R.C., c.1038), Schedule IV, Part III, which came into force 01 June 2009.

103 Department of Justice, *Motor Vehicle Safety Regulations* (C.R.C., c. 1038), which came into force 01 June 2009.

104 Gross vehicle weight rating (GVWR) means the value specified by the vehicle manufacturer as the loaded weight of a single vehicle.

See Appendix D for additional information on these standards.

- Vehicles with a GVWR between 4536 kg (10 000 pounds) and 11 793 kg (26 000 pounds) must meet a baseline of essential safety criteria (brakes, steering, etc.), but are subject to fewer safety standards than lighter vehicles.
- Vehicles with a GVWR of 11 793 kg (26 000 pounds) and above are in the heaviest vehicle weight category, which includes tractor-trailers and most transit and inter-provincial buses. These vehicles must meet a baseline of essential safety criteria (brakes, steering, etc.). Some vehicle safety standards will apply only to this weight category. While these vehicles are generally subject to the fewest safety standards, nothing precludes a manufacturer from designing vehicles that exceed the standards.

CMVSS Standard 101 specifies the location and identification of controls and displays as it applies to motor vehicles, including transit buses. This standard requires that automotive controls and components, such as the engine start and stop control, the parking / emergency brake pedal or lever, and the service brake pedal or lever, be fitted in such a manner that they are operable by the driver while seated in the designated seating position with the seat belt fastened.

For transit buses with a GVWR greater than 4536 kg (10 000 pounds), some of the applicable requirements include the following:

- The driver's designated seating position must be equipped with a seat belt assembly in accordance with CMVSS Standard 208, Occupant Protection in Frontal Impacts (required only for the bus driver seating position).
- The seat belt assembly (webbing, buckle) must meet the requirements of CMVSS Standard 209, Seat Belt Assemblies (required only for the bus driver seating position).
- The seat belt anchorages must meet the positioning and strength requirements of CMVSS Standard 210, Seat Belt Anchorages (required only for the bus driver seating position).

An ADL E500 bus, which has a GVWR of 23 481 kg (51 767 pounds), meets these requirements.

There are no Canadian standards / guidelines governing the following:

- in-vehicle obstructions related to driver visibility outside of the vehicle;
- the positioning and use of in-vehicle monitors or displays;
- frontal impact, side impact or minimum bumper requirements for transit buses; and
- event data recorder (EDR) requirements for any vehicles.

1.28.1 Canada Motor Vehicle Safety Standards *and school bus design*

School buses are designed to protect occupants from impact during a collision and must meet several CMVSS standards that are specific to school buses. Other general design safety features of school buses are from the Canadian Standards Association (CSA) standard CSA D250, School Buses.

Safety design features for school buses typically include the following:

- To reduce the effects of a collision, school buses have full length horizontal impact rails located at the shoulder, cushion and floor levels of the bus to increase body strength.
- The floor is raised to protect passengers by having them sit above the area where an automobile would strike a school bus during a collision.
- School buses must meet CMVSS Standard 220, Rollover Protection, to reduce the risk of serious injury caused if the bus were to roll.
- The interior of the bus is a smooth rounded shell, free from sharp edges.
- School buses must meet CMVSS Standard 221, School Bus Body Joint Strength. This standard sets forth strength requirements for body joints in the passenger compartment area to ensure that joints do not come apart during a collision, causing sharp edges to be exposed in the passenger compartment.
- The interior of a school bus is compartmentalized in order to minimize the impact and injury during a collision. To meet the requirements of CMVSS Standard 222, School Bus Passenger Seating and Crash Protection, the seats are made with high backs with padding on the front and back made from impact-absorbing material. The seats are well anchored and spaced closely together to create compartments. If a collision were to occur, the compartments would absorb the impact, dispersing it throughout a passenger's entire body.
- The bus windows are small to prevent passengers from being ejected from the vehicle.
- Emergency exits are located on both sides of the bus, the back and a roof hatch.

In the Province of Ontario, school bus companies generally use the following types of school buses:

- full size 70- to 72-passenger school buses with a GVWR of 10 557 kg (23 274 pounds);
- 20-passenger school vans (single rear wheels) with a GVWR of 3832 kg (8448 pounds); and
- 20-passenger school vans equipped with dual rear wheels or a wheelchair lift with a GVWR of 4286 kg (9449 pounds).

1.28.2 Determining conformance to Canada Motor Vehicle Safety Standards

When importing a vehicle to Canada, it 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.

For the ADL E500 bus, Care Transportation in Canada was designated by the manufacturer as the *Nominated Importer* to handle the customs and certification paperwork. ADL provided a copy of the necessary certification reports to the *Nominated Importer* who in turn provided the reports to TC for review. After reviewing the material, TC advised the *Nominated Importer* in writing that the certification package was acceptable, authorizing the ADL E500 bus to be imported to Canada. There was no formal inspection or risk assessment of the vehicle required prior to delivery, and no certificate was issued.

1.29 Bus information

The bus was a 42-foot-long Enviro 500 (E500) model, designed and manufactured by ADL in the United Kingdom in August 2012. In 2013, a total of 657 ADL double-decker buses were being operated in Canada and the United States. This number included 60 buses in Victoria, British Columbia, 14 buses in Sherwood Park, Alberta, 127 buses in Toronto, Ontario, and the 75 buses at OC Transpo.

The ADL E500 is a low-floor transit / commuter double-decker bus. These buses are designed in accordance with, and are fully compliant to, the legislative requirements of the *Federal Motor Vehicle Safety Standards* (FMVSS) in the United States and CMVSS in Canada. Each bus is equipped with either 2 forward-facing wheelchair positions, or 2 rearward-facing wheelchair positions, on the lower deck complete with retractor belt restraints that are compliant with the *Americans with Disabilities Act* and the requirements of CAN / CSA-D435-02 (R2012), *Accessible Transit Buses*. The front entrance has wide-opening doors, a low step and is fitted with a ramp to allow full access for wheelchairs. The ADL E500 bus is also designed to meet applicable American states and Canadian provincial legislation.

The ADL E500 bus is equipped with a single wheel front axle, a dual wheel rear drive axle and a single wheel auxiliary axle (tag axle) located behind the drive axle. The bus is powered by an electronically controlled 6-cylinder turbocharged Cummins diesel engine driving a portal rear axle through an electronically controlled Allison B500R automatic transmission.

All ADL E500 buses are equipped with a video monitor that provides the driver with interior views and exterior views of the bus. In the United Kingdom, where these buses are also operated, video or other devices are required to allow the driver to be able to see the interior of all service doors and within the vicinity / area around the stairwell on the upper deck.[105] Although there are no similar requirements in Canada, all ADL double-decker buses are delivered to clients equipped with the video monitor. The client determines which views are presented on the monitor.

All single-deck OC Transpo buses are equipped with a bumper that is designed to withstand a full frontal 5 mph (8 km / h) impact without sustaining any damage. Although bumpers were available as an option, OC Transpo ordered the initial ADL E500 buses without any bumpers.

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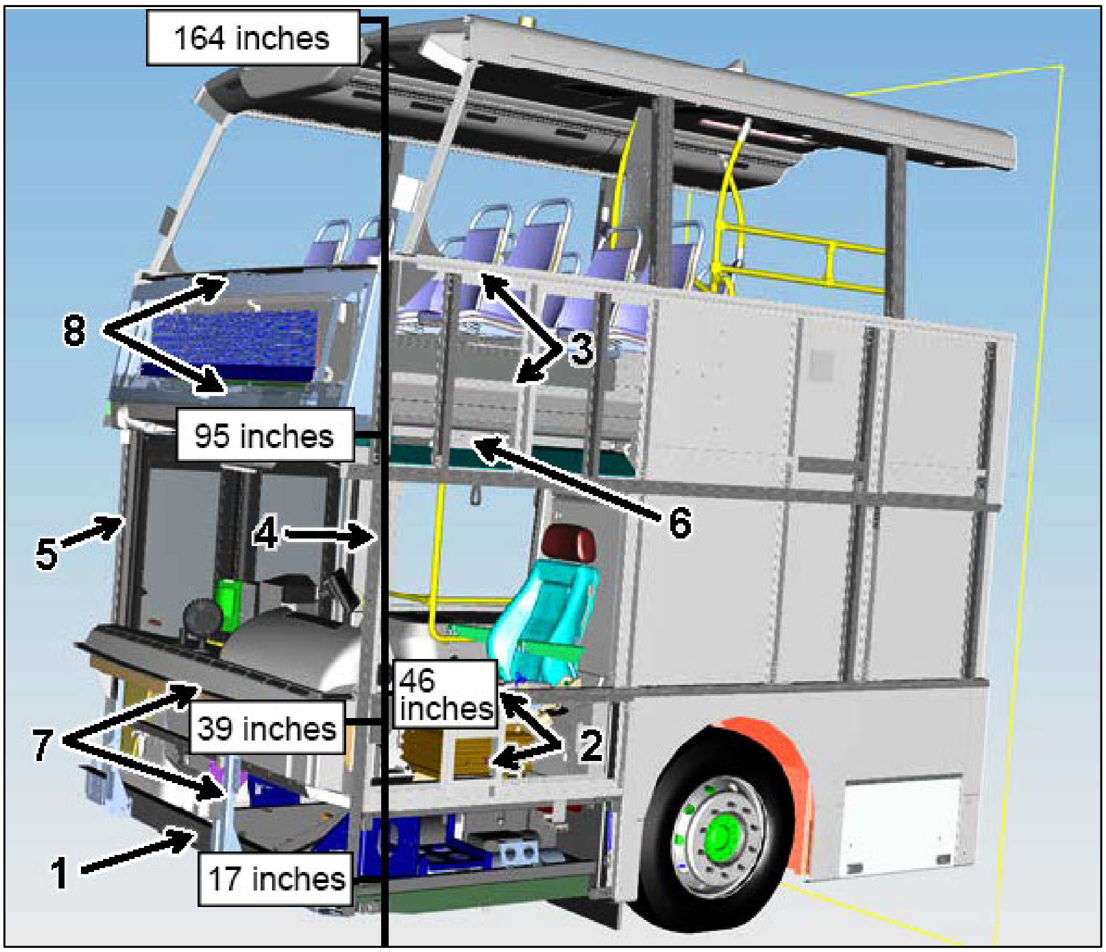
105 European Commission, Directive 2001 / 85 / EC relating to Special provisions for vehicles used for the carriage of passengers comprising more than eight seats in addition to the driver's seat, and United Nations Economic Commission for Europe, Regulation No. 107-04, Uniform Provisions Concerning the Approval of Category M_2 or M_3 Vehicles with regard to their General Construction.

The occurrence bus was delivered to OC Transpo in September 2012. Prior to delivery, a series of mandatory certification tests had been conducted to verify its compliance with the CMVSS. Upon delivery of the bus, an MTO inspection was performed on 21 September 2012, with no exceptions noted. The vehicle met or exceeded all required criteria for operation in Canada. At the time of the accident, the bus had been in operation for 12 months and had accumulated approximately 42 500 km (26 408 miles). An annual MTO inspection had been scheduled for 26 September 2013.

1.29.1 Bus structure

The structural components of the front part of the bus are illustrated in Figure 12. (Note: The vertical scale in the figure indicates the height relative to ground level.)

Figure 12. Schematic showing the front structure of the ADL E500 bus (Source: Alexander Dennis Limited, with TSB annotations)



1 – Front portion of chassis
2 – Lower left front side wall (only the side frame is shown here)
3 – Upper left front side wall (only the side frame is shown here)
4 – Left front corner pillar
5 – Right front corner pillar
6 – Upper deck floor (interfloor)
7 – Lower front-end framing
8 – Upper front-end framing

The low-height chassis frame is made of all welded steel channel and box sections. The front beam of the chassis is a ¼-inch (6 mm)-thick steel z-beam with its top located about 17 inches (43 cm) above ground level.

The low-weight body structure consists primarily of aluminum extrusions and shear panels with the addition of stainless steel in areas of higher stress to ensure high body stiffness and durability while minimizing the vehicle weight. All structural members are mechanically joined.[106] Exterior aluminum side panels are flush-fitted with the glazing units (windows) to ensure that body panel protrusions have been minimized.

The frames of the side wall at the lower and upper decks are constructed using vertical pillars mechanically joined to longitudinal beams (rails) using monobolts.[107] The foremost vertical pillars of the side walls are the front corner pillars, which are made of 2 sections of aluminum beam mechanically joined using a cast aluminum insert. The bottom end of each front corner pillar is connected to the front beam of the chassis by 2 brackets and monobolts.

The upper deck floor frame is constructed using roof sticks (long lateral beams) and monitors (short longitudinal beams). The roof sticks are mechanically joined to the side walls using cast aluminum brackets. The lower deck and upper deck floors are constructed of birch plywood bonded to the framing using a structural adhesive. Options for composite flooring are also available.

The lower and upper front-end framings are located in front of the lower and upper decks respectively. The front-end framings are made of stainless steel and are joined to the front corner pillars using ¼-inch (6 mm) monobolts. Two vertical beams also connect the lower front-end framing to the front beam of the chassis.

The lower front-end framing provides support to the lower front dome and windshield, provides an attachment point for interior trim components and the heating and demisting unit, and provides support to exterior trim and corner panels. Similarly, the upper front framing provides support to the upper windshield and destination gear, and provides an attachment point for interior trim components. The front-end framings are not designed to provide impact protection, nor are they required to by the applicable regulations.

The lower deck of the ADL E500 bus, fitted with a combination of transverse rows of seats and longitudinal rows facing the aisle, provides a seating capacity of 27 and a standing capacity of 25. The upper deck passenger seats are arranged in a transverse, forward-facing configuration with a seating capacity of 55. A fully loaded bus has an estimated GVWR of 24 000 kg (52 911 pounds).[108]

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106 Alexander Dennis Limited, Specification Enviro500 42' (12.9m) Low Height Double Deck Transit or Commuter Bus, available at: http://www.alexander-dennis.com/wp-content/files_mf/1413192873E500Specification.pdf (last accessed 28 September 2015).

107 Monobolts are high-strength structural blind rivets with a locked stem and a positive hole fill for use in heavy-duty applications. Monobolt is a trademark of Avdel products.

108 Based on a rounded estimate of the gross vehicle weight rating of a fully loaded bus with standing passengers.

A stairwell located behind the driver's seat on the left side of the bus provides access to and exit from the upper deck. There are 2 doors on the right side of the lower deck: an entrance door at the front of the bus and an exit door in the middle. The bus is also fitted with emergency windows on both decks. On the upper deck, there are 3 emergency windows on each side. On the lower deck, there are 1 emergency window on the right side and 2 on the left side. The roof of the bus is fitted with 2 emergency ceiling hatches. In this occurrence, none of the emergency exits were used during the evacuation of the passengers from the bus.

1.30 Analysis of bus electronic modules

The bus did not have a dedicated EDR to store vehicle performance and operational data (i.e., black box). The system monitoring the multiple video cameras installed on the bus did not have recording enabled; thus no information was recovered from the system. However, a number of electronic units containing non-volatile-memory (NVM) were recovered. The relevant data were downloaded and examined at the TSB Engineering Laboratory. A summary of each electronic unit is presented below.

1.30.1 Anti-lock braking system/anti-slip regulation control module

The bus was equipped with an anti-lock braking system / anti-slip regulation (ABS / ASR) control module. The ABS portion of the system is designed to prevent the vehicle wheels from locking when excessive force is applied to the brakes. The ASR portion of the system is designed for traction control to prevent the wheels from slipping while accelerating on a slippery road surface. The purpose of the ABS / ASR system is to prevent skidding, improve traction and maintain steerability.

The unit had no time stamp data. However, a number of faults had been recorded, including 2 cable breaks, a short circuit and problems communicating on a data connector. Based on the type of faults and the damage to the bus during the accident, the recorded faults were likely due to damage incurred as a result of the accident.

1.30.2 Central controller

Many inputs and outputs were used to control and monitor the various on-board systems. The central controller contained the NVM data for the system. The central controller recorded 3 active fault codes. Based on the type of faults and the location of the damage to the bus during the accident, the recorded faults were likely due to damage incurred as a result of the accident.

1.30.3 Transmission control module

The bus was equipped with a transmission control module (TCM) to control and monitor the transmission system. The TCM recorded 1 fault code. As the fault code indicated that multiple parameters had failed simultaneously, the fault code and failures were likely due to damage incurred as a result of the accident.

1.30.4 Heating, ventilation and air conditioning system

The heating, ventilation, and air conditioning (HVAC) system controlled and monitored the bus thermal systems. Although the HVAC module contained NVM, the stored information was not related to bus performance during the occurrence and the data were not downloaded.

1.30.5 Automatic fare recording Presto system

Upon entering the bus, passenger cards are scanned and payment information is stored within the Presto system. MicroSD cards were recovered from the Presto readers and the data were extracted. No data relevant to the occurrence were present.

1.30.6 Intelligent Vehicle Network system

The Intelligent Vehicle Network (IVN) system enables fleet tracking and monitoring. OC Transpo uses the information to view schedule adherence of the overall fleet and to monitor general driving behaviours. Bus drivers also use the IVN system to view a GPS display that includes real-time schedule information.

The GPS receiver detects the bus current time and position based on the GPS data coming from the satellites and relays this information to the IVN computer, which then displays the data to the driver along with the current adherence to the schedule. The system also transfers the data by wireless transmission to the City data centre servers.

The IVN system captures the data and then saves them to the CompactFlash memory card every 100 milliseconds. The unit captures GPS data to tag each communication request that occurs within the unit and between units on the bus.

The IVN system lost some of its data due to the sudden loss of power during the accident and subsequent data file repair during recovery. The last GPS position recovered from the IVN system memory was located at the last bus stop before the occurrence located at the OC Transpo Fallowfield Station. Otherwise, the IVN system NVM contained little useful information pertinent to the operation of the bus.

1.30.7 Global positioning system data from the City

The GPS data from the City servers were recovered on 19 September 2013. These data enable fleet tracking and planning, and help in schedule adherence. The GPS data received by the servers are what has been transmitted from each individual bus. The data that the bus transmitted were what was captured through the IVN system. This was the only GPS system on the bus. The GPS unit was not a differential GPS, but the GPS data were guaranteed to have an accuracy of 10 feet (3.1 m) or better.

The GPS transmission from the bus was sent once every 30 seconds, and whenever a transmittable event occurred such as doors opening or the stop button being pushed. No data were sent back to the bus.

The last GPS–recorded position of the bus was at a location of about 1083 feet (330 m) south of the Transitway crossing. At this location, the bus was listed as being 3 minutes 48 seconds behind schedule and travelling at 30 mph (48.3 km / h).

1.30.8 Engine control module

The bus was equipped with an engine control module (ECM) to control and monitor the engine. Although the events recorded in the ECM were time stamped, the time stamp was limited to ECM run time and did not provide real date and time. While the ECM recorded and monitored all engine control functions, it was also programmed to capture some basic information when the bus was involved in a sudden deceleration event. The recording of sudden deceleration events was automatically triggered when the bus decelerated at a rate of more than 9.0 mph / s (14.5 km / h / s). Had the bus not achieved this deceleration rate, the ECM would not have recorded an event. For sudden deceleration events, the ECM captured data in 1-second increments for 59 seconds before the event and for 15 seconds after the event.

In the recorded event, the bus was stopped at 38 seconds back from the sudden deceleration activation with the brake status “ON” and the engine speed was at idle (at about 700 rpm). The engine load was low (at about 15%) and the bus speed was 0 mph (0 km / h). See Table 11 and Appendix E for the sudden deceleration event recorded for this occurrence.

Table 11. Engine control module summary

Time to deceleration activation (seconds)	Event*
-41	Brake status** is no longer “ON”.
-39	Throttle is non-zero.
-37	Vehicle speed*** is non-zero.
-2	Vehicle reaches a maximum speed of 42 mph (67.6 km / h).
-1	Engine load drops to 0% and throttle drops to 0%.
0	Vehicle speed drops 7 mph (11 km / h) to 35 mph (56 km / h). Engine speed drops 246 rpm at 1004 rpm. Brake status comes “ON”.
+1	Vehicle speed drops 10 mph (16 km / h) to 25 mph (40 km / h). Engine speed drops to idle at 708 rpm.
+2	Vehicle speed drops 20 mph (32 km / h) to 5 mph (8 km / h). Engine speed is just below idle (659 rpm). Engine load has a spike from 0 to 20.3%.
+3	Vehicle speed drops 3 mph (5 km / h) to 2 mph (3 km / h). Engine speed is well below idle (285 rpm). Lamp status turns “ON”. Engine load drops back to 0%.
+4	Vehicle speed is at zero. Engine speed is almost stopped (51 rpm).

* The sudden deceleration event occurred at about time 0.

** The brake status is based on pressure sensors in the brake line. The pressure sensors switch on at a pressure of 5 psi + / - 1 psi, which equates to an 8-degree pedal angle and the beginning of the engagement of the foundation brakes. The first 8 to 10 degrees of pedal movement activate the transmission retarder.

*** While the ECM does not directly read vehicle speed, the transmission communicates tail shaft speed to the ECM. The vehicle speed is calculated based on vehicle trims and tail shaft speed. There may be some small differences in the range of $\pm$ 1 mph (1.6 km / h) between the recorded speed and the actual vehicle speed.

Based on the ECM data, it was determined that the bus had travelled approximately 1601 feet (488 m) from an initial stop to its final resting position. The distance between the rail crossing and the bus stop at the OC Transpo Fallowfield Station was approximately 1591 feet (485 m).

The ECM had recorded 31 active faults that occurred very close together. These faults were mainly related to wiring issues for either power or communications. Due to the nature of the faults, and since they occurred so close together, the faults were likely recorded as a result of damage incurred by the bus during the impact.

While the ECM data were useful, they lacked sufficient detail to conduct a thorough analysis.

1.31 Analysis of braking system

A comprehensive review of the OC Transpo ADL E500 bus fleet records relating to the braking system was conducted. The following was determined:

- There was no indication of any systemic problem that would affect the safe operation of the braking system.
- There were no driver-reported defects for the occurrence bus on the day of the accident.
- A maintenance campaign was in place to address lubrication of the brake S-cam rollers and pins to prevent seizing. Seized S-cam rollers could lead to a flat spot on the roller and / or irregular wear on the cam surface. If left unchecked, this condition could cause brake noise and slow release of the brakes, but would not affect the ability of the brakes to be applied. The occurrence bus had not been through the new lubrication campaign.
- The ADL E500 bus had undergone a series of tests to demonstrate compliance with CMVSS Standard 121, Air Brake System. These tests included, among others, service brake, emergency brake and air system performance tests. The vehicle met or exceeded all required criteria for operation in Canada.

1.31.1 ADL E500 brake system

The air brake system is divided into 3 separate circuits:

1. the service brake 1 circuit, which operates the front and tag axle brakes;
2. the service brake 2 circuit, which operates the drive axle brakes; and
3. the park / emergency brake 3 circuit, which operates the park / emergency brakes on the drive and auxiliary axles.

The service brake 1 and the service brake 2 circuits are controlled simultaneously through separate sections of the foot brake valve.

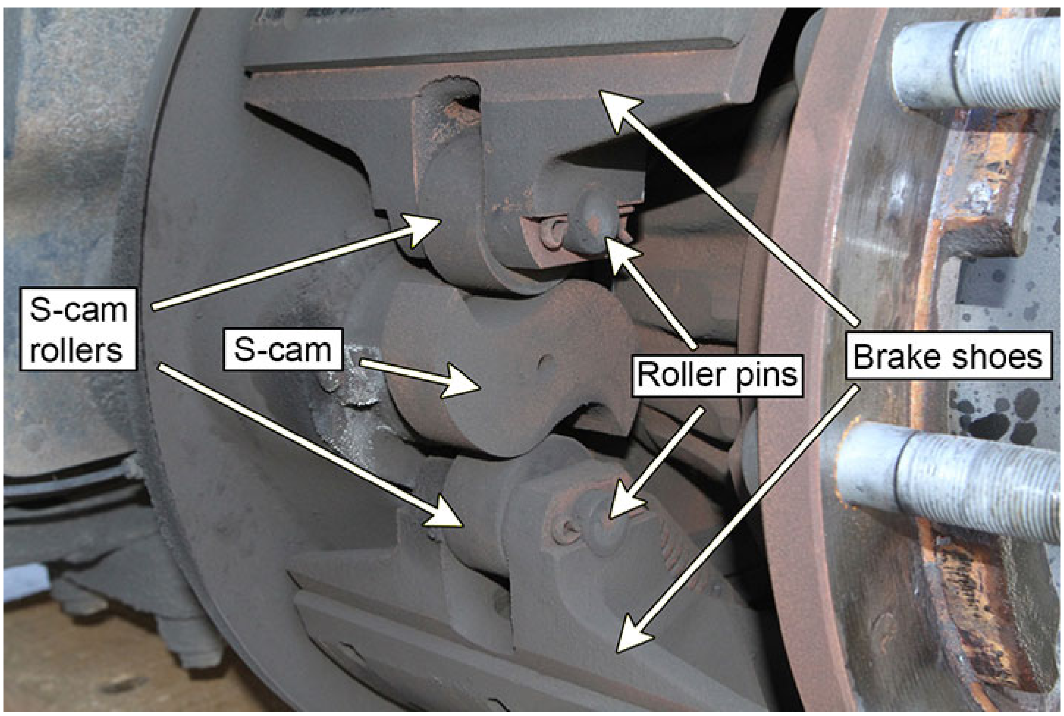
Compressed air for the air brake system is provided by an engine-driven compressor that supplies 8 reservoirs. The service brake 1 and auxiliary axle reservoirs supply air to the service brake 1 circuit. The service brake 2 reservoir supplies air to the service brake 2 circuit. The park / emergency brake 3 reservoir supplies air to the park / emergency brake circuit. The braking system incorporates a wet tank, a purge reservoir and a system backup reservoir. The auxiliary and suspension reservoir supplies air to the air suspension, kneeling system and body services such as door operation.

A quadruple protection valve supplies each circuit independently with compressed air and ensures that downstream failure in any of the 4 circuits will result in isolation of that circuit. In the event of a failure, the quadruple protection valve will sense a pressure decrease and will automatically isolate the failed circuit while maintaining a supply of compressed air to the remaining circuits.

The front and rear wheel brake assemblies are equipped with automatic brake adjustment devices designed to maintain a constant running clearance between the brake linings and the brake disc/drum.

The front axle is fitted with disc brake assemblies with electric pad wear sensors and ABS traction control. The front brakes are applied by single diaphragm actuators. The drive and auxiliary axles are fitted with S-cam drum brake assemblies (Figure 13).

Figure 13. View of S-cam assembly with brake drum removed



The S-cam brake system is commonly used in air brake systems for heavy trucks and buses. When the foot brake is depressed, air pressure in the actuator chamber pushes a rod out, moving the slack adjuster, thus twisting the brake camshaft. This turns the S-cam (shaped like the letter “S”). The S-cam forces the brake shoes away from one another and presses them against the inside of the brake drum. Rollers installed on the brake shoes provide a contact surface between the S-cam and the brake shoe. When the foot brake is released, the S-cam rotates back and a spring pulls the brake shoes away from the drum, letting the wheels roll freely.

The S-cam assemblies are equipped with ABS traction control and incorporate dual-type brake actuators to accommodate the park / emergency brake. The dual-type actuators have front and rear service portions. The front service portion is a single diaphragm brake chamber while the rear service portion is a cylinder containing a powerful coiled spring (maxi), which is held compressed by introducing air behind the diaphragm.

When the park / emergency brake control is in the OFF position, air is supplied to the dual actuators to compress the spring and hold the brakes off. When the park / emergency brake control is in the ON position, the air supply is cut off and the pressure is exhausted to allow the springs in the dual actuators to apply the brakes. The park / emergency brake control can also be applied gradually to moderate the spring forces and allow a gradual stop in an emergency situation. Application of the park / emergency brake illuminates a red parking brake symbol on the driver's display screen.

To assist in the deceleration and to reduce wear on the service brakes, a transmission retarder is installed at the output of the transmission. The retarder is automatically activated when the foot brake is depressed and will remain active until a speed of 1.6 to 1.9 mph (2.5 to 3 km / h) is attained, the ABS system is active or the retarder is switched off by the driver.

The foot brake valve assembly located to the left of the accelerator pedal has 2 supply ports and 2 delivery ports. One set is for the service brake 1 circuit while the other set is for the service brake 2 circuit. This is built in for redundancy; failure of one circuit will not affect the other circuit. The foot brake valve controls the application of the bus service brakes and transmission integral retarder. Light braking applications will utilize the retarder first with increasing pedal effort applying both the retarder and service brakes.

The driver is provided with brake and air system warning indications on 2 panels located at the driver's station. The driver's display screen located in the centre of the instrument panel displays warning symbols associated with situations categorized in priority levels 1 to 6.

1. Priority 1 warnings indicate emission malfunctions;
2. Priority 2 warnings require immediate attention and are accompanied by a red STOP warning display symbol and an audible warning;
3. Priority 3 warnings represent errors and warnings provided for driver awareness;
4. Priority 4 warnings indicate selected functions and low-level warnings;
5. Priority 5 warnings are associated with transit warnings and / or requests for the driver; and
6. Priority 6 level is for information and / or warnings where drivers are permitted to continue with caution.

Whenever a priority 2 (red STOP) warning is displayed, drivers are instructed to drive the vehicle to the side of the road and switch the engine off as soon as it is safe to do so. In this occurrence, no attempt was made to pull over after departing from the OC Transpo Fallowfield Station, which indicates that the warning was not displayed.

The ADL E500 bus has the following additional brake system fail-safe features:

- An audible warning will sound when the ignition is turned on and will remain until the air pressure is above 87 psi.
- The park / emergency brake will not release until the air pressure in the service brake reservoirs is above 87 psi.
- The quadruple protection valve will automatically isolate a failed circuit while maintaining a supply of compressed air to the remaining circuits.
- The foot brake must be depressed before the drive gear can be selected. The park / emergency brake must be in the ON position for the kneeling system to operate.
- The park / emergency brake must be in the ON position to operate the loading ramp.
- An interlock feature will apply the park / emergency brake and disable the throttle when the door control is activated.
- If a driver leaves the seat without applying the park / emergency brake, a warning lamp will flash, a buzzer will sound and the interlock will apply the park / emergency brake.

1.31.2 Brake system examination

Detailed examination of the bus braking system, in conjunction with observations at the site, determined the following:

- There were no outstanding brake-related defects on the bus at the time of the accident.
- The system was based on a fail-safe design that would isolate a failed circuit and ensure that the other circuits were not affected.
- The park / emergency brakes were locked on, which was consistent with a catastrophic loss of air within the braking system.
- There were no extended skid marks on the surface of the road leading to the bus as would be expected with a functional ABS system.
- On site, a visual examination and photo documentation of the tires, wheels and brake assemblies were performed. While no obvious defects were identified, 3-inch-long abrasion marks were noticed on the road surface under the right front wheel as well as drive and tag axle wheels. The abrasion marks had likely occurred as a result of a slight rearward push during the accident.
- Rubber abrasion was evident around the circumference of each tire, which was consistent with ABS operation. Isolated scuff marks related to rearward skidding were observed on the drive and tag axle tires.
- The drive axle, right upper brake shoe S-cam roller was seized onto the roller pin. There was no discernible flat spot on the roller and no wear observed on the S-cam surface. This condition would not have adversely affected the ability of the brakes to be applied.
- The park / emergency brake control lever mechanism had a damaged plastic lock lever and a broken lock tab, which suggested that the park / emergency brake lever was in the ON position during the impact. It could not be determined if, or at what

point in the sequence of events, the park / emergency brake was moved to the ON position. It is possible that the damage occurred as a result of the impact. However, activation of the emergency brake would have had no effect on the braking, as long as air supply was available and the foot brake was depressed.

- The mechanical and pneumatic components of the air brake system did not have any pre-accident deficiencies that would have affected normal operation of the brake systems.
- Once the brakes were applied, bus deceleration fell within the braking system design criteria.

1.32 Braking analysis and determination of bus speed

The stopping distance requirements applicable to the occurrence bus are defined in the United States National Highway Traffic Safety Administration (NHTSA) FMVSS. These requirements had been adopted by TC in the CMVSS.

The stopping distance required by the NHTSA standard is the minimum safety requirement that vehicles in the same weight category must meet. A vehicle would normally be designed to have a sufficient safety margin above the minimum requirement. In the NHTSA standard, the required stopping distances are identified for different speeds. These stopping distances are applicable for a fully loaded bus and an unloaded bus.

Braking analysis was performed to determine event timing, braking distance and amount of braking force applied to a loaded bus during the accident scenario. The analysis incorporated measurements and observations made on site immediately following the accident and detailed engineering calculations for a loaded bus based on ECM data, brake system reaction time and brake performance charts from both the bus certification tests and manufacturer tests.

The following observations and calculations were made:

- The ECM data indicated that the initial application of the bus brakes occurred when the bus was travelling at a speed of 42 mph (67.6 km / h), which exceeded the posted speed limit of 60 km / h (37.3 mph).
- The stopping distance varies as the square of the initial speed of the vehicle. Thus, the stopping distance requirement for the speed of the occurrence bus at the time the brakes were applied (42 mph or 67.6 km / h) was determined by interpolation to be 137.0 feet (41.8 m).
- The estimated stopping distance of the occurrence bus without a collision occurring was 117.8 feet (35.9 m). This is well below the stopping distance required by the standard (137.0 feet or 41.8 m), which indicates that there was no malfunction of the braking system.
- The bus was 116.8 feet (35.6 m) away from the point of collision when braking was initiated.

- The speed of the bus was between 4 and 4.8 mph (6.4 to 7.7 km / h) when the bus initially collided with the train. The bus moved another 4.3 feet (1.3 m) in the forward direction after the initial impact.
- The certification data revealed that deceleration was constant throughout each certification test. The ECM data identified that the deceleration of the occurrence bus was progressive, which indicated that initially the brakes were not fully applied.
- If full braking force had been applied from the beginning of the brake application and assuming a constant deceleration of 0.6 g,[109] which is the manufacturer's minimum value specified for deceleration, the stopping distance for the bus was calculated to be 112.5 feet (34.3 m).
- Data provided by the manufacturer indicated that the braking system was designed to produce a maximum deceleration ranging from 0.6 g to 1.0 g. For the speed range of 25 mph (40.2 km / h) down to 5 mph (8 km / h), the bus ECM recorded an actual deceleration of 0.91 g.
- If maximum braking force was initially applied and a deceleration of 0.91 g was achieved throughout the brake application, the calculated stopping distance would have been further reduced to 101.1 feet (30.8 m).

To understand the influence that speed may have had, additional calculations were performed based on the posted speed limit of 60 km / h (37.3 mph) with the following results:

- The stopping distance for a bus travelling at the posted speed limit (60 km / h), with all other factors remaining the same, would have been 29.5 m (96.8 feet), or 6.1 m (20 feet) before the point of collision.
- An increase of 7.6 km / h (4.7 mph) above the posted speed limit increases the stopping distance required to bring a bus to a stop by 6.4 m (21 feet).

1.33 TSB bus crashworthiness assessment

Crashworthiness of a vehicle refers to the design characteristics that protect the occupants from injury or death during a crash event.[110] The fundamental principles of crashworthiness are often described using the acronym CREEP:

- Container
- Restraints
- Energy management
- Environment
- Post-crash factors

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[109] 0.6 g is the manufacturer's minimum value specified for deceleration (1 g is equal to an acceleration / deceleration of 32.1 feet / s^2 or 9.8 m / s^2).

[110] D. F. Shanahan, "Basic Principles of Crashworthiness", Research and Technology Organization, Human Factors and Medicine, lecture series on Pathological Aspects and Associated Biodynamics in Aircraft Accident Investigation, Königsbrück, Germany, 2-3 November 2004, published in RTO-EN-HFM-113.

In this occurrence, environment and post-crash factors were not contributory to survivability as the occupants were not exposed to fire, smoke, water or chemicals that can result in injuries such as burns, drowning or asphyxiation. For this occurrence, the crashworthiness assessment considered the 3 factors of container, restraints and energy management.

1.33.1 Container

The container is the occupiable portion of a vehicle. It is the most critical factor for crashworthiness as a strong, enclosed container should be maintained around the occupants to create a survivable space. Failure of the container will generally result in a reduction of survivable space due to crushing. It can also result in the loss of a protective shell for the occupants and / or of supporting structure for the restraint system. In this occurrence, as a result of the structural damage sustained during the accident, the bus no longer provided an intact protective shell for the occupants located in its front portion.

Another function of the container is to prevent penetration of external objects into occupied space. In this occurrence, the collision took place in open terrain and the train penetrated the bus structure.

The upper portion of the stairwell was damaged during the collision, but it remained functional and was used by the upper deck passengers to evacuate. Emergency exits were available, but were not used as the side exit door was forced open and used.

1.33.2 Restraints

An intact structure provides primary protection during an accident. However, occupants can still be injured from forceful contact with injurious surfaces and / or objects in their environment. A restraint system, consisting of the seat belt, the seat structure and their anchorages, can be used to prevent occupants and objects from striking each other within the vehicle. Failure of any part of the restraint system can result in injury.

In this occurrence, the only occupant required to be provided with a restraint system was the bus driver. The passenger seats were not fitted with seat belts, nor were seat belts required by federal regulations.

The driver’s cab assembly and seat were separated from their supporting structure during the accident. The first 2 rows of seats (4 seats) on the left side of the upper deck were separated from the bus with the supporting floor structure. The seats located on the right side of the bus remained intact. A front window guardrail was separated from the bus during the impact.

1.33.3 Energy management

Survivability is also influenced by how well the severity of the impact is attenuated by the energy-absorbing features of the vehicle, and then directed away from the occupants. In this occurrence, although the breakup of the front structure of the bus absorbed some impact energy, it did not benefit the occupants as it also resulted in the loss of the protective shell for the occupants. The breakup of the front part of the bus demonstrates that the degree of protection provided by the structure of the ADL E500 bus was not sufficient for the significant loads involved in this accident.

When vehicles collide, the transfer of momentum from one vehicle to the other produces an impulse.[111] This can result in a change in the speed and direction of the vehicles and / or cause impact damage to the vehicles.

During a collision, vehicles also lose kinetic energy[112] as some of the energy is consumed by friction, deformation and fracture that occur when the vehicles interact with each other. A heavier vehicle has greater momentum and requires more energy to slow down than a lighter vehicle. A lighter vehicle will experience greater deceleration than the heavier vehicle for a given impact force.

Table 12 summarizes the collision parameters for the occurrence bus and train. The momentum and kinetic energy of the occurrence train were respectively 2 and 3 orders of magnitude greater than those of the occurrence bus.

Table 12. Momentum and kinetic energy of the bus and train

Vehicle	Mass (kg)	Speed		Momentum (kg·m/s)	Kinetic energy (J)
		mph	km/h		
Bus	24 000*	5	8	53 000	59 000
Train	283 636 (312 tons)	43	69.2	5 452 000	52 403 000
		15	24.1	1 902 000	6 377 000

* Based on a rounded estimate of the gross vehicle weight rating of a fully loaded bus with standing passengers.

The table highlights that, even if train speed is reduced to 15 mph (24 km / h) and all other parameters remain the same, the train's momentum and kinetic energy would still be several orders of magnitude greater than those of the bus.

1.33.4 Other crashworthiness observations

The following observations were made with respect to the crashworthiness of the bus:

- The left front corner of the bus, which connects the left side wall and the front-end framings, was broken up when it collided with the side of VIA 915's short hood. This initial collision created a vertical dent on the side of VIA 915's short hood that extended from a height corresponding to the top of the bus lower front-end framing to that of the top of the left front corner pillar. The structural integrity of the front end of the bus was compromised as it no longer provided an intact protective shell for the occupants located in its front portion.

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111 An impulse is a force acting on an object for a certain time.

112 The kinetic energy (KE) is the energy of an object due to its motion. It quantifies the amount of work that a moving object could do if it strikes another object. The kinetic energy is given by $KE = 1/2\, m \cdot v^2$ where m is the mass and v is the speed of the object.

- Due to the angle between the bus and train at the time of collision, the initial impact loading was concentrated on the left front corner structure of the bus instead of being distributed over the width of the front-end structure.
- The low-height chassis of the bus, which was about 17 inches (43 cm) above ground level, passed beneath the bottom portion of the skirt behind the pilot of VIA 915, and was not involved in the initial collision with the locomotive. The initial impact loading was imparted on the less robust structural components of the bus located above the chassis.
- It was estimated that the bus travelled about 1.3 m (4.3 feet) between the initial impact and the final stop. During this part of the collision sequence, the front of the bus continued to interact with the side of the train. The interaction created a large force, pulling the bus structure toward the left, in the direction of train movement, which caused the left side wall to be peeled back and bent toward the rear of the bus.
- The framing of the upper deck and lower deck floor was torn off as a result of the excessive force pulling in the direction of train movement. The tearing away 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.
- The front structure of the bus exhibited modest amounts of longitudinal compression and gross plastic deformation. This indicates that the breakup of the bus front structure did not require considerable impact energy. The front structure was not designed to provide impact protection, nor is frontal impact protection required by federal regulations.
- A more robust front structure and crash energy management design might have reduced the damage to the bus and prevented the loss of a protective shell for the occupants. However, the CMVSS contain no requirements for frontal impact, side impact, rollover or crush protection for vehicles with a GVWR in excess of 11 793 kg (26 000 pounds), which include most transit buses. Buses in this weight category can have a variety of different structural features.
- When the bus braked suddenly and collided with the train, the sudden deceleration likely caused the occupants to experience uncontrolled movement as a result of their inertia.

1.33.5 TSB crashworthiness assessment of single-deck transit bus

OC Transpo operates a fleet of conventional single-deck buses on the same routes as ADL E500 double-decker buses. The structural design characteristics of other representative single-deck buses were visually examined for comparison. The front-end framing of the single-deck buses examined was made of welded steel beams with joints reinforced with gussets.[113] In some cases, the side walls had a truss design,[114] also made of welded steel beams. Figure 14 gives a generic schematic illustration of this type of body structure.

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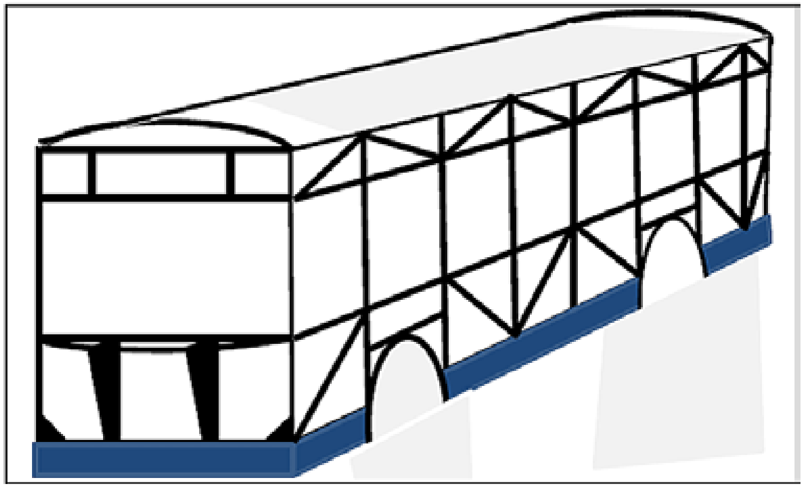
[113] Gussets are triangular steel plates that are used to strengthen the joints between the members of a structure.

Figure 14. Generic single-deck bus structure schematic



OC Transpo single-deck buses are fitted with bumpers that meet the American Public Transportation Association (APTA) requirement for a 5 mph (8 km / h) impact without damage. Some single–deck models have been tested to meet the 25 mph (40 km / h) side impact requirement.

The following observations were made:

- The general design characteristics of the comparison single-deck bus structure are different from those of the ADL E500. This suggests that the single-deck bus structure may behave differently if subjected to the occurrence impact loading.
- In this accident, 4 of the passengers who sustained fatal injuries 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.
- With no upper deck on the single-deck bus and a requirement for standing passengers to be located behind the driver's station, it is less likely that passengers would have been exposed in the area that was compromised by the collision. While more standing passengers may be at risk of injury resulting from hard braking, the number of fatalities may be reduced.

1.34 *Ergonomic study of ADL E500 driver's workstation*

An ergonomic assessment related to driver workstation design was conducted. The assessment included a review of the manufacturer's documentation, consultation with OC Transpo bus drivers and maintenance employees, and observations made as drivers interacted with bus controls and in-vehicle devices. As OC Transpo's bus fleet consists of 4 bus types and drivers can be assigned to drive any of the bus types, the assessment

114 A truss consists of straight members connected at joints typically in a triangle configuration because of the structural stability of that shape and design.

included observations for all bus types. The participating drivers sat in the driver's seat of each of the 4 bus types and completed the following 8 separate tasks:

1. sitting in their usual driving position and fastening the seat belt;
2. reaching for the ignition switch;
3. depressing the brake pedal from the foot resting on accelerator pedal;
4. reaching for emergency brake control;
5. looking at the destination sign screen;
6. looking at the video monitor (ADL E500 bus only);
7. engaging and picking up the bus radio; and
8. looking at the transit control head (TCH) display.

The participants discussed any perceived difficulties or discomfort that they experienced while carrying out the tasks, and compared the driving experience among the bus types. The results of this assessment are summarized in Appendix F.

Workstation ergonomics can affect driver behaviour and performance while a bus is in motion. The following ergonomic elements were reviewed:

- accommodation and adjustability;
- visibility from the driver's seat;
- driver's reach and use of controls; and
- position and use of in-vehicle displays.

1.34.1 Accommodation and adjustability

To accommodate the range of statures and body types, the driver workstation should be designed to provide maximum adjustability in its components. The driver seat was fully adjustable for the fore and aft positions, seat height and seat back angle, and adjustments for these features could be made while a vehicle was in motion. The steering wheel tilt / angle and column length were similarly adjustable, but could only be adjusted when the bus was stationary with parking brake on and bus in neutral gear. ADL documentation for the workstation layout indicated that the complete range of driver anthropometrics could be accommodated in terms of positioning of vehicle controls. The male drivers who participated in this study ranged in height from 5 feet 8 inches (177 cm) to 6 feet 3 inches (192 cm), which represent approximately 25% to 95% of average height for 45 year-old Caucasian North American males.

The driver's seat belt, which is required by law to be worn at all times when the bus is in motion, was assessed for fit and was reported as generally good. However, some drivers did not wear it all the time as they had experienced discomfort due to pressure on their torso and / or abdomen when wearing it for extended periods.

A broad range of driver seated eye heights existed, depending on a driver's anthropometry. Seated eye height and other anthropometric variables such as leg and arm length had an effect on the distance at which drivers positioned themselves from the vehicle controls and display screens. For example, on the ADL E500, 2 drivers of the same height (5 feet 8 inches or 177 cm) had the same seated eye heights (48 inches or 122 cm), but positioned themselves at different distances from the dashboard (32 inches or 81 cm compared to 34.5 inches or 88 cm). This resulted in different distances between the driver's eye point, the video monitor and the destination screen, both of which were located forward of the driver and above the line of sight. This difference in viewing distance has an impact on the eye angle at which a driver would have to look in order to view the overhead in-vehicle displays.

1.34.2 Visibility from the driver's seat

Driver visibility at level crossings can be compromised by features of the road vehicle itself, such as front window pillars, rear- and side-view mirrors. This is particularly true in larger vehicles, such as heavy trucks and buses, which are commonly equipped with protruding mirrors and other equipment that occupies a significant portion of the driver's visual field.

At the occurrence crossing, the left-side (west) front A and B pillars on the ADL E500 bus would have partially obscured a driver's view toward the crossing from about 740 feet (226 m) up to about 402 feet (122.5 m) south of the crossing stop line (northbound lane of the Transitway). Similarly, near the crossing, the right-side (east) pillars and front door structure would have partially obscured a driver's view of a train approaching from the east.

During the TSB re-enactment, the centre rear-view mirror was lowered as much as possible and a men's bicycle was mounted on the front bike rack. The re-enactment demonstrated that these objects would not have obscured a driver's view toward an oncoming train east of the crossing.

1.34.3 Driver's reach and use of controls

To assess whether safety-relevant controls in the bus types were easily operable and accessible from the driver's seat, the use of the ignition switch, the brake pedal and the emergency brake was examined.

1.34.3.1 Ignition switch

The locations and types of ignition controls varied among the bus types:

- The ADL E500 ignition was controlled by means of a green push button located to the right of the steering wheel.
- The Orion VII Hybrid ignition was a push button located to the left of the steering wheel on a panel adjacent to the window.
- The New Flyer ignition was a toggle switch located to the left of the steering wheel on a panel adjacent to the window.

1.34.3.2 Accelerator and brake pedals

Structurally, the accelerator and brake pedal configuration in the ADL E500 did not differ significantly from the other bus types. Although the Orion VII Hybrid pedals did not have a heel rest, the general shape, size, height from the floor, angle, distance apart and distance from driver's seat was common among all types. Functionally, the drivers reported that they did not notice any significant difference in the force necessary to depress the pedals among the bus types.

1.34.3.3 Emergency brake

In all cases, the emergency brake can be used for parking a bus. However, the ADL E500 emergency brakes can also be applied like a service brake in the event that the service brakes become inoperable. This functionality is different from the other OC Transpo bus types in that the ADL E500 emergency / parking brake can also be applied gradually by the driver using air from a separate reservoir. Not all drivers understood the functionality of the ADL E500 emergency / parking brake. The ADL E500 emergency brake is activated by a lever located to the left of the steering wheel, on a panel adjacent to the window. The emergency brake for the New Flyer 40-foot-long Invero D40i bus and the 40-foot-long Orion VII Hybrid bus are activated by a button located left of the steering wheel, on a panel adjacent to the window. The New Flyer 60-foot-long articulated bus has the emergency brake button located on the floor, to the left of the driver's seat.

1.34.4 Position and use of in-vehicle displays

Within the driver workstation, all OC Transpo buses were equipped with a destination screen and a TCH screen. The ADL E500 driver workstation contained an additional video monitor with a second similar monitor located at the base of the stairwell. The following sections describe the dimensions, position, and use of these features for OC Transpo buses.

1.34.4.1 Video monitor

Within the driver workstation of an ADL E500 bus, a video monitor was located on the left side of a forward panel above the driver seat (Photo 17). The location and angle of the monitor was not adjustable, images were not recorded, there was no sound provided, and the driver was not able to turn the display off or change the camera views.

The video monitor measured 6 inches (15.2 cm) wide by 3¾ inches (9.5 cm) high. The monitor was divided into 4 quadrants, each measuring 3 inches (7.6 cm) wide by 1⅞ inches (5 cm) high. Each quadrant showed a view from one of 4 on-board video cameras. The location of the monitor created a significant upward viewing angle for the driver (i.e., 30 to 40 degrees from the horizontal). Its location, about 22 inches (56 cm) from a driver's eye point, made the image appear very small to a driver (Photo 18).

The human visual field is large, extending 90 degrees to the left and right (peripherally) and approximately 55 degrees above the horizontal and 70 degrees below the horizontal. However, in this large visual field, only a small area – an elliptical cone of approximately 2 to 3 degrees directly ahead of the viewer – allows for clear and accurate vision. Outside of this cone, visual acuity drops rapidly.[115] When viewing displays at a significant upward angle,

[115] American Association of State Highway and Transportation Officials, *Highway Safety Manual*, 1st edition, 2010.

drivers are unable to benefit from their peripheral vision and its sensitivity to change and motion.[116]

Photo 17. Driver's workstation on ADL E500 bus

Photo 18. Driver's view of video monitor (upper left)

The 4 quadrant views had been fixed in a standard configuration on all OC Transpo ADL E500 buses as follows:

- the lower left image displayed the side doors;
- the upper left image displayed the stairwell;
- the lower right image displayed the upper deck; and
- the upper right image displayed the exterior rear of the bus.

When reverse gear on the bus was selected, the video monitor went blank for 1 or 2 seconds and then displayed the exterior rear camera view in full screen with guiding arrows to assist the driver with reversing manoeuvres. OC Transpo drivers were required to have an additional person guide them when reversing a bus.

The standard display arrangement of the video monitor had been selected following feedback provided to OC Transpo from drivers. In April 2013, OC Transpo had held an information session for drivers and requested feedback on the ADL E500 fleet. A list of issues was compiled and many were added to a "priority list" for consideration by the Bus Technical Advisory Committee (BTAC)[117] that OC Transpo had previously convened. The drivers suggested that the video monitor only display 3 views (i.e., stairs, side door and upper deck) rather than 4 views, so that they could have a better view of the images.

Video monitoring protocols used by other transit companies that operate ADL double-decker buses in Canada were also examined. Video monitoring practices vary throughout

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116 M. Wittman, M. Kiss, et al., "Effects of display position of a visual in-vehicle task on simulated driving", *Applied Ergonomics*, Volume 37, Issue 2, March 2006, pp. 187-199.

117 The Bus Technical Advisory Committee is a joint committee comprised of drivers, mechanics, union representatives, vehicle engineers and managers with the mandate to review vehicle characteristics and specifications and to suggest modifications.

Canada with no overall consistent strategy to minimize the risk of driver distraction (Appendix G).

1.34.4.2 Video monitor at the base of ADL E500 stairwell

ADL E500 buses in the OC Transpo fleet are also equipped with a second video monitor located at the base of the stairwell, facing customers. The monitor is placed to assist customers with determining seating availability on the upper deck. The monitor is the same size as the driver station monitor but the display is divided into 2 views:

- one view of the upper deck from the front facing rear; and
- one view from the rear facing forward.

While this monitor may provide some passengers with information on the upper deck, the images' small size still makes it difficult to determine if there is seating available, particularly if people navigate the stairs when the bus is in motion.

1.34.4.3 Destination screen

The destination screen was used by drivers to program the destination sign on the front of the bus. As such, it was typically used only when the bus was stationary (e.g., at the start or end of a run).

Within the ADL E500 driver workstation, and similar to the quad screen, the destination display was positioned on a panel above the driver. In this position, a significant upward viewing angle ranging from 15 to 30 degrees from horizontal was required. Unlike the quad screen, it was placed in the centre of the overhead panel. The position and angle of the destination screen were not adjustable.

The version and position of the destination screen in the other 3 bus types varied. However, they all provided similar functionality and each was located on a panel overhead of the driver workstation.

1.34.4.4 Transit control head screen

The TCH screen provided

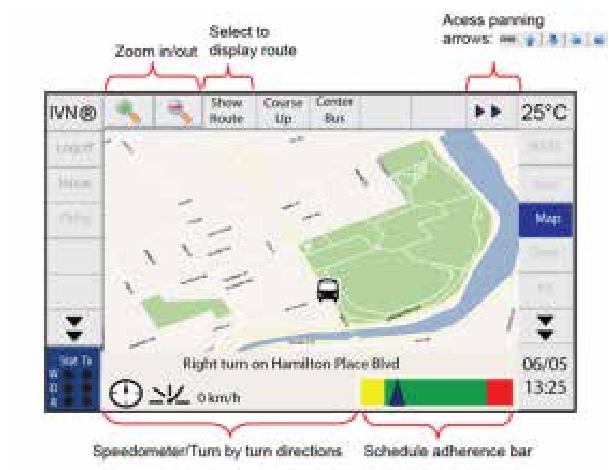
- real-time access to schedule;
- route and traffic information;
- on-time performance data; and
- messages to and from OC Transpo dispatch.

The TCH system used GPS data to display route maps, bus location and an on-time performance schedule adherence bar to drivers. The TCH screen measured approximately 11 inches wide by 8 inches high (28 cm by 20 cm). The display within the screen measured 8¾ inches wide by 5⅜ inches high (22 cm by 14 cm). In all of the bus models, the TCH screen was positioned to the right of the steering wheel at dashboard height (Photo 19). The position of the TCH screen was slightly adjustable and the horizontal angle could be changed depending on a driver's seated eye point, viewing angle, and personal preference.

The input functions of the TCH were locked out to the driver when the bus was travelling at speeds in excess of 16 km / h (10 mph). At this speed, a map display was automatically displayed. However, input controls related to the map features, such as zoom, route shown, route options, panning, speedometer, turn-by-turn directions, and the schedule adherence bar, remained active at speeds above 16 km / h (Photo 20).

Photo 19. Transit control head screen position

Photo 20. Transit control head display



1.35 United States Driver Distraction Guidelines for In-Vehicle Electronic Devices

There are currently no federal motor vehicle safety regulations in North America for original equipment information and communication systems. TC encourages vehicle and electronics manufacturers to design devices that are compatible with safe driving and to follow current safety guidelines and best practices.

As part of the joint Canada–United States Regulatory Cooperation Council (RCC) agreement, Canada and the United States have pledged to work together on auto safety issues, and this includes distraction.[118] In 2013, the United States announced voluntary driver distraction guidelines,[119] which were designed to encourage automakers to forego in-vehicle systems that require the manual input of data while a vehicle is in motion, or that require unreasonably long glances away from the forward visual scene.

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118 P. Burns, "Emerging technologies, emerging issues", International Conference on Distracted Driving, Toronto, Canada, 01 March 2012, available at: http://www.distracteddriving.ca/presentations/EmergingTechnology-SpeakerBurns.pdf (last accessed 28 September 2015).

119 United States Department of Transportation, National Highway Traffic Safety Administration (NHTSA), *Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices*, Federal Register, Volume 78, Number 81, 26 April 2013, available at: http://www.gpo.gov/fdsys/pkg/FR-2013-04-26/pdf/2013-09883.pdf (last accessed 28 September 2015).

The driver distraction guidelines apply only to light passenger vehicles. However, in its comments on the proposed guidelines, the United States National Transportation Safety Board (NTSB) provided detailed narrative descriptions of several serious distraction-related crashes that involved heavy vehicles. Among these accidents were a crash involving a heavy truck and a crash involving a motor coach. The drivers for both of these accidents had been distracted by cell phone tasks at the time of the crash. The NTSB commented that,

> Considering the significance of large commercial vehicles in overall crash and fatality rates, and given the increasing availability and use of electronic logs, global positioning system(s), and other potentially distracting systems in these vehicles, the NTSB encourages NHTSA, with the Federal Motor Carrier Safety Administration, to monitor the introduction of in-vehicle technology and aftermarket technology into medium trucks, heavy trucks, and buses, including motorcoaches, and to conduct research as appropriate.[120]

While the NHTSA agreed with the NTSB that addressing driver distraction in heavy vehicles was important, it responded that research needs to be performed before distraction-related recommendations for heavy vehicles can be made. The NHTSA noted that “nothing precludes heavy vehicle manufacturers from following the principles and Guidelines set out in this document should they find them useful.”[121]

The driver distraction guidelines specifically recommended the disabling of, or making inaccessible, certain in-vehicle system operations unless the vehicle was stopped and in park. Activities that were considered to interfere with a driver’s ability to safely operate the vehicle included

- displaying and viewing video not related to driving; and
- displaying and viewing non-video graphical or photographic images.

The driver distraction guidelines also recommended that a device’s active display be located as close as practicable to the driver’s forward line of sight with a maximum downward viewing angle of 30 degrees as measured from the driver’s seated eye point to the geometric centre of each display. There was no recommendation related to an upward viewing angle.

1.36 American Public Transportation Association

The APTA is a North American industry association which, among other things, develops standards, shares best practices and conducts peer reviews within its membership. APTA members are public organizations that are engaged in the areas of bus, paratransit, light rail, commuter rail, subways, waterborne passenger services, and high-speed rail. OC Transpo is a member of the APTA.

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[120] Ibid., p. 24845.

[121] Ibid., p. 24846.

1.36.1 American Public Transportation Association bus crashworthiness guidelines

The 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 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. The principal crashworthiness requirements in the APTA guidelines pertaining to transit buses are summarized in Appendix H.

The APTA guidelines include the following considerations:

- Technical specification (TS) 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 TS recommends mounting a front bumper such that the top of the bumper is located 27 inches (68.58 cm) ±2 inches (5.08 cm) above the ground.
- TS 70.2 requires that no part of the bus, including the bumper, shall be damaged as a result of a 5 mph (8 km/h) impact of the bus at curb weight with a fixed, flat barrier perpendicular to the bus longitudinal centreline. The bumper shall return to its pre-impact shape within 10 minutes of the impact.
- The technical specifications also include static and dynamic strength requirements for passenger seating and seat back handholds to minimize the potential for occupant injuries.

1.36.2 American Public Transportation Association distracted driving guidelines

In 2009, after recognizing that distracted driving by transit drivers can be a serious public safety issue, the APTA published 2 recommended practices (RP) outlining strategies for minimizing driver distraction.

- APTA-BTS-BS-RP-005-09, entitled “Reducing Driver-Controlled Distractions While Operating a Vehicle on Agency Time,”[122] recommended that transit authorities should
  - educate employees about the industry-wide issues of operator distraction;
  - develop training programs to include driver distraction training;
  - ensure that policies and procedures include enforcement and disciplinary actions; and
  - analyse data to determine the effectiveness of agency policies and training.

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[122] American Public Transportation Association (APTA), *Reducing Driver-Controlled Distractions While Operating a Vehicle on Agency Time*, APTA Standards Development Program Recommended Practice, 31 December 2009, available at: http://www.apta.com/resources/standards/Documents/APTA-BTS-BS-RP-005-09.pdf (last accessed 28 September 2015).

- APTA-BTS-BS-RP-006-09, entitled “Reducing Agency-Controlled Distractions While Operating a Vehicle on Agency Time,”[123] recommended that transit authorities should
  - develop policies, procedures and training programs to mitigate distractions;
  - keep dispatch communications to a minimum;
  - create and enforce disciplinary steps or actions in accordance with agency’s policies and procedures; and
  - create an operator’s workstation to minimize distractions.

1.36.3 American Public Transportation Association peer review of OC Transpo

The APTA provides peer review services for public transportation systems through its subsidiary, the North American Transit Services Association (NATSA). Prior to the accident, in July 2013, the Ottawa Transit Commission approved OC Transpo‘s plan for the APTA to conduct a peer review of current system safety and security strategies and practices.

The peer review was initiated in March 2014. A panel of 5 industry peers reviewed documentation, conducted a system tour, and interviewed pertinent OC Transpo staff. While the results of the review were generally favourable, the review panel suggested that OC Transpo develop a System Safety Branch and refine safety responsibilities for all personnel. Specifically, the review noted the following:

- Top agency support is necessary for system safety to be successful. Important elements of a system safety program are a safety policy statement and a safety program plan signed and endorsed by the agency General Manager or Chief Executive Officer (CEO), a Chief Safety Officer reporting directly to the CEO, and a safety culture within the organization including reporting of information, sharing of information and learning from that information.[124]
- OC Transpo should share Riskmaster collision data with its Training Department to help determine training needs and curriculum for drivers.[125]

1.37 Safety management

Safety management refers to an organization’s ability to identify hazards that are associated with its operation and to put in place mitigation strategies to reduce the risks associated with the hazards to a level as low as reasonably practicable. In terms of safety, risk assessment is a process that

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[123] American Public Transportation Association (APTA), *Reducing Agency-Controlled Distractions While Operating a Vehicle on Agency Time*, APTA Standards Development Program Recommended Practice, 31 December 2009, available at: http://www.apta.com/resources/standards/Documents/APTA-BTS-BS-RP-006-09.pdf (last accessed 28 September 2015).

[124] American Public Transportation Association, *Report of the American Public Transportation Association Peer Review Panel on the Safety and Security Programs of City of Ottawa Transit Services*, 27 May 2014.

[125] Ibid., p. 15.

- identifies hazards;
- analyses or evaluates the risk associated with that hazard; and
- determines appropriate ways to eliminate or control the hazard.

Effective hazard mitigation requires

- knowledge of, and competence in, the field being analysed;
- processes to support the identification of hazards;
- means of identifying effective mitigations; and
- processes for tracking mitigations and identifying whether further action may be required.

All organizations engage in some form of safety management. In some industries, safety management systems (SMS) provide a formalized approach to safety management, which may be required by regulation and may be audited periodically by the regulator or other third party.

Under TC's *Railway Safety Management System Regulations*, all federally regulated railway companies must implement and maintain an SMS, which includes documented systems and procedures to monitor safety performance. VIA has had an SMS in place since 2001.

Canadian municipal transit operators are not required to have an SMS. In the United States, safety requirements for transit agencies require that

- the agency's governing body approve its safety program plan; and
- an agency's Chief Safety Officer report directly to the CEO.[126]

At the time of the accident, OC Transpo did not have a formal SMS in place for its transit operations, nor was it required to by regulations.

1.38 OC Transpo organizational issues

Organizational issues examined at OC Transpo included

- agency-controlled driver distractions;
- driver performance monitoring;
- route scheduling; and
- on-time performance.

1.38.1 Agency-controlled driver distractions

Agency-controlled driver distractions are those that arise from the driver's interaction with

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[126] United States Department of Transportation, Federal Transit Administration, Advance notice of proposed rulemaking, docket number FTA–2013–0030, 03 October 2013, available at: http://www.gpo.gov/fdsys/pkg/FR-2013-10-03/pdf/2013-23921.pdf (last accessed 28 September 2015).

- in-vehicle communications equipment and on-board vehicle displays of schedule adherence;
- work conditions such as workspace ergonomics and fitness for duty; and
- work activities, which include interactions with passengers, communications protocols and enforcement of rules.

In this occurrence, sources of agency-controlled distraction included

- position of the quad screen display within the driver workstation, which was significantly outside of the driver's line of sight;
- small size of the video monitor image displaying the upper deck;
- the requirement for drivers to monitor passengers on the upper deck while in service; and
- the requirement for drivers to make announcements to inform passengers that standing was not permitted on the upper deck while the bus was moving.

Formal risk assessment of the potential for driver distraction while using in-vehicle video monitors and displays should include the compilation and review of published research, standards and guidelines concerning the potential hazard and the evaluation of the hazard risk. While formal risk assessment can provide broad coverage of an issue, it may overlook operational aspects. In contrast, a pilot test may reveal unusual aspects of operations, but may not cover all potential uses of a device or technology in a limited time period. Pilot testing is not a sufficient method to identify risks that could lead to adverse operational consequences, such as traffic collisions.

In 2006, OC Transpo conducted pilot testing of an earlier model of ADL double-decker bus. The ADL E500 bus was pilot-tested upon its introduction to the bus fleet in May 2012. However, there was no formal risk assessment of the video monitor or the TCH display prior to their introduction into the fleet. The risks associated with the in-vehicle displays and their use was not systematically assessed until the 75 ADL E500 buses were operational.

At the time of the accident, OC Transpo

- was not aware of any guidelines or APTA recommended practices relating to agency-controlled driver distraction;
- had no specific policy or standard in place concerning potential distractions relating to workstation design; and
- did not employ an appropriately qualified individual to oversee this aspect of operations and ergonomics.

OC Transpo management may have assumed that the devices were safe, as they were commercially available products. Public opinion research indicates that 49% of Canadians believe that in-vehicle information and communication devices are tested to meet safety regulations ensuring that they are "not too distracting for the average driver."[127]

1.38.2 Driver performance monitoring

Research shows that a driver's accident history, number of traffic citations[128] and risky driving behaviours[129] are predictive of a driver's future accident involvement. Deficits in higher-order cognitive processes such as distractibility, inattention, judgment, reasoning, and hazard (or risk) perception are thought to underlie risky driving behaviours.[130] Specialized advanced driver training that addresses these issues, among others, can lead to modest decreases in crash risk of between 5% and 13%.[131]

Like many transportation industries, driver performance monitoring is important to determine whether drivers are performing their jobs safely, serving the customer adequately and following the work rules, policies and procedures.

At the time of the accident, OC Transpo employed about 1600 drivers, supervised by 10 section heads, with each section head responsible for about 160 drivers. Given the number of drivers, each bus driver could not be directly supervised. The bus drivers were monitored through the use of other less direct measures of performance including

- the number of customer complaints since last review;
- the number of customer commendations;
- a review of the provincial driver's abstract; and
- a review of at-fault accidents and incidents (once per 18-month period).

The OC Transpo Training Department is responsible for performing the periodic review of driver abstracts obtained through the MTO. The purpose of the review is to verify that drivers possess a valid commercial driver's licence and to flag drivers who have received demerit points on their driver's licence since the last review.

If the periodic abstract review reveals that a driver has received 6 or more demerit points since the last review, the OC Transpo Training Department will inform the driver's section

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127 Transport Canada, Strategies for Reducing Driver Distraction from In-Vehicle Telematics Devices: Report on Industry and Public Consultations, TP 14409 E, 2005, available at: http://www.tc.gc.ca/media/documents/roadsafety/tp14409e-tp14409.pdf (last accessed 28 September 2015).

128 M.A. Gebers, California Department of Motor Vehicles, *An Inventory of California Driver Accident Risk Factors*, report number RSS-03-204, 2003.

129 S. Blows, S. Ameratunga, et al., "Risky driving habits and motor vehicle driver injury", *Accident Analysis & Prevention*, Volume 37, Issue 4, July 2005, pp. 619-624.

130 L. Jerome and A.U. Segal, "Prediction of problem driving risk in novice drivers in Ontario: Part II Outcome at two years", in L. Dorn (Editor) *Driver Behaviour and Training, Volume III*, Human Factors in Road and Rail Transport, Ashgate, Aldershot, March 2008, pp. 75-88.

131 S. Washington, R.J. Cole and S.B. Herbel, "European advanced driver training programs: Reasons for optimism", *IATSS Research*, Volume 34, Issue 2, March 2011, pp. 72-79.

head. If drivers received a total of 15 or more demerit points, all while driving City vehicles, their licences would automatically be suspended by the MTO for at least 30 days, and their employment at OC Transpo would be terminated. If drivers received any of the demerit points while driving a vehicle that is not owned by the City, and if the licence suspension was for a period of less than 18 months, the collective agreement stipulated that, if alternate work was available and the employee met all requirements and qualifications, the employee could be assigned such work.

When section heads were made aware of a driver's demerit points, they were required to look at the behaviour that led to the demerit points and to request that the driver attend a meeting to discuss the behaviour and the potential ways to improve it. However, the meeting with the section head relating to demerit points was not mandatory. Even if a driver attended the meeting, reprimands or suspensions were rarely issued. It was noted that

- OC Transpo has no demerit threshold that would prompt additional recurrent or supplementary driver training;
- some section heads and training staff did not fully understand the MTO demerit point system and the related OC Transpo procedures; and
- information regarding demerit points from the drivers' abstracts, as well as the behaviours commonly leading to demerit-point infractions, is not used by OC Transpo to modify OC Transpo driver training.

OC Transpo Transit Operations maintained a database of reports of accidents and incidents that involved drivers while they were on duty. The collision / incident information was entered into the Riskmaster risk management collision database. The City's Risk Management Section assessed each incident as being preventable, preventable–minor, or non-preventable. Information from the database was available to section heads in the driver's employee file. If obvious negligence or incompetence on the part of a driver was identified, the section head could make disciplinary recommendations to senior management, who would decide on the consequences. These recommendations could include refresher training, driving assessments, medical referrals and / or steps under OC Transpo's progressive discipline process. The OC Transpo Training Department did not have access to Riskmaster, nor was the information included in a driver's training file.

1.38.3 Route scheduling

Transit route scheduling is complex. To be effective, a scheduling system must be designed with in-depth knowledge of scheduling practices, as well as a transit authority's policies, service standards and the local road environment. Many modern route scheduling systems are computer-based. OC Transpo had its own Scheduling Department, and used a commercially available computer software package to conduct its route planning and scheduling.

The route scheduling system used a number of inputs to generate the most efficient transit network possible. One input was bus GPS data that had been previously recorded on the route. Some of the GPS data may have included instances where a bus driver had exceeded the speed limit. Feedback from drivers was also obtained through OC Transpo's Service

Improvement Request (SIR) system. If drivers regularly found that they could not complete a route in the time allotted, or if they found that there was insufficient time to get from the end of one route to the beginning of next route, they could submit an SIR to the OC Transpo Scheduling Department.

There were 4 booking periods each year. The collective agreement with the City stipulated that drivers had to wait at least 10 days into a booking period before they could submit an SIR. Management then had 21 days to review the request and to provide a response. Any changes to routes were made at the beginning of a subsequent booking period. With the complexity of the route scheduling process, route changes could take a significant amount of time before they were implemented. Although some changes may be introduced within days, changes were typically implemented between 3 to 6 months from the date the response was sent by the Scheduling Department to the driver.

1.38.4 On-time performance

On-time performance is important to all parties involved in transit operations. OC Transpo considered a bus that left a scheduled stop early more negatively than one that left the scheduled stop late. Drivers were more likely to be contacted by the controller or their section head for departing from route time points early, rather than for arriving late.

Drivers may also experience pressure to maintain schedules from several sources:

- The TCH’s schedule adherence bar would show red if a driver was early, yellow if a driver was more than 5 minutes late, and green if a driver was on time (no more than 5 minutes late).
- Passengers sometimes react negatively to drivers who are behind schedule. Passengers expect to arrive at destination as quickly as possible, which can sometimes place pressure on a driver to speed in order to meet passenger expectations.
- Making up time en route can also be advantageous for drivers when they reach a run’s final destination where they can then extend their break and make full use of their “recovery time” before starting the next run.

There were also less direct, subjective pressures for drivers to stay on schedule. The collective agreement with the City required a guaranteed 5% minimum recovery time between trips to ensure the start time of the next run. While drivers were not formally provided with break time during their work day, they could use any additional recovery time (i.e., lay-up time) to take care of personal needs, to arrive at the beginning of a subsequent route or to return to the garage at the end of a shift.

1.39 Bus speed testing

Approaching the crossing, the Transitway had a posted speed limit of 60 km / h, which transitioned to 90 km / h north of the crossing. OC Transpo speed testing records were reviewed. The TSB also conducted some speed testing on the Transitway. The investigation determined that it was not uncommon for drivers to exceed the posted speed limit on the Transitway to make up time.

1.39.1 OC Transpo speed testing

The operation of vehicles on the Transitway is governed by City of Ottawa by-law 2007-268 respecting public transit (enacted 13 June 2007). The by-law has provisions governing speed.

OC Transpo special constables are responsible for monitoring bus speed on the Transitway system. Speeding violations are considered to be by-law infractions and there is no record placed on a driver's licence. Generally, at OC Transpo, a recorded bus speed of 12 km/h (7.5 mph) in excess of the posted speed limit was considered as speeding.

The following bus speed monitoring was performed:

- In the 2 years before the accident (18 September 2011 to 17 September 2013), on 6 occasions, OC Transpo special constables conducted speed tests. Although no records were kept for the number of tests performed, during this time, a total of 53 buses were recorded as speeding. Verbal follow-up was conducted on only 3 occasions.
- Between 03 February 2014 and 13 February 2014, speed monitoring was conducted between the Nepean Sportsplex and the OC Transpo Fallowfield Station. Of 128 buses checked, 17 buses were determined to be speeding.
- Between 03 March 2014 and 31 July 2014, speed monitoring was conducted between the Nepean Sportsplex and the OC Transpo Fallowfield Station. No buses were determined to be speeding.

Prior to the accident, there is no record of OC Transpo special constables issuing any tickets or citations to bus drivers for speeding violations under the by-law.

1.39.2 Speed testing

Effective speed testing and enforcement can reduce casualty rates. In 1997, a laser speed detection program implemented in Melbourne, Australia, was successful in reducing casualty crashes on arterial roads when monitoring and enforcement activities were conducted at low-to-medium intensity levels (i.e., sessions typically less than 1 hour, for up to 15 hours, per site, per year).[132]

In June 2014, the TSB conducted a number of speed tests on the Transitway from a location near the crossing.[133] The speed test results are summarized in Table 13.

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132 M. Fitzharris, K.R. Gelb, et al., "Evaluation of the effect of the deployment of hand-held laser speed detection devices in the Melbourne Metropolitan area", 1999 Research, Policing, Education Road Safety Conference: proceedings, volume one and two, University House, Canberra, Australia, 28-30 November 1999, pp. 709-720.

133 Speeds were monitored during peak periods over a 4-day period, for a total of about 17 hours.

Table 13. TSB Transitway speed testing results

Date (2014)	Total vehicles recorded	< = 50 km/h	51–55 km/h	56–60 km/h	61–65 km/h	66–70 km/h	>70 km/h	Total >50 km/h	Excess of posted speed
17 June	73	58	10	2	2		1	15	21%
18 June	254	194	37	18	4	1		60	24%
19 June	152	105	31	10	3	3		47	31%
25 June	191	144	27	12	2	5	1	47	25%
Total vehicles	670	501	105	42	11	9	2	169	25%

For additional reference, the distance that a vehicle travels per second at various speeds is listed in Table 14.

Table 14. Vehicle distance travelled at various speeds

Speed km/h (mph)	Distance travelled per second in metres	Distance travelled per second in feet
50.0 (31)	13.86	45.47
60.0 (37)	16.54	54.27
67.6 (42)	18.78	61.60
70.0 (43)	19.23	63.10
80.0 (50)	22.35	73.33

1.40 Time recorded for a bus to clear a crossing from a stop

The length of time it took a bus to traverse the Transitway crossing was examined. During this examination (04 October 2013), the roadway conditions were dry, the visibility was good and traction was considered ideal. The following results (i.e., time from the stop line on the northbound lane until the rear of the bus was clear of the crossing) were obtained:

- A loaded 60-foot-long single-deck articulated bus took 7.4 seconds to clear the crossing.
- A loaded 42-foot-long ADL E500 double-decker bus took 7.0 seconds to clear the crossing.
- A loaded 40-foot-long single-deck bus took 5.6 seconds to clear the crossing.

1.41 Buses stopping at crossings

In September 1988, OC Transpo introduced a policy requiring all vehicles to stop at all level crossings at all times. This policy had been introduced following representation by a local school board where safety was cited as the main consideration. The former City of Nepean opposed the policy.

In February 1992, the policy was rescinded following discussions between OC Transpo and TC officials. An operational bulletin identified that "retiming of signal activity" had been standardized, suggesting that the policy had been introduced due to inconsistent signal timing at railway crossings protected by AWDs.

OC Transpo provides service in both Ottawa and Gatineau, Quebec. The City of Gatineau's transit system does likewise in Ottawa. Drivers from both companies must be aware of and adjust their actions as appropriate when moving between jurisdictions. The OHTA states that buses and other public vehicles are required to stop at railway crossings that do not have AWDs, while school buses must stop at all railway crossings regardless of protection. The Quebec *Highway Safety Code* requires that buses, minibuses and hazardous material transporters stop at all railway crossings.

OC Transpo operating procedures met the OHTA and Quebec *Highway Safety Code* requirements, and OC Transpo had not reported any incidents involving driver error resulting from the difference in policies. OC Transpo buses operating in Ottawa were not required to stop at railway crossings protected with AWDs when the AWDs were not activated.

1.41.1 Stopping at railway crossings with automatic warning devices

In October 2013, the City contracted the MMM Group Limited (MMM) to produce a study[134] of OC Transpo procedures for traversing at-grade (level) railway crossings and other procedures used throughout Canada and the United States. The study included a literature review of research specific to the risks associated with vehicles stopping at railway crossings protected with AWDs when the AWDs were not activated. The study identified that the available technical information was limited and focused mainly on school buses and hazardous load transporters.

The study noted the following:

> Reducing accidents at rail-highway grade crossings has long been a subject of public concern. No other kind of motor-vehicle accident has such a high severity, making this a safety issue of primary significance. The ratio of persons killed and injured to the number of accidents at grade crossings is 40 times the same ratio for all motor vehicle accidents.[135]

Vehicle-train collisions are only one component of the accidents that occur at crossings. About 5 times as many roadway accidents that do not involve trains occur at railway crossings. These accidents include rear-end collisions with vehicles stopped at the crossing, collisions with crossing devices and run-off-the-road collisions by drivers losing control on rough crossings, severely humped crossings[136] or when trying to avoid a collision with a vehicle stopped at the crossing.

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[134] MMM Group Limited, Buses at Highway / Railway At-Grade Crossings, An assessment of risk associated with alternative bus crossing policies for at-grade highway / railway crossings, prepared for the City of Ottawa, 07 April 2014.

[135] J. Glennon and P. Hill, *Roadway Safety and Tort Liability: Second Edition*, Lawyers & Judges Publishing Company, Inc., Tucson, Arizona, 01 June 2004, p. 256.

[136] Ibid., p. 257.

The seminal North American research in looking at the value of requiring certain types of vehicles (not just buses) to stop at crossings protected with AWDs when the AWDs are not activated was published in 1985 by the United States FHA.[137]

The FHA study indicated that not mandating stops at railway crossings protected with AWDs when the AWDs were not activated would result in a net annual decrease in train-involved accidents for hazardous material transporters, school buses, and passenger buses of 2.6%, 10.8%, and 17.4%,[138] respectively. While the 17.4% decrease occurred in cases where a train struck a vehicle, there was a small 3.3%[139] increase in accidents where a train was struck by a vehicle.

The time required to completely traverse and clear an at-grade railway crossing represents a period of exposure to the risk of collision with a train. The longer that a vehicle occupies a crossing, there is a greater risk of a collision with a train. Research shows that exposure periods are longer when vehicles must stop before entering and clearing a crossing and larger vehicles typically have longer clearance times.

1.41.2 Other transit authorities

The MMM study included a survey of transit authorities across Canada to identify what practices were in place for transit buses with regards to traversing railway crossings. The Toronto Transit Commission (TTC), GO Transit, City of Mississauga, Region of Waterloo and York Region transit services require all buses to stop at railway crossings, regardless of the type of crossing protection.

However, provincial regulations and transit authority policies differ across the country. While school buses are required to stop at railway crossings in most jurisdictions, some authorities do not require transit buses to stop in all cases (Appendix I).

1.41.3 Advantages and disadvantages of stopping

The MMM study outlined some of the advantages of requiring buses to stop at railway crossings protected with AWDs when the AWDs are not activated, including the following:

- The OC Transpo procedures would be consistent with Quebec procedures and would simplify the driving task by eliminating possible confusion and the potential for error on the part of the vehicle driver.
- The bus driver’s decision process would be simplified as the same procedure would apply to all crossings.

The MMM study also outlined several disadvantages of requiring buses to stop at railway crossings protected with AWDs when the AWDs are not activated, including:

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137 United States Department of Transportation, Federal Highway Administration, *Consequences of Mandatory Stops at Railroad–highway Crossings*, report number FHWA/RD-86/014, December 1985.

138 Ibid., p. 158.

139 Ibid., p. 76.

- increased motor vehicle / motor vehicle grade crossing collisions due to an increase in traffic conflicts between stopped / slow moving buses and higher-speed general traffic;
- transit buses and their passengers would be subjected to a higher risk of train / bus collision as buses crossing railway tracks from a stop require more time to clear the grade crossing than vehicles moving through without stopping;
- increased driver workload for the bus operator, which is typically associated with a greater potential for driver error.

There would be negative impacts on traffic operations and the overall capacity and level of service offered by the roadway in the vicinity of the crossing. This is due to the increased traffic turbulence generated by the braking, avoidance and lane-changing actions of other traffic responding to the presence of a decelerating / stopping bus when such action is not required.

The MMM study indicated that the OC Transpo policy of not stopping at railway crossings protected with AWDs when the AWDs are not activated is acceptable. The study also recommended that AWD protection that includes flashing lights, bells and gates should be installed at all rail crossings used by OC Transpo buses.

The study did not discuss the possibility of OC Transpo buses stopping at select crossings protected with AWDs when the AWDs are not activated. The study also did not identify other factors that could affect the ability of a bus to safely negotiate a level crossing, such as approach gradient, the type and condition of the roadway surface and weather conditions at the time.

1.41.4 Other crossing accidents involving a bus

In this occurrence, the bus struck the side of the train while the crossing AWDs were activated. However, there have also been cases where a bus stopped at a protected crossing and then drove into the path of an oncoming train (Appendix J).

1.42 Other OC Transpo bus incidents at level crossings

Between 18 September 2013 and December 2014, there were 5 incidents at the Transitway crossing and 3 incidents at the Fallowfield Road crossing involving an OC Transpo bus. Although these incidents were not reportable to the TSB, the TSB followed up on the incidents as part this investigation (Appendix K).

In May 2014, VIA installed video cameras at the Woodroffe Avenue / Transitway and Fallowfield Road crossings. As of May 2015, there were 5 reports of gates down on top of vehicles that had stopped beyond the roadway stop line. One of the incidents involved a waste management truck while another involved an OC Transpo ADL E500 bus.

1.42.1 Fail-safe automatic warning device activations

Crossing AWD protection is generally highly reliable. However, crossings can periodically experience unwanted activations as a result of the fail-safe design or other issues. During a

4-month period (commencing in January 2014), a series of unwanted activations occurred at 6 VIA crossing locations in the Barrhaven area (Table 15).

Table 15. Barrhaven crossings

Smiths Falls Subdivision mileage	Location
3.28	Woodroffe Avenue
3.30	Transitway
3.88	Fallowfield Road
5.10	Greenbank Road
5.73	Jockvale Road
6.81	Strandherd Road

Although not reportable to the TSB, as part of this investigation, the TSB followed up on and reviewed a total of 20 crossing AWD trouble calls that occurred between 23 January 2014 and 12 April 2014 (Appendix L).

The events appear to be individual faults rather than a systematic failure. Of the 20 trouble calls reviewed,

- 7 were determined to be normal operation of the AWDs;
- 7 were related to technical issues; and
- 6 were categorized as other causes.

The trouble calls that were considered to be normal operation of the AWDs included a series of reports that the AWDs were not working. For these trouble calls, subsequent testing and review of the operation history log indicated that the AWDs were performing as designed due to

- the approach circuit being occupied;
- the AWDs being disabled due to routine maintenance; or
- a train crew not following the proper activation procedure for the crossing.

Technical issues that caused the AWDs to revert to the fail-safe mode and remain activated included

- frost on the motor contacts;
- salt water accumulation in the ballast, which affected conductivity;
- high winds, which caused a gate to move;
- loss of power to the AWDs; and
- a momentary reactivation of the AWD protection that occurred after a train had passed. The gates started to descend, then immediately recovered. This was determined to be due to wheel noise generated by the train and required recalibration of the detection circuit to fix the problem.

Other causes for unwanted activation included

- roadway surface work repair;
- synchronization mismatch between the AWDs and the City traffic lights;
- minor maintenance issues noted during an inspection that did not adversely affect the AWD performance;
- a broken gate due to an impact from a vehicle; and
- stray voltage[140] from City transmission lines caused the AWDs to revert to the fail-safe mode.

VIA implemented a corrective action plan, in conjunction with its sub-contractors, to address the issues and to minimize the potential for recurrence.

1.43 Other crossing warning systems

There are a number of crossing warning systems available to alert drivers to upcoming hazards. For example, active advance warning signs, crossing lighting, rumble strips, or enhanced delineation with retroreflective signs are helpful at appropriate sites. Over the years, technology has improved and other crossing warning system options are available. Talking GPS systems have become quite advanced and could be programmed to alert drivers to an upcoming crossing and the need to slow down approaching the crossing.

Research on active advance warning signs indicates that, when active yellow flashers were added to a slightly enlarged advance warning sign and were activated by an approaching train, driver recognition and speed reduction improved significantly. Active advance warning signs that are not interconnected with railway crossing signals tend to be ignored by drivers because they flash permanently and do not necessarily indicate the presence of an approaching train. To address this, TC's new GCR and associated standards now require that, by 2021:

> 67. (1) A Prepare to Stop at Railway Crossing sign must be installed if:
>
> [...]
>
> (b) at least one set of front light units on the warning system is not clearly visible within the stopping sight distance of at least one of the lanes of the road approach [....]

The sign must be equipped with flashing lights and interconnected with the railway crossing signals.

Following the accident, the roadway speed on the Transitway approaching the crossing was reduced to 50 km/h. In addition, a flashing advance warning light was installed for

[140] This issue was referred back to the manufacturer (Siemens), the maintenance contractor (RailTerm) and an independent engineering contractor (Hatch Mott MacDonald) for review and comment so as to suggest possible ways to minimize the effect on the automatic warning devices.

northbound buses approaching the curve. However, the light flashes permanently and is not interconnected with the crossing AWDs, as recommended by RTD 10.

Other train detection technologies (e.g., GPS, radar, wheel sensors based on magnetic flux) can be used to provide low-cost active warning sign alternatives. As these technologies are not track circuit-based, they can be installed, maintained or replaced without great cost or impact on railway operations. However, the use of active warning signs, although showing potential, has not been widespread.

More recently, various collision avoidance technologies, including blind spot detection, vehicle spacing, speed control and automated emergency braking, have been implemented by the automobile industry. Most of these advancements focus on traffic ahead or behind a vehicle and have not sufficiently advanced to detect a vehicle (train) approaching from the side. None of the existing commercial applications include systems for detecting and automatically responding to a potential collision with a train approaching from the side.

Intelligent speed adaptation (ISA) systems are also being developed. ISA is an in-vehicle system that uses information on the position of the vehicle in a network in relation to the speed limit in force at that particular location. ISA supports drivers by helping them to comply with the speed limits everywhere in the network. Currently available ISA systems are based on fixed speed limits and may also include location-dependant or advisory speed limits.

Brake assist is a system designed to mitigate collision speed. It is designed to boost brake pressure to levels beyond those of the driver's pedal and shorten stopping distances. This technology is already available on cars and some buses. Dynamic brake assist is designed as an enhancement of brake assist coupled with obstacle sensors to further improve braking performance.

Protran Technology has developed a collision avoidance system intended to prevent crossing accidents. The system is a train detection system with wireless communication and an emergency notification link. The detection unit could be installed at a distance up to 2600 feet (792.5 m) from the crossing. To operate the system, each vehicle would have to be equipped with the vehicle unit and each crossing would have to be equipped with a wayside unit for detecting trains. When the wayside unit detects the presence of a train, it would send a notification to all vehicles in the vicinity of the crossing that are equipped with a vehicle unit. Once the train has passed the crossing, the units would automatically reset.

There are no systems to automatically detect a train approaching from the side and stop the vehicle. Most emerging technology still relies on the vehicle driver responding appropriately to the warnings received or displayed.

1.44 Bus accident statistical summary

1.44.1 Railway level crossing accidents involving buses in Canada

Between 2005 and 2014, there were 8 crossing accidents in Canada involving buses (i.e., 3 involving transit buses and 5 involving school buses).[141] None of the buses involved in these accidents were equipped with a dedicated crashworthy event recorder. While the CMVSS does not require commercial commuter vehicles to be equipped with event recorders, nothing precludes an operator from implementing crashworthy event recorders throughout its fleet.

1.44.2 Roadway collisions involving buses in Canada and the United States

The following data for police-reported motor vehicle traffic collisions involving buses were obtained for Canada[142] and the United States.[143]

In Canada, between 2009 and 2013 inclusive,

- there were 44 471 police-reported motor vehicle traffic collisions involving buses;[144]
- there were 158 bus collisions with fatalities; and
- there were 9958 bus collisions with injuries.
- In 2013,
    - there were 38 bus collisions with fatalities. Of the 38 collisions, 13 involved transit buses and 6 involved school buses.

In the United States, between 2009 and 2013 inclusive,

- there were 287 243 police-reported motor vehicle traffic collisions involving buses;[145]
- there were 1250 bus collisions with fatalities; and
- there were 65 000 bus collisions with injuries.
- In 2013,
    - there were 280 bus collisions with fatalities. Of the 280 collisions, 81 involved transit buses and 114 involved school buses.

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141 TSB railway occurrences R05S0032, R08T0111, R08T0340, R09T0010, R14T0081 and R14T0290, and TSB railway investigation reports R13W0083 and R13T0192.

142 Data obtained on request from Transport Canada's National Collision Database.

143 Data taken from the Large Truck and Bus Crash Facts 2013 of the United States Department of Transportation, available at: https://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/docs/Large-Truck-and-Bus-Crash-Facts-2013_0.pdf (last accessed 28 September 2015).

144 That number includes school buses, smaller school buses, urban transit buses, inter-city buses, and unspecified buses.

145 Any motor vehicle designed primarily to transport 9 or more persons, including the driver.

1.45 National Transportation Safety Board investigation of highway accidents involving buses

1.45.1 National Transportation Safety Board Highway Special Investigation Report

In a letter from the NTSB to the NHTSA,[146] the NTSB outlined the findings from its special investigation[147] that examined bus crashworthiness 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 apply to other types of large buses, such as motorcoach or transit buses.

In addition to bus crashworthiness, the NTSB investigation addressed data collection issues that hampered effective accident study and the need for a vehicle on-board EDR to facilitate data collection. EDRs have been commonly used by over 100 United States jurisdictions to manage school bus fleets. European[148] and United States studies[149] have found the use of EDRs to have had a positive impact on the operational safety of vehicle fleets.

In one case, Laidlaw Incorporated (Laidlaw),[150] prompted by the comparatively high accident rate in a school bus fleet in Bridgeport, Connecticut, studied the effect on safety following installation of fleet management EDRs.[151] The study consisted of fitting 65 of the 150 (43%) school buses in the Bridgeport fleet with EDRs. During the study, driver speeding was monitored, and those drivers who spent over 25% of their trip miles at speeds over a set threshold were required to participate in counselling sessions. At the end of the trial period, those buses not equipped with EDRs accounted for 72% of the fleet’s accidents. Subsequently, EDRs were installed in the remainder of the Bridgeport fleet. After a year, additional factors that contributed to accidents that were related to driver training were identified and Laidlaw modified its training program.

The presence of EDRs in many bus fleets shows that some jurisdictions are already taking advantage of the tools that EDRs can provide. Through years of experience with EDRs in the

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

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

148 G. Lehmann and T. Reynolds, “The Contribution of Onboard Recording Systems to Road Safety and Accident Analysis”, Proceedings of the International Symposium on Transportation Recorders, Transportation Recording: 2000 and Beyond, 3-5 May 1999, Arlington, Virginia, pp. 243-245.

149 Final Report for Bridgeport, CT Facility, ARGO Fleet Systems, VDO North America LLC, 12 June 1997.

150 Laidlaw is the largest contract operator of school bus fleets in the United States.

151 While these were not full crashworthy event data recorders, parameters such as speed were recorded.

aviation, rail and marine modes of transportation, the NTSB, TSB and the transportation industry have learned a great deal about the effective introduction of recording technology. Establishing industry standards for recording in these modes has been critical to effective implementation of EDRs. Industry standards ensure consistency in recorded data and prevent the proliferation of multiple formats and configurations.

Because of the safety improvements that have resulted from using on-board recorders, both for accident data and for fleet management, the NTSB concluded that

- the use of on-board recorders may help reduce the accident rates of vehicle fleets; and
- establishing on-board recording standards for vehicles will provide a necessary foundation for the future use of on-board recorders.

Subsequently, the NTSB recommended that the NHTSA

> Require that all school buses and motorcoaches manufactured after January 1, 2003, be equipped with on-board recording systems that record vehicle parameters, including, at a minimum, lateral acceleration, longitudinal acceleration, vertical acceleration, heading, vehicle speed, engine speed, driver's seat belt status, braking input, steering input, gear selection, turn signal status (left / right), brake light status (on / off), head / tail light status (on / off), passenger door status (open / closed), emergency door status (open / closed), hazard light status (on / off), brake system status (normal / warning), and flashing red light status (on / off) (school buses only). For those buses so equipped, the following should also be recorded: status of additional seat belts, airbag deployment criteria, airbag deployment time, and airbag deployment energy. The on-board recording system should record data at a sampling rate that is sufficient to define vehicle dynamics and should be capable of preserving data in the event of a vehicle crash or an electrical power loss. In addition, the on-board recording system should be mounted to the bus body, not the chassis, to ensure that the data necessary for defining bus body motion are recorded. (H-99-53)
>
> Develop and implement, in cooperation with other government agencies and industry, standards for on-board recording of bus crash data that address, at a minimum, parameters to be recorded, data sampling rates, duration of recording, interface configurations, data storage format, incorporation of fleet management tools, fluid submersion survivability, impact shock survivability, crush and penetration survivability, fire survivability, independent power supply, and ability to accommodate future requirements and technological advances. (H-99-54)

1.45.2 Developments following the National Transportation Safety Board recommendations

Developments that occurred following the NTSB recommendations include the following:

- A truck and bus EDR working group was established by the NHTSA in 2000.[152]
- SAE International (SAE)[153] published Recommended Practice (RP) J1698 in 2003 to establish a common format for displaying and presenting post-downloaded crash-related data recorded and stored within electronic components currently installed in many light-duty vehicles;
- SAE published RP J1698/1 in 2003 to provide definitions for event-related data items;
- SAE published RP J1698/2 in 2004 to define a common method for extracting event data;[154]
- the American Trucking Association (ATA) published RP 1214 in 2004 to provide guidelines for the collection, storage, and retrieval of event-related data from electronic control units in commercial vehicles;[155]
- the FHA published requirements for EDR components, hardware, software, sensors, and databases in 2004 as part of the Federal Motor Carrier Safety Administration Commercial Vehicle Safety Technology Diagnostics and Performance Enhancement Program; and
- the Institute of Electrical and Electronics Engineers (IEEE) published Standard P1616, "Standard for Motor Vehicle Event Data Recorders" in 2005.[156]

Despite these developments, the use of EDRs remains voluntary for roadway vehicles. As of May 2015, safety recommendations H-99-53 and H-99-54 remain classified by the NTSB as "Open—Unacceptable Response" because the NHTSA has not required the use of EDRs on buses.

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[152] United States Department of Transportation, National Highway Traffic Safety Administration (NHTSA), *Event Data Recorders*, Summary of Findings by the NHTSA EDR Working Group, Supplemental Findings for Trucks, Motorcoaches, and School Buses, DOT HS 809 432, Volume II, May 2002.

[153] SAE International was initially the Society of Automotive Engineers. It is a United States–based, globally active professional association and standards organization for engineering professionals in transportation industries. SAE International coordinates the development of technical standards based on best practices identified and described by SAE International committees and task forces.

[154] SAE International, Vehicle Event Data Interface – Output Data Definition, Recommended Practice J1698/1, Warrendale, Pennsylvania, December 2003.

[155] American Trucking Associations, Technology & Maintenance Council, Guidelines for Event Recording: Collection, Storage, and Retrieval, Recommended Practice 1214, Alexandria, Virginia, January 2004.

[156] Institute of Electrical and Electronics Engineers (IEEE), IEEE Standard for Motor Vehicle Event Data Recorders (MVEDRs), Standard 1616-2004, Los Alamitos, California, February 2005.

1.45.3 Additional National Transportation Safety Board Recommendation

On 30 January 2009, at about 1606 Mountain Standard Time, a 2007 Chevrolet Starcraft 29-passenger medium-size bus, occupied by the driver and 16 passengers, was travelling northbound in the right lane of United States Highway 93, a 4-lane divided highway, near Dolan Springs, in Mohave County, Arizona.

While proceeding at 70 mph, the driver overcorrected steering to the left, and the bus struck a depressed earthen median, causing the bus to overturn 1.25 times before coming to rest on its right side across the southbound lanes. During the rollover, 15 of the 17 occupants (including the driver) were fully or partially ejected. Seven passengers sustained fatal injuries and 9 passengers along with the driver sustained injuries ranging from minor to serious.

As a result of the investigation, the NTSB issued Safety Recommendation H-10-007, which superseded Safety Recommendation H-99-53. The NTSB recommended that the NHTSA

> Require that all buses above 10,000 pounds gross vehicle weight rating be equipped with on-board recording systems that: (1) record vehicle parameters, including, at minimum, lateral acceleration, longitudinal acceleration, vertical acceleration, heading, vehicle speed, engine speed, driver's seat belt status, braking input, steering input, gear selection, turn signal status (left / right), brake light status (on / off), head / taillight status (on / off), passenger door status (open / closed), emergency door status (open / closed), hazard light status (on / off), brake system status (normal / warning), and flashing red light status (on / off; school buses only); (2) record status of additional seat belts, airbag deployment criteria, airbag deployment time, and airbag deployment energy; (3) record data at a sampling rate sufficient to define vehicle dynamics and be capable of preserving data in the event of a vehicle crash or an electrical power loss; and (4) are mounted to the bus body, not the chassis, to ensure recording of the necessary data to define bus body motion. (H-10-007)

1.46 TSB Watchlist 2014 and outstanding TSB recommendations

1.46.1 TSB Watchlist 2014 – Railway crossing safety

The TSB Watchlist serves as a blueprint for change in transportation by generating discussion and engagement by key stakeholders. The Watchlist identifies the transportation safety issues that pose the greatest risk to Canadians. Based on investigation reports, safety concerns and Board recommendations, the first Watchlist was released in 2010. It was revised in 2012 and again in 2014. The 2014 Watchlist contains 5 rail safety issues, including the issue of *Railway crossing safety*. The Board concluded that the risk of trains and vehicles colliding at crossings remains too high.

The risk of collisions between passenger trains and vehicles, particularly in the busy rail corridor between Québec, Quebec, and Windsor, Ontario, was identified on the TSB's first Watchlist in 2010. The crossings in this corridor became a focus of attention by TC, the railways, and road authorities. There was a significant decrease in accidents in this corridor, as many crossings were assessed and improved.

However, the number of level crossing accidents in the rest of Canada had not decreased substantially over the past 10 years.[157] During this period (i.e., 2004 to 2013), outside the corridor, there were 1865 train-vehicle crossing collisions, with 165 fatalities and 271 serious injuries.

Warning signs at both public and private crossings are the first line of defence to help reduce risk, by making drivers aware of crossings. Approximately one-third of public crossings in Canada have AWD protection, which includes either flashing lights and bells or flashing lights, bells and gates.[158] Despite these warning devices, collisions between vehicles and trains continue to occur.

TC has been actively dealing with this issue for many years. Recent safety action includes the following:

- developing new grade crossing regulations to provide more comprehensive standards for all railway crossings;
- developing new low-clearance advance warning signs at railway crossings in collaboration with the TAC; and
- supporting OL for public education about railway safety.

In November 2014, TC implemented the new GCR. While the new GCR are considered an improvement, it is important that TC continue its leadership in assessing crossing safety and funding improvements. A fully comprehensive solution must also include consultation with provincial authorities and further public driver education on the dangers at railway crossings.

1.46.2 Outstanding Board recommendations

The TSB has issued 11 recommendations aimed at reducing the risk to rail crossing safety over the past 21 years. As of May 2015, one recommendation remains active.

1.46.2.1 TSB Recommendation R09-01 (issued February 2009)

On 17 December 2007, at approximately 1549 Eastern Standard Time, VIA passenger train No. 35, travelling westward at 62 mph on the south main track of CN's Kingston Subdivision, struck an empty tractor-trailer that was immobilized on the 3e Avenue level public crossing located at Mile 23.57, near Pincourt / Terrasse-Vaudreuil, Quebec. The truck driver sustained minor injuries.

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157 Non-corridor crossing accidents involving vehicles: 176 in 2009, 156 in 2010, 152 in 2011, 161 in 2012, and 165 in 2013.

158 Source: Transport Canada (active warning devices can be found at 5606 public crossings).

The investigation identified that the risks for crossing collisions continue, particularly for high-speed passenger trains along the Québec-Windsor rail corridor. Even though many of the crossings are equipped with the highest level of AWD protection available in Canada, it is not always adequate to protect against crossing collisions.

Before authorizing VIA to increase train speed up to 100 mph (160.9 km / h) on the Québec–Windsor rail corridor in the early 1990s, crossing safety assessments were conducted to identify crossings that required upgrading. These crossing assessments were nearly 20 years old and did not accurately reflect the risks nor consider emerging risks. Over the same period of time, rail traffic had increased and communities along the corridor had experienced substantial industrial and residential expansion. These factors increased the likelihood for a crossing collision involving a passenger train. To ensure that the increased risk to rail passengers and vehicle drivers is adequately addressed, the Board recommended that

> Transport Canada conduct safety assessments of level crossings on the high-speed passenger rail Québec–Windsor corridor and ensure that defences are adequate to mitigate the risk of truck / train collisions.
>
> **TSB Recommendation R09-01**[159]

1.46.2.2 Board reassessment of the response to Recommendation R09-01 (March 2015)

The new GCR came into force in November 2014. They will ensure that railways and road authorities exchange safety-related crossing information within 2 years of them coming into force. The requirement that all grade crossings meet the safety requirements of the GCR within the following 5 years will substantially reduce the level of risk at grade crossings. In addition, TC will be inspecting the remaining 50 non-protected passive crossings on the Québec–Windsor high-speed corridor in 2015 as part of its standard passive grade crossing inspection program.

These inspections, when completed in combination with the other safety actions taken, will fully address the safety deficiency. Until then, the Board considers the response to the recommendation as having Satisfactory Intent.

1.47 TSB laboratory reports

The TSB completed the following laboratory reports in support of this investigation:

- LP192 / 2013 – Locomotive Event Recorder Data Analysis – VIA Passenger Train 51
- LP193 / 2013 – OC Transpo ADL E500 Bus – Brake System Examination
- LP194 / 2013 – Site Survey – VIA Passenger Train / OC Transpo Bus
- LP195 / 2013 – OC Transpo Bus ADL E500 Non-Volatile Memory Extraction & Analysis
- LP211 / 2013 – OC Transpo ADL E500 Bus Speed Determination and Braking Analysis

[159] TSB Railway Investigation Report R07D0111.

- LP075/2014 – Crossing Signal Log Review
- LP101/2014 – OC Transpo ADL E500 Bus Crashworthiness Analysis

2.0 Analysis

The investigation into this accident was complex. The accident timeline was reconstructed using data recorded from the locomotive event recorder (LER), crossing signal bungalow downloads, closed circuit television (CCTV) at the OC Transpo Fallowfield Station and the bus engine control module (ECM). Event times were normalized to coincide with the LER. Due to insufficient information available from the ECM, complex engineering calculations based on reasonable assumptions had to be made to establish stopping distance and the braking force involved. Additional engineering work could not commence until this was completed. The investigation team conducted over 90 interviews, reviewed over 120 statements from other agencies, and reviewed over 2000 pages of related technical documents.

The investigation determined that, at the time of the accident:

- The automatic warning device (AWD) crossing protection for both the Woodroffe Avenue and the Transitway crossings operated as designed with no malfunctions.
- The ADL E500 double-decker bus met or exceeded all required air brake system criteria for operation in Canada.
- There was no indication of any pre-accident conditions or deficiencies with the air brake system mechanical and pneumatic components that would have precluded normal operation of the brake systems.
- OC Transpo considered the driver a typical employee with a good work record. The occurrence driver had not accumulated more than 4 demerit points within a 2-year period since receiving a Class C / Z driver's licence in 2005.
- Before the bus departed from the OC Transpo Fallowfield Station, the driver announced that seats were available upstairs, which displayed a sense of customer service. The driver also requested that passengers standing near the driver station on the lower deck move behind the yellow line on the floor, indicating that the driver had been following procedures and understood the need to maximize visibility while driving and to avoid potentially distracting conversations.
- In the 39 seconds after departing from the OC Transpo Fallowfield Station, the driver encountered a series of factors that culminated in the crossing accident. The elimination of any one of these factors may have affected the outcome.

The analysis will focus on the human factors associated with the accident, environmental factors that contributed to the accident, the crashworthiness of the bus, the influence of OC Transpo speed enforcement, operating procedures, training and organizational issues. Historical grade separation issues in the vicinity of the VIA Rail Canada Inc. (VIA) Fallowfield Station and the practice of requiring buses to stop at all railway crossings will be analysed. In response to questions posed by the public and external organizations during the investigation, the analysis will also include additional information on factors that were considered, but determined not to have caused or contributed to the accident.

2.1 The collision and derailment

The train crew first noticed the bus travelling northward toward the crossing when the train was approximately 600 feet (183 m) from the crossing. The crossing protection (lights and gates) for both crossings was activated. Just prior to impact, the train crew realized that the bus was not going to stop. At 0848:04, the train had slowed to 47 mph (75.6 km / h) when the locomotive engineer (LE) initiated emergency braking. At 0848:06, with the train travelling at 43 mph (69.2 km / h), the bus collided with the left (south) side of the locomotive cab. Although the crossing protection was activated, the bus did not stop as required and struck the train as the train entered the crossing.

The front of the bus body collapsed, and the driver side wall tore away as the bus collided with the train and the bus chassis (frame) partially extended under locomotive VIA 915 (VIA 915). As the train traversed the crossing, the bus frame contacted VIA 915's battery box and severed the electrical wiring that provided power to VIA 915. With the loss of power, the LER stopped recording. The frame of the bus also contacted VIA 915's rear truck, which was located just behind the battery box. As the bus frame contacted VIA 915's rear truck, the bus was pushed back about 3 inches (7.62 cm) where it came to rest on the northbound lane of the Transitway.

The position of the train when it came to rest, in conjunction with the wheel flange marks on the crossing and the observed track damage, revealed that VIA 915's lead truck followed the main track while its rear truck derailed on the Transitway crossing when the locomotive was contacted by the bus chassis. Then, the rear truck of VIA 915, along with the lead truck of the first car (VIA 3455), took a diverging route into the VIA siding. This caused VIA 915 and VIA 3455 to jackknife and straddle the main and siding tracks while VIA 3455's rear truck and 3 remaining passenger cars followed along the main track. As VIA 915 and VIA 3455 jackknifed, the lateral restraint capacity of both tracks was exceeded as the rail on both tracks spread out of gauge and rolled to the field side, resulting in the derailment of the remaining passenger cars.

2.2 Driver experience with the crossing

Between 01 September 2012 and 18 September 2013, the driver had worked a total of 407 shifts, 67 (16%) of which were driving an ADL E500 bus. The driver was familiar with the Transitway crossing, having driven various routes southward over it 16 times and northward over it 44 times in the 12-month period prior to the accident. Although it is not known precisely how many times the driver encountered a train at the crossing while driving a bus, given the varied schedules of OC Transpo buses and VIA trains, it is likely that an encounter rarely occurred.

When a driver becomes familiar with a particular level crossing or with a particular type of level crossing, and where the driver has never, or seldom, encountered an approaching train at the level crossing, the driver will tend to have a "no trains" expectation at the crossing. These drivers expect the absence, rather than the presence, of a train due to the infrequency of previous train encounters. Drivers who are familiar with a crossing will tend to look less, and are less likely to reduce their approach speed, than drivers who are unfamiliar with a crossing. Heavy-vehicle drivers (including transit bus drivers) will typically not look in either direction on approach to a level crossing protected by AWDs between 35% and 65% of the time. Furthermore, when drivers receive information contrary to their expectations, their reaction tends to be slow or inappropriate.

Since the driver was familiar with the crossing and had not encountered many trains there, the driver would likely have formed the expectation that there would not be a train at the crossing. The driver's actions were consistent with this expectation.

It was not uncommon for drivers to use the section of Transitway beyond the crossing to make up time. In these situations, drivers tend to exceed the posted speed limit in this area. In June 2014, speed monitoring conducted by the Transportation Safety Board of Canada (TSB) determined that 25% of the buses were still travelling above the new posted speed limit of 50 km/h (31 mph).

Upon departing from the OC Transpo Fallowfield Station, the driver would have been aware that the bus was almost 4 minutes behind the scheduled departure time.[160] As it was common for drivers to use the section of the Transitway immediately following the crossing to make up time, and because the driver did not expect to encounter a train, the bus was accelerated beyond the posted speed limit.

2.3 Speed and stopping distance

While the bus ECM data were useful to help establish the accident timeline, it lacked sufficient detail to conduct a meaningful analysis. A detailed examination of the bus braking system and a braking analysis were required.

The braking analysis revealed the following:

- The initial application of the bus brakes occurred when the bus was travelling at a speed of 42 mph (67.6 km/h), which exceeded the posted speed limit of 60 km/h (37.3 mph).
- The estimated stopping distance of the occurrence bus without a collision occurring, given the braking force applied, was 117.8 feet (35.9 m).
- The bus was 116.8 feet (35.6 m) south of the point of collision when brakes were applied.
- The speed of the bus was between 4 and 4.8 mph (6.4 to 7.7 km/h) when it initially collided with the train. The bus moved another 4.3 feet (1.3 m) in the forward direction after the initial impact.
- The stopping distance for a bus travelling at the posted speed limit of 60 km/h (37.3 mph), with all other factors remaining the same, would have been 96.8 feet (29.5 m), or 20 feet (6.1 m) before the point of collision.

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160 OC Transpo considers a bus that is up to 5 minutes behind the scheduled departure time from a station stop to be on time.

The engineering analysis identified that, even the modest increase of 7.6 km/h (4.7 mph) in excess of the posted speed limit of 60 km/h can significantly increase the stopping distance required to bring a bus to a safe stop. The bus speed of 42 mph (67.6 km/h) exceeded the posted speed limit of 60 km/h by 7.6 km/h just prior to the initial brake application, which increased the stopping distance required.

2.4 Brake application

Analysis of the brake certification data revealed that deceleration was constant throughout each certification test. The ECM data identified that the deceleration of the occurrence bus was gradual, indicating that initially the brakes were not fully applied. If full braking force had been applied from the beginning of the brake application and assuming a constant deceleration of 0.6 g, which is the manufacturer's minimum value specified for deceleration, the stopping distance for the bus was calculated to be 112.5 feet (34.3 m).

Data provided by the manufacturer indicated that the braking system was designed to produce a maximum deceleration ranging from 0.6 g to 1.0 g. In this occurrence, for the speed range of 25 mph (40.2 km/h) down to 5 mph (8 km/h), the bus ECM recorded an actual deceleration of 0.91 g. If maximum braking force was initially applied and a deceleration of 0.91 g was achieved throughout the brake application, the stopping distance was calculated to be 101.1 feet (30.8 m). Therefore, if maximum braking force had been initially applied and maintained while stopping the bus, the bus would likely have stopped in advance of the point of collision. The gradual deceleration of the occurrence bus indicates that the driver did not initially fully apply the brakes, which increased the bus stopping distance.

The primary focus of OC Transpo driver training in brake application is on how to apply the brakes smoothly to limit passenger displacement. With the emphasis on smooth braking, drivers may be predisposed toward not making sudden and/or strong brake applications, even in emergency situations. While this is reasonable in day-to-day driving, in emergency situations, this training may lead to a driver not applying the maximum braking force at the onset of the braking action, which increases the bus stopping distance. OC Transpo's training on brake application, which focused on smooth braking to minimize passenger discomfort, may have contributed to the driver not initially applying maximum braking force in an emergency situation.

2.5 Speed monitoring and enforcement

Reliable speed monitoring and ongoing enforcement efforts, including disciplinary means, are critical for posted speed limits to be effective in reducing speeding.[161] Research has also

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161 A. Delaney, K. Diamantopoulou, and M. Cameron, Monash University Accident Research Centre (MUARC), *MUARC's Speed Enforcement Research: Principles Learnt and Implications for Practice*, report number 200, Melbourne, Australia, March 2003, available at: http://www.monash.edu.au/miri/research/reports/muarc200.html (last accessed 28 September 2015).

shown that visible speed enforcement can also be effective in reducing accident frequency. Speeding is a traffic violation under the *Ontario Highway Traffic Act* (OHTA).

However, the OHTA does not apply to vehicles operating on the Transitway as the Transitway is a private road. The operation of vehicles on the Transitway is governed by the City of Ottawa (City) by-law No. 2007-268. The by-law contains provisions governing speed, and OC Transpo special constables are responsible for monitoring bus speed on the Transitway system. As speeding violations are by-law infractions, there is no record placed on a driver's licence. Generally, at OC Transpo, a recorded bus speed of 12 km / h (7.5 mph) in excess of the posted speed limit was considered as speeding. In the 2 years prior to the accident (from 18 September 2011 to 17 September 2013), OC Transpo special constables conducted speed tests on 6 occasions. Although no formal records were kept for the number of speed tests performed, a total of 53 buses were recorded as speeding. Verbal follow-up was conducted only 3 times.

The OC Transpo speed monitoring and enforcement activities on the Transitway in the vicinity of the crossing were insufficient to reinforce adherence to the speed limit. As a result, not only was the occurrence driver exceeding the posted speed limit on approach to the crossing, but 25% of the OC Transpo drivers who traversed the Transitway crossing were recorded as speeding after the accident despite the reduced speed limit.

As outlined in the Ministry of Transportation of Ontario (MTO) *Official Driver's Handbook*, when approaching a railway crossing at grade, drivers should always slow down, be prepared to stop and yield the right-of-way to a train. OC Transpo speed monitoring and enforcement activities on the Transitway in the vicinity of the crossing were not sufficient to prevent drivers from exceeding posted speed limits when approaching the crossing, in contravention of recommended safe driving practices.

2.5.1 Ontario Highway Traffic Act and City of Ottawa by-law

The OHTA details laws that are in place to reinforce consistent safe driving practices for all roadway users. In particular, drivers who violate the OHTA can receive demerits on their licence if convicted for the following:

Section 78 – Distracted driving: On 26 October 2009, the Province of Ontario enacted "Distracted Driving" legislation, which banned the use of display screens and hand-held devices while driving.

Section 128 – Rate of speed: This section indicates that the City sets speed limits for municipal public roadways within city limits that can be enforced under the OHTA.

Section 163 – Vehicles required to stop at railway crossing signal: This section states that "When the driver of a vehicle is approaching a railway crossing at a time when a clearly visible electrical or mechanical signal device or a flagman is giving warning of the approach of a railway train, he or she shall stop the vehicle not less than 5 metres from the nearest rail of the railway and shall not proceed until he or she can do so safely."

Section 164 – Driving of vehicles under crossing gates prohibited: This section states "No person shall drive a vehicle through, around or under a crossing gate or barrier at a railway crossing while the gate or barrier is closed or is being opened or closed."

Although the City by-law contains speed enforcement provisions, it has no provisions to cover driving violations that occur under sections 78, 163 or 164 of the OHTA. This represents a significant gap in the availability of enforcement tools for both constables and special constables. If officials tasked with the enforcement of traffic violations on the Transitway are not provided adequate enforcement tools, there is an increased risk for a related vehicle accident to occur.

2.6 Distracted driving

Human information processing takes place constantly during wakefulness. There is so much information available in the driving environment that it is necessary for drivers to filter out less important information so that they can attend to more important, relevant information. While drivers can switch attention among multiple information sources, they can attend well to only one source at a time when driving. For the driver to have interrupted what he was doing (i.e.,, approaching the crossing with the intention of accelerating up to speed along the upcoming, empty section of the Transitway), a stimulus in the driving environment would have needed to be perceived, and to have been perceived as sufficiently important to require immediate action.

In the seconds before the accident, passengers on both the upper deck and lower deck began to shout "stop stop" to warn of the approaching train and of the need to stop the bus. The first shouts uttered were likely from passengers seated in the upper deck, as their higher seating positions provided a more direct line of sight to the crossing and the approaching train. However, the signal-to-noise ratio (SNR) between the passenger shouts from the upper deck [60 dB(A)] and the background noise at the driver location [65 dB(A)] would have been about -5 dB(A), and likely inaudible to the driver. Therefore, it is likely that the driver only perceived the shouts of one or more lower deck passengers in the seconds before the accident. Once the shouts were detected, the driver refocused attention to the road ahead and applied the brakes. This suggests that the driver was distracted in the seconds prior to applying the brakes.

Driver distraction occurs when attention is diverted from activities that are critical for safe driving toward a competing activity. Driver distraction impairs driving performance and is one of the leading causes of motor vehicle accidents.

In this occurrence, there were 2 types of driver distraction that likely contributed to the accident:

- visual distraction arising from the use of the in-vehicle video monitor;
- cognitive distraction arising from
  - a requirement to monitor the upper deck for standing passengers;
  - a conversation between the driver and a passenger about seating availability prior to the bus departing from the OC Transpo Fallowfield Station; and

- conversations regarding available seating on the upper deck among lower deck passengers who were near the driver following departure from the OC Transpo Fallowfield Station.

2.6.1 Visual distraction

All Alexander Dennis Limited (ADL) double-decker buses are equipped with a video monitor that provides the driver with interior views and exterior views of the bus. Within the driver workstation, the video monitor is located on the left side of a forward panel above the driver seat.

The video monitor measures 6 inches (15.2 cm) wide by 3¾ inches (9.5 cm) high. The monitor is divided into 4 quadrants, each measuring 3 inches (7.6 cm) wide by 1⅞ inches (5 cm) high. Each quadrant shows a view from 1 of 4 on-board video cameras. When reverse gear on the bus is selected, the video monitor goes blank for 1 or 2 seconds and then displays the exterior rear camera view in full screen with guiding arrows to assist the driver with reversing manoeuvres. Otherwise, the 4 views are continuously displayed.

The position and angle of the video monitor are not adjustable, and the driver is not able to turn the display off or change the camera views. In addition, the images are not recorded and no sound is provided. The position of the video monitor creates a significant upward viewing angle for the driver (i.e., 30 to 40 degrees from the horizontal). When viewing displays at a significant upward angle, a driver's peripheral vision is less sensitive to change and motion. The screen's position far away (22 inches or 56 cm) from the driver seat makes the image appear very small to the driver.

With respect to the video monitor, OC Transpo drivers were instructed not to stare at the video monitor while driving. At station stops and while in service, OC Transpo drivers were required to view the monitor to ensure that upper deck passengers were seated. If passengers were seen to be standing on the upper deck, drivers were required to make an announcement to inform the passengers that standing was not permitted on the upper deck or in the stairwell. While signs were posted on the stairwell and on the lower deck indicating that standing on the stairs while the bus is in motion was not permitted, there were no signs indicating that standing was not allowed on the upper deck.

To find available seating after boarding a double-decker bus, some passengers would remain moving or standing on the upper deck after the bus was in motion. Under these conditions, a driver would need to periodically glance at the screen while the bus was in motion to monitor the small image displaying the upper level. Research has determined that driver eye glances away from the forward visual scene, especially glances lasting 2 seconds or longer, are significantly associated with accidents and near accidents.

To observe the video monitor, a driver must alternate glances between the roadway view ahead and the video monitor upward and to the left. The upward viewing angle of the video monitor combined with the small image size displayed on the 4-quadrant screen would make the driver's task of perceiving and understanding the image even more difficult. The driver's eyes would be directed completely away from the forward roadway view while looking at the screen. The difficulty of the task would also likely result in a driver making prolonged glances toward the video monitor and away from the forward roadway in order to accurately assess what was being displayed. Therefore, the driver was likely visually distracted by looking at the video monitor during the critical driving sequence of negotiating the left-hand curve and approaching the crossing.

2.6.2 Cognitive distraction

Research has shown that cognitive distraction can also impair driving performance. Cognitive distraction occurs when a driver's attention is withdrawn from the processing of information necessary for the safe operation of a vehicle and applied to a non-driving–related activity. Cognitive distraction slows driver reaction time and increases the likelihood that a driver will miss critical visual stimuli within the visual field on the roadway ahead. It can also lead to inattentional blindness and "looked-but-failed-to-see" (LBFTS) errors.

Studies have shown that cognitively distracted drivers tend to have the following behaviour:

- They do not adequately visually scan and monitor the driving environment.
- They are less likely to visually search for approaching traffic at intersections.
- They make fewer anticipatory glances when entering a curve on rural roads.

In this occurrence, while stopped at the OC Transpo Fallowfield Station, the driver was monitoring the upper deck and had to make an announcement about seats being available upstairs. The driver also asked passengers standing near the front of the bus on the lower deck to move back behind the yellow line on the floor, indicating that he was concerned with safety and the need to maximize visibility from the driver's seat.

Just prior to departing from the OC Transpo Fallowfield Station, the driver engaged at least one passenger in conversation regarding seating availability on the upper deck. Once the bus was moving, the driver would have been able to hear nearby passengers on the lower deck involved in similar conversations about seating. The upper deck view on the video monitor displayed a standing passenger near the top of the stairs and the driver was glancing at the video monitor. The driver may have been contemplating the need to make an announcement. Therefore, conversations between the driver and a passenger and among passengers near the driver, as well as the perceived need to make an announcement to passengers standing on the upper deck, created a situation where the driver was likely cognitively distracted in the seconds before the accident.

2.6.3 Agency-controlled driver distractions

The introduction of new technology and operations is a normal part of a company's operation. To remain safe, any new potential hazards must be identified and mitigated in a timely way. Effective hazard mitigation requires

- knowledge of, and competence in, the field being analysed;
- processes to support the identification of hazards;
- means of identifying effective mitigations; and

- processes for tracking mitigations and identifying whether further action may be required.

While OC Transpo carried out pilot-testing of the ADL E500 buses before placing them in service, there was no formal risk assessment process in place to evaluate potential risks and the impact on safety associated with the use of either the video monitor or the transit control head (TCH) display.

The ADL E500 buses were delivered to OC Transpo with the video monitor already installed in a location significantly away from a driver's horizontal line of sight and configured so that operators could adjust the views and image characteristics. The TCH display was an aftermarket driver communications display that was supplied and serviced by an external supplier. These devices were likely assumed to be safe to use, as they were commercially available products. Public opinion research indicates that 49% of Canadians believe that in-vehicle information and communication devices are tested to meet safety regulations, ensuring that they are "not too distracting for the average driver."

Although OC Transpo did not formally assess these devices for driver distraction, there were indications that management understood that a driver looking toward either the video monitor or the TCH display while the bus was in motion could represent a risk. It was noted that:

- Some of the TCH input functions were set to 'lock out' when a bus was travelling 16 km/h (10 mph) or faster.
- OC Transpo training specified that drivers should not stare at the video monitor while the bus was in motion, but rather look toward it before departing from a station stop to ensure that upper deck passengers were seated.
- At the time of the accident, OC Transpo management had not conducted research into, and was not aware of, industry best practices regarding agency-controlled driver distractions.

With no formal risk assessment process in place, OC Transpo did not identify or mitigate the risks arising from driver attention being inappropriately directed at the video monitor when the bus was in motion and from the need to make announcements if passengers were observed standing on the upper deck.

2.6.4 Distracted driving guidelines

In April 2013, driver distraction guidelines[162] were published in the United States. These guidelines apply to light vehicles such as passenger vehicles and trucks with a gross vehicle weight rating (GVWR) of not more than 10 000 pounds. The guidelines were based on the

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[162] United States Department of Transportation, National Highway Traffic Safety Administration (NHTSA), *Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices,* Federal Register, Volume 78, Number 81, 26 April 2013, available at: http://www.gpo.gov/fdsys/pkg/FR-2013-04-26/pdf/2013-09883.pdf (last accessed 28 September 2015).

fundamental principle that a driver's eyes should be looking at the road ahead rather than at an in-vehicle device. The guidelines were designed to encourage automakers to forego in-vehicle systems that require the manual input of data while a vehicle is in motion, or that require unreasonably long glances away from the forward visual scene. The guidelines recommended

- disabling certain in-vehicle system operations unless the vehicle is stopped and in park;
- locking out video displays and making them inaccessible to the driver while driving; and
- positioning any active displays as close as practicable to the driver's forward line of sight, with a maximum viewing angle of 30 degrees downward from horizontal.

Many jurisdictions, including the Province of Ontario, have laws in place to limit the potential for driver distraction. However, for the OC Transpo double-decker bus, the video monitor was deemed to be necessary for the operation of the bus and was therefore exempt from the OHTA restricting the use of display screens. Furthermore, the position and use of the video monitor in the OC Transpo ADL E500 bus did not conform to any of the United States recommendations or guidelines relating to driver distraction.

There are no similar standards or guidelines in place for Canada. If mitigating strategies are not put in place to address driver distraction, bus drivers may not always remain focused on the driving task and on the roadway ahead, increasing the risk of a roadway accident.

2.7 Visual obstruction of the crossing automatic warning devices

The TSB re-enactment identified that a driver's view of Woodroffe Avenue and the Transitway crossings was obstructed by trees, shrubs and foliage on the north side of, and adjacent to, the Transitway from the stop at the OC Transpo Fallowfield Station until a bus exits the curve and begins to proceed northward toward the crossing. The height of the trees between the Transitway and the rail tracks varied from 43 to 46 feet (13 to 14 m) above ground level near the VIA Fallowfield Station, to 36 to 39 feet (11 to 12 m) above ground level near the Transitway crossing. The foliage was about 24 feet (7.3 m) thick along the tree-line over a length of 387 feet (118 m). The recommended stopping sight distance (SSD) for a transit bus travelling on the Transitway in the vicinity of the crossing, which had a posted speed limit of 60 km/h (37.3 mph), is 130 m (426.5 feet). The SSD measured during the TSB re-enactment was 122.5 m (401.9 feet).

While road signs are not considered obstructions to sightlines between road users and trains, they are considered obstructions when they obscure sightlines between road users and railway crossing signs or warning signals. In this occurrence, there were 2 road signs installed for southbound traffic on the west side of the Transitway, south of the crossing. One was a smaller roadway sign for the curve ahead and the other was a larger "OC Transpo Fallowfield Station" sign. Both signs and the front corner and window pillars of the ADL E500 bus would have also obscured the driver's view of the crossing lights at different times on the approach. The trees, shrubs, foliage, and roadway signage on the Transitway right-of-way, as well as the bus front corner and window pillars, obstructed the driver's view of the activated AWDs until the bus was 122.5 m (402 feet) from the crossing, a distance that was slightly less than the recommended SSD of 130 m (426.5 feet).

2.7.1 Negotiating a left-hand curve

Negotiating a curve increases the mental workload of a driver. On a straight road, drivers will tend to look straight ahead and rely on visual stimuli passing within the peripheral visual field to guide steering behaviour. When negotiating a curve, a driver must look intermittently toward the vehicle's current and future positions, which are visually separate.

When drivers negotiate a curve, they visually rely on the tangent point on the inside of the curve and direct anticipatory glances toward the occlusion point (i.e., the nearest point where the view of the road ahead is blocked). In this occurrence, while negotiating the Transitway curve on the approach to the crossing, the driver would have generally gazed toward the tangent point at the centreline of the road and made anticipatory glances toward the occlusion point where the view of the road ahead was obstructed by trees, shrubs, foliage, and roadway signage. In addition to distractions that likely influenced the driver, the additional driver workload associated with negotiating the left-hand curve on approach to the crossing likely decreased the driver's ability to detect the activated AWDs.

2.7.2 Absence of active advance warning sign

There was no active advance warning sign (AAWS) (flashing) interconnected to railway crossing signals installed in advance of the crossing for northbound traffic. The crossing AWDs were activated for 49 seconds before the accident. The bus departed from the OC Transpo Fallowfield Station 39 seconds before the accident. Although the crossing AWDs had been activated before the bus departed from the station, the view of the activated AWDs was obstructed and there was no active advance warning of the train's approach available to the driver.

The Transitway was constructed in accordance with Transportation Association of Canada (TAC) guidance and roadway construction engineering principles. However, the configuration of the Transitway with its significant left-hand curve and the relatively short approach to the crossing contributed to the reduced SSD. As a result, northbound drivers exiting the curve have a relatively short window of 2 to 4 seconds to react to the activated AWDs. For such roadways with a significant curve in close proximity to a crossing and / or with inadequate SSD, draft technical document *Road/Railway Grade Crossings: Technical Standards and Inspection, Testing and Maintenance Requirements* (RTD 10) suggests that an AAWS (flashing) be interconnected with the railway crossing signals and installed at a location in advance of the crossing to provide advance warning to vehicles that a train is approaching. The lights of an AAWS that is interconnected with the railway crossing signals would only begin to flash once the crossing AWDs were activated by an approaching train and would shut off once the crossing AWDs were deactivated.

The purpose of a standard advance warning sign (no lights) is to warn vehicle operators that there is a railway crossing ahead and that they should be aware of the possibility of an approaching train. There are several other warning systems available to alert drivers to upcoming hazards. For example, AAWS, crossing illumination, rumble strips, or enhanced delineation with retro-reflective signs are helpful at appropriate sites.

Research on AAWS indicates that, when active yellow flashers were added to a slightly enlarged advance warning sign and were activated by an approaching train, driver recognition and speed reduction improved significantly. AAWS that are not interconnected with railway crossing signals tend to be ignored by drivers, as they do not necessarily indicate the presence of an approaching train. If AAWS interconnected with railway crossing signals are not installed on roadways with a significant curve near a crossing or at locations with inadequate SSDs, drivers may not have sufficient time to react to an approaching train, increasing the risk of a crossing accident.

2.7.3 Maintaining stopping sight distance

Both RTD 10 and the TAC *Geometric Design Guide for Canadian Roads* outline the minimum requirements for driver SSD, which is the distance for a driver to clearly see and safely react to crossing signal lights when activated. RTD 10 indicates that sightlines must be maintained to ensure adequate SSD on crossing approaches and that particular attention should be given to trees, brush, other vegetation, pole lines, signs, bus shelters or other roadside installations upon a vehicle’s approach to a crossing.

The road construction of the Transitway and the Woodroffe Avenue widening was performed in accordance with City guidelines and the TAC *Geometric Design Guide for Canadian Roads*. Both crossings were constructed in accordance with the detailed safety assessments (DSAs), RTD 10 and established railway engineering standards and practices. When construction was completed in December 2005, the SSD for the crossing was within the recommended limit. However, the trees, shrubs and foliage grew to the point where the recommended SSD of 130 m (426.5 feet) was reduced to 122.5 m (402 feet), obstructing the view of the crossing for northbound buses. If the SSD is not periodically checked by road authorities, especially along roadways with trees and other growing vegetation, the view of the crossing from the roadway may become obstructed over time, increasing the risk of a crossing accident.

2.8 Bus crashworthiness

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.

The *Canada Motor Vehicle Safety Standards* (CMVSS) identify the prescribed tests required for the certification of various weight categories of vehicles. These requirements vary according to the weight and type of vehicle. The 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 in Canada, as well as all applicable state and provincial requirements.

To meet the CMVSS, Transport Canada (TC) reviews the material provided by the manufacturer and advises the *Nominated Importer* by way of a short letter when the certification package is acceptable, after which the vehicle can be imported to Canada. There is no formal inspection performed of the vehicle and there is no risk assessment required even though the vehicle may have significantly different design characteristics.

CMVSS crashworthiness standards have evolved over time. These performance standards were developed to improve the safety of automobiles, which historically have posed the greatest risk of injury during an accident. Once these were completed, attention turned to addressing larger vehicles and school buses. Crashworthiness standards for vehicles in the heaviest weight category (i.e., GVWR of 11 793 kg or 26 000 pounds) were perceived as the lowest risk based on accident history, as these vehicles were usually the largest vehicles on the road. Consequently, very few of the CMVSS crashworthiness standards apply to vehicles in this category.

The heaviest vehicle weight category includes tractor-trailers and most transit and inter-provincial buses. 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. While these vehicles are generally subject to the fewest safety standards, nothing precludes a manufacturer from designing a vehicle to exceed the standards. As such, some transit bus manufacturers, including ADL, do perform side impact testing. However, frontal impact testing is rarely done and not required under the CMVSS.

In contrast, school buses were designed to reduce the effects of a collision, and have increased body strength provided by full length horizontal impact rails located at the shoulder, cushion and floor levels. The floor is raised to protect passengers by having them sit above the area where an automobile would strike a school bus during a collision.

School buses must also meet rollover protection standards. The interior of the bus is a smooth rounded shell, free from sharp edges, and the design is intended to ensure that joints do not come apart during a collision, causing sharp edges to be exposed in the passenger compartment. The interior of a school bus is further compartmentalized to minimize the impact and injury during a collision. Given the different design characteristics (raised floor, horizontal impact rails and compartmentalization) of a school bus, it has an increased ability to withstand an impact and to protect occupants during a vehicle accident.

In the Province of Ontario, a school bus carrying between 20 and 72 passengers must meet a number of CMVSS crashworthiness standards. In comparison, transit buses, including some dedicated to only school children, can carry over 100 passengers; yet, they are subject to fewer CMVSS crashworthiness standards.

Although the ADL E500 bus met all federal, state and provincial regulatory requirements, the front-end framings were not designed to provide impact protection, nor were they required to by the applicable regulations. In this occurrence, the break-up of the front part of the ADL E500 bus demonstrates that the degree of protection provided by the structure was not sufficient for the loads involved in this accident.

It was determined that, even if the speed of the train was reduced to 15 mph (24 km / h) and all other parameters remained the same, the train's momentum and kinetic energy were still orders of magnitude greater than those of the bus. This suggests that reducing the speed of the train would not have significantly reduced the damage sustained by the bus, but the severity of the derailment would likely have been reduced.

The CMVSS contain no requirement for bus bumpers. Although only a guideline, American Public Transportation Association (APTA) technical specification (TS) TS 70.2 sets forth requirements for bus bumpers and requires that front bus bumpers be installed with its top 27 inches (68.58 cm) above the ground. Single-deck buses at OC Transpo are fitted with front and rear bumpers that meet the APTA requirements, which include sustaining a 5 mph (8 km / h) impact without damage, and some of these single–deck models were tested to meet the 25 mph (40 km / h) side impact requirement. Although front bumpers were available as an option for the ADL E500, the OC Transpo procurement agreement did not include these bumpers. Consequently, the 75 ADL E500 buses initially purchased by OC Transpo were not equipped with front bumpers.

A front bumper with its top located 27 inches above the ground as required by APTA TS 70.1, and connected to the frame of a bus, would have been high enough to strike the bottom portion of VIA 915's skirt behind the pilot and would have been the first part of the bus to strike the locomotive. Consequently, it is considered likely that such a bumper could delay the contact between the left front corner of the bus and locomotive as well as undertake some of the initial impact loading. This might have reduced the extent of damage sustained by the left front corner during the initial part of the collision. However, the occurrence involved a more severe impact condition than those required for the front bumper performance tests specified in APTA TS 70.2. Thus, it is unknown if a bumper would have had a significant effect on the overall damage sustained by the front structure of the bus during this occurrence.

The general design characteristics of single-deck bus structure are different from those of the ADL E500 and as such the single-deck bus structure may behave differently if subjected to the occurrence impact loading. In particular, 4 of the 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. Since there is no upper deck on the single-deck bus, and standing passengers are required to be located behind the driver's station, it is less likely that passengers would have been exposed to an area that was compromised by the collision. However, for single-deck buses, there could be more passengers standing who may be injured as a result of hard braking, but the number of fatalities may be reduced.

The CMVSS contain no requirements for frontal impact, side impact, rollover or crush protection for vehicles with a GVWR in excess of 11 793 kg (26 000 pounds), which include most transit buses. As a result, buses in this weight category can have different structural features. Although not required by regulation, a more robust front structure and crash energy management design may have reduced the damage to the bus and prevented the loss of a protective shell for the occupants. If vehicle safety standards for transit buses do not include requirements for enhanced crashworthiness, there is an increased risk of injury to vehicle occupants in the event of an accident.

2.9 Bus event data recorders

The ADL double-decker buses were equipped with a video monitor that provides the driver with interior views and exterior views of the bus. However, the system monitoring the video cameras installed on the bus did not have recording enabled and no video information was recovered from the system.

While the rail, air and marine modes of transportation require locomotives, as well as many commercial aircraft and vessels, to be equipped with event data recorders (EDRs) that record a number of specified elements, the CMVSS contain no requirements for buses (including school, transit and inter-city) to be equipped with an on-board crashworthy EDR. While nothing precludes an operator from implementing crashworthy EDRs throughout its fleet, OC Transpo had no such requirement. Consequently, the occurrence bus was not equipped with a crashworthy EDR (i.e., black box) to record and store vehicle operation data that occurred prior to and during the accident sequence.

However, there were a number of electronic units that contained non-volatile memory (NVM), and a total of 8 units were recovered and analysed.

- The anti-lock braking system / anti-slip regulation (ABS / ASR) control module, central controller, transmission control module (TCM), heating, ventilation, and air conditioning system memory, and Presto units did not contain any useful information relevant to the operation of the bus just before the accident.
- The Intelligent Vehicle Network (IVN) system lost some of its data due to the sudden loss of power during the accident and subsequent data file repair during recovery. The last global positioning system (GPS) position recovered from the IVN system memory was located at the last bus stop prior to the occurrence located at the OC Transpo Fallowfield Station. Otherwise, the IVN system’s NVM contained little useful information pertinent to the operation of the bus.
- The ECM recorded 3 sudden deceleration events, 31 faults, and had a total run time of 1737 hours 53 minutes 40 seconds. A sudden deceleration event is triggered when the ECM determines that a deceleration of 9 mph / s (14.5 km / h / s) or more has occurred. Recorded events are time stamped, but are limited to the ECM run time. Real-world date and time are not recorded. While the recovered ECM data were useful, when compared to LER data, they lacked sufficient detail to conduct a meaningful analysis. Specifically:
    - There was no meaningful time stamp.
    - No distance travelled was recorded.
    - The recorded time interval of 1 second was not sufficient for detailed analysis.
    - The operation of the ABS and emergency brake was not identified.

- The ECM data indicated that the brakes had been applied, but no other meaningful braking information was recorded.
- There was no brake line air pressure recorded to determine the amount of force applied to the brakes.

Although these important elements may have been available, they were not recorded in any of the recovered NVM. Consequently, a detailed braking analysis had to be performed to determine event timing, braking distance and amount of braking force applied by the bus during the accident. The braking analysis incorporated measurements and observations made on site immediately following the accident and detailed engineering calculations using ECM data and brake performance charts from the bus certification test and the manufacturer brake tests. The complexity of this work added a number of months to the investigation process. In contrast, TSB investigators were able to review the LER data with all parameters on the evening of the accident. The capture of these data enabled immediate detailed analysis of train handling in support of the investigation.

In 1999, a National Transportation Safety Board (NTSB) special investigation report identified that data collection issues hampered effective accident study and that vehicle on-board EDRs should be required to facilitate data collection. Subsequently, the NTSB has recommended EDRs for buses since that time (H-99-53 and H-99-54). While some progress has been made in the interim, the use of EDRs remains voluntary for roadway vehicles, and the NTSB classified the safety recommendations as “Open—Unacceptable Response” due to the fact that the NHTSA did not require the use of EDRs on buses. Following an NTSB investigation into a highway accident involving a 29-passenger bus near Dolan Springs, Arizona, the NTSB issued Safety Recommendation H-10-007, which superseded previous recommendations H-99-53 and H-99-54, and required that all buses with a GVWR of more than 10 000 pounds be equipped with on-board EDRs.

With regards to bus accidents,

- since 2005, there were 8 crossing accidents in Canada involving 3 transit buses and 5 school buses;
- between 2009 and 2013 (inclusive) in Canada and the United States, there were 331 714 police-reported motor vehicle traffic collisions involving buses that resulted in a total of 74 958 injuries and 1408 fatalities; and
- in 2013 alone, in Canada and the United States, there were 318 bus collisions that resulted in fatalities, 94 of which involved transit buses and 120, school buses.

In the majority of these cases, the buses were not equipped with a dedicated crashworthy EDR.

Although accidents involving transit buses at level crossings are rare, they are considered to be high-risk events due to the number of passengers transported in each bus and the potential for injury to the travelling public. In such cases, it is imperative that investigators have access to real-time recorded data that are consistent and meaningful to quickly identify safety deficiencies and prevent recurrence.

Through years of experience with EDRs in the air, rail and marine modes of transportation, the TSB, NTSB and the transportation industry have learned a great deal about the effective introduction of recording technology. Establishing industry standards for recording in these modes has been critical to effective implementation of EDRs. Industry standards ensure consistency in recorded data and prevent the proliferation of multiple formats and configurations. They also foster the efficient introduction of new recording system technology.

Identifying human factors is critical to understanding why accidents happen. All safety, regulatory, law enforcement and company accident investigations benefit from the efficient, timely and accurate collection, assimilation and analysis of available information. In many cases, EDRs provide and validate much of this valuable information. Early recovery of the information can also result in more timely communication of safety deficiencies and accident reports to industry, regulators and the public, which in turn can result in the implementation of measures to prevent a recurrence. If buses are not equipped with crashworthy EDRs, the circumstances and factors contributing to a bus accident may not be fully understood and appropriate safety action may not be implemented, increasing the risk that other similar bus accidents will occur.

2.9.1 Use of bus event data recorder data to manage and improve safety

Railway companies routinely use LER data in conjunction with operator (driver) proficiency testing to identify potential areas of improvement within the context of a railway company's safety management system (SMS). These improvements can occur through modifications to company training and / or employee mentoring.

EDRs have been commonly used by over 100 United States jurisdictions to manage school bus fleets. Research studies have determined that the use of EDRs has also led to operational safety improvements for vehicle fleets. In the United States, Laidlaw Incorporated (Laidlaw) studied the effect on safety following the installation of EDRs in 65 of 150 (43%) school buses in its bus fleet in Bridgeport, Connecticut. During the study, driver speeding was monitored, and those drivers who spent over 25% of their trip miles at speeds over a set threshold were requested to participate in counselling sessions. It was also determined that the Laidlaw buses that had not been equipped with EDRs accounted for 72% of the fleet's accidents. EDRs were then installed in the remainder of Laidlaw's Bridgeport fleet. After a year, additional factors that contributed to accidents related to driver training were identified, and Laidlaw modified its training program.

EDR information can be a useful tool for monitoring driver performance in conjunction with a transportation company's safety program, which can further reduce risk and improve safety before an accident occurs.

While some school bus transportation companies have installed EDRs on their fleets and have begun to analyse the data with a view to making safety improvements, there is no regulatory requirement for the installation and use of EDRs for buses. In Canada, the use of EDRs in buses is not widespread. Consequently, transportation companies and authorities that do not use or do not have access to EDR data are deprived of significant opportunities to reduce risk and improve safety before an accident occurs. Considering the overall crash and fatality rates involving buses and the increasing availability and use of electronic logs and GPS, if bus companies do not have access to or do not use available technology and EDR data for proactive safety analysis, there is an increased risk that opportunities to improve operational safety will not be identified.

2.10 Grade separation

The VIA Fallowfield Station (Mile 3.57) is located between the Woodroffe Avenue / Transitway and Fallowfield Road crossings (Mile 3.28 / 3.30 and 3.88 respectively) and adjacent to the OC Transpo Fallowfield bus station. Woodroffe Avenue and Fallowfield Road are arterial roads that service the area, and the crossings at these locations had a high cross-product. The railway signalling system throughout this area was complex with a number of additional built-in safety features. While the signalling system was generally reliable, with the additional features and programming, additional potential points of failure were introduced. Ultimately, the safety of the crossings was dependent on the roadway vehicle driver making appropriate decisions based on the information displayed.

Over the years, technology has improved and is capable of providing additional crossing warning systems. Talking GPS systems have advanced and can be programmed to alert drivers to an upcoming crossing and the need to slow down approaching the crossing. In recent years, the automobile industry has implemented various types of collision avoidance technology, including blind spot detection, vehicle spacing, speed control, and automated emergency braking. However, most of these technology advancements focus on the traffic ahead or behind a vehicle and are not yet sufficiently advanced to detect a vehicle (train) approaching from the side. None of these systems can yet detect a train and automatically stop a vehicle. The additional protection relies on heightened vehicle driver workload and the driver responding appropriately to any additional warnings.

While additional crossing protection may be useful, the only way to ensure that similar accidents do not occur at this location is to physically separate the roadway from the railway through grade separation.

2.10.1 Previous studies for grade separation

In 1995, due to the planned and expected urban development in the area of what is now the south Ottawa suburb of Barrhaven, the Regional Municipality of Ottawa-Carleton (predecessor to the City of Ottawa), undertook 2 environmental assessments (EAs). The need for grade separations at Woodroffe Avenue, the Transitway, and Fallowfield Road was identified early in the planning stage. Initially, the EA included various options for the grade separations. However, during the EA public consultations, there was local opposition to any overpass alternatives. The National Capital Commission (NCC) supported the public position and also preferred the underpass alternatives given that the views of the Greenbelt would be preserved. With the underpass alternative selected as the preferred option, roadway overpass alternatives were not considered in the final EAs.

Based on the EAs, the original plan had focused on the preferred option of open-cut roadway underpass grade separations at Woodroffe Avenue, the Transitway, and Fallowfield Road. However, by February 2003, subsurface testing had determined that the conditions were not suitable for the construction of open-cut roadway underpasses. Due to the unexpected subsurface conditions, the estimated cost to construct the open-cut roadway underpasses increased from 40 million dollars to more than 100 million dollars. Noting that this option also presented significant risks, the underpass alternative was therefore not pursued.

The roadway overpass alternatives were then reconsidered. Although the soils in the area were determined to have limited load-bearing capacity, it was noted that roadway overpass structures could have been built using light approach fills and multiple bridge spans. However, construction of any of the roadway overpass options would have required reopening the EAs that had been previously undertaken. The time required to redo the EAs would further delay completion of the project beyond the time constraints imposed through Millennium funding (end of March 2006). This would have resulted in the loss of the Millennium funding, which accounted for approximately 70% of the original estimated project cost.

While it was possible to construct roadway overpass grade separations for Woodroffe Avenue, the Transitway, and Fallowfield Road, the need to reopen the EAs, the possible loss of Millennium funding and the clear preference for the roadway underpass alternative demonstrated by both the public and the NCC limited the grade separation options considered by the City in 2004.

2.10.2 Change in cross-product values since 2004

Cross-product has always been one of the primary criteria used to assist in identifying potential grade separation projects. Historically, a cross-product of 200 000 was the accepted threshold used by TC and industry for considering grade separation. There was no indication of when, why or how the 200 000 threshold was established.

TC records indicated that, for the approximately 15 000 public crossings across Canada, Fallowfield Road is 1 of 43 level crossings protected by AWDs that has a cross-product in excess of 400 000. Similarly, Woodroffe Avenue is 1 of 15 level crossings protected by AWDs that has a cross-product in excess of 600 000.

Population, train traffic, vehicle traffic and vehicle occupant data (starting from 2004) for Woodroffe Avenue, the Transitway, and Fallowfield Road are summarized in Table 16.

Table 16. Population, train, vehicle and occupant data for crossings

Location	Year	Area population	Vehicle traffic	Number of trains	Cross-product	Number of vehicle occupants	Occupant cross-product
Woodroffe Avenue	2004	100 358	18 163	10	181 630	n / a	
	2007	n / a	22 335	15	335 025	n / a	
	2010	130 537	25 154	15	377 310	n / a	
	2013	145 062	30 396	23	699 108	1.08	755 036
	2020*	171 000					
Transitway	2004	100 358	n / a	10	n / a	n / a	
	2007	n / a	n / a	15	n / a	n / a	
	2010	130 537	390	15	1350	n / a	
	2013	145 062	1007	23	23 161	32	532 703
	2020*	171 000					
Fallowfield Road	2004	100 358	18 795	10	187 950	n / a	
	2007	n / a	16 787	10	167 870	n / a	
	2010	130 537	19 387	10	193 387	n / a	
	2013	145 062	25 412	16	406 592	1.08	439 119
	2020*	171 000					

* Estimated for 2020

Prior to 2004, due to planned urban development, the City considered there would be a need for grade separation at the crossings. At that time, with 10 trains per day, the cross-product was 181 630 for Woodroffe Avenue and 187 950 for Fallowfield Road. Once the preferred option of open-cut roadway underpasses was no longer available, it was decided to forgo grade separations and to install / upgrade the level crossings with enhanced AWD protection given the train and vehicle traffic at the time (i.e., cross-product less than 200 000). As well, all passenger trains were stopping at the VIA Fallowfield Station and these trains were restricted to 20 mph (32.2 km / h) over both the Woodroffe Avenue and Fallowfield Road crossings.

To support this decision, a number of detailed safety assessments (DSAs) and consultant reports were conducted. Several DSAs and studies did note that the cross-products examined at the time of the studies had exceeded the 200 000 threshold typically used to trigger an examination of grade separation. Once the crossings were constructed, the need for grade separation at Woodroffe Avenue, the Transitway, and Fallowfield Road was not formally reviewed or reconsidered, nor was it required to be.

By 2013, the population for the south end of Ottawa had increased to 145 062 (45% increase) and was projected to grow to 171 000 by 2020. In addition, the cross-product, based on weekday train traffic, had increased to 699 108 (285% increase) for Woodroffe Avenue and 406 592 (116% increase) for Fallowfield Road.

In 2013, the Transitway cross-product was 23 161. However, to more accurately quantify the risk for a bus on the Transitway, the average number of occupants per bus should also be considered. By multiplying the number of occupants on the bus with the Transitway cross-product, the occupant cross-product was 532 703. As a comparison, the occupant cross-product for Woodroffe Avenue was 755 036 and for Fallowfield Road, was 439 119.

By 2013, the number of trains had increased to 23 trains per weekday (130% increase). In addition, due to adjustments in the VIA schedule, some passenger trains were now traversing the crossings at 40 to 60 mph (64.4 to 96.6 km/h). Any future increase in train traffic on this corridor would further increase the risks.

Moreover, the City currently has active projects to widen Greenbank Road and Strandherd Drive. These are locations where VIA trains may travel at track speed of up to 100 mph (160.9 km/h). Greenbank Road has a cross-product of 309 400, and the project includes a roadway underpass that is under construction. Strandherd Drive has a cross-product of 442 400, and the project includes a roadway overpass, but that project has been suspended pending funding. In comparison, the present cross-product for Woodroffe Avenue and the occupant cross-product for the Transitway exceed the estimated cross-product for both current projects while the cross-product for Fallowfield Road exceeds the estimated cross-product for Greenbank Road. The elevated cross-product alone would warrant reconsideration of all options for similar grade separation of Woodroffe Avenue, the Transitway, and Fallowfield Road.

In 2004, the decision to proceed with level crossings was based on known risk factors at the time. However, since that time, changes have occurred in the risk factors such as area population, number of trains, train speed, number of vehicles, resulting cross-product, and average number of vehicle occupants. These risk factors will continue to increase with further urban development in the area. If the need for grade separation is not periodically reconsidered, changes in the risk factors may not be identified in a timely manner, increasing the risk that existing crossing protection may no longer be adequate to address increases in train and roadway vehicle traffic.

2.10.3 Fallowfield Road and Transitway Crossing

The Fallowfield Road and Transitway crossing presents a number of challenges relating to crossing safety. While a number of reviews had been conducted to mitigate the risk for road and rail traffic at the Fallowfield Road and Transitway crossing, the studies focused primarily on adding features to improve level crossing safety.

Although there was no mandate to re-evaluate the need for a grade separation, in response to proposed speed increases for VIA rail traffic, the 2012 Delphi-MRC final report to the City concluded in part the following:

- The Fallowfield Road grade crossing is already an exceptional crossing as the current cross-product exceeds the 200 000 threshold typically used to trigger an examination of grade separation. The ultimate decision to proceed with an at-grade crossing at this location was only obtained as a result of a thorough technical investigation conducted by the City that was based on the understanding that trains would either stop at the

VIA Fallowfield Station, or slow to 10 mph (16 km / h) as they travelled through the station.

- Planned growth in the Barrhaven area is expected to result in significant increases in traffic volume on Fallowfield Road and the roadway network within Barrhaven. These forecasted traffic volumes will result in a cross-product 2 or 3 times greater than the threshold typically used to trigger the examination of grade separation.

The Fallowfield Road crossing was not only exceptional due to the high cross-product, but also in terms of the overall complex and challenging context within which it operates. This included the challenging and unusual nature of the crossing, the complex interactions of public motor vehicle traffic, rail traffic, and bus traffic using the exclusive Transitway crossing, as well as the significant and unique active transportation corridor facilities in the surrounding area that interact with the rail crossing.

The VIA rail crossing traversed Fallowfield Road at an acute angle of 33 degrees, which was less than the minimum 45 degrees specified in RTD 10 for new construction. Options to realign Fallowfield Road to produce a more favourable angle were explored, but these options were not feasible. As a result of the crossing angle, the grade crossing clearance distance was greater than usual. The acute angle presented additional challenges to drivers, requiring them to look back over their right shoulder to view trains approaching from behind and to the right.

To offset these risks, the Fallowfield Road and Transitway crossing was equipped with roadway and railway signage, roadway markings and interconnected traffic lights to control traffic on Fallowfield Road while providing protection for the railway crossing and adjacent Transitway. The crossing AWDs were interconnected with the traffic lights equipped with a pre-emption circuit. The circuit was timed so that eastbound vehicles that had entered the crossing and were beyond the roadway stop line could clear the crossing before the lights on the crossing warning system started to flash. The traffic lights at the intersection of the Fallowfield Road and the Transitway were aligned such that they could not be seen from the roadway stop line for the crossing, but they were visible to drivers if the vehicle was beyond the stop line.

Due to the complexity of the crossing, for eastbound roadway users that stop beyond the stop line, it may not be clear if the traffic light pre-emption is for bus traffic on the Transitway or for rail traffic approaching the crossing. Between 18 September 2013 and May 2015, there were 7 incidents recorded at Fallowfield Road where the driver stopped beyond the railway crossing roadway stop line; 4 of these incidents involved professional drivers. Although no accident occurred as a result of these incidents, the incidents demonstrate that the driver workload at the Fallowfield Road crossing may have reached a point where even professional drivers have difficulty understanding the steps required to negotiate this crossing. For grade crossings that require increased driver workload, if vehicle drivers do not fully understand crossing AWD protection, interconnected traffic signals, visual cues, approach signage and roadway markings, the risk of a crossing accident is increased.

2.10.4 Guidelines for grade separation

In Canada, there is no specific cross-product value at which grade separation should be built. In addition, there is no specific guidance provided in the new *Grade Crossings Regulations*, the accompanying *Grade Crossings Standards*, RTD 10 or the accompanying *Canadian Road/Railway Grade Crossing Detailed Safety Assessment Field Guide* to assist road authorities in determining when a grade separation may be warranted.

In comparison, the United States Department of Transportation (DOT) Federal Highway Administration (FHA) *Railroad-Highway Grade Crossing Handbook* (2007) provides specific guidance as to when grade separation should be considered. Chapter V, Part A, Section 6, Grade Separation, states in part:

> […]
>
> b. Highway-rail grade crossings should be considered for grade separation across the railroad right of way whenever the cost of grade separation can be economically justified based on fully allocated life-cycle costs and one or more of the following conditions exist:
>
> […]
>
> viii. Crossing exposure (the product of the number of trains per day and AADT [average annual daily traffic]) exceeds 500,000 in urban areas or 125,000 in rural areas; or
>
> ix. Passenger train crossing exposure (the product of the number of passenger trains per day and AADT) exceeds 400,000 in urban areas or 100,000 in rural areas.

For the 2013 traffic volumes, both the Woodroffe Avenue and Fallowfield Road crossings met the FHA criteria for grade separation. However, there is no similar guidance available in Canada. If there are no guidelines established for when a grade separation should be constructed, level crossings with elevated risk factors can remain in place, increasing the risk of a crossing accident.

2.11 Train horn audibility and anti-whistling

Regulatory requirements specify that a high-level emergency passenger locomotive horn must be capable of producing a minimum sound level of 110 dB(A), while a freight locomotive horn must be capable of producing a minimum sound level of 96 dB(A) at a distance of 100 feet (30.5 m).

Despite their proven effectiveness to alert pedestrians and cyclists to an approaching train, train horns are considered as a secondary alerting system for vehicle drivers. Train horn audibility can be affected by many factors, including the speed of a train, the dampening of sound through a road vehicle shell, and the background noise within a vehicle.

In this occurrence, the bus was operated on the roadway with the windows and doors closed and the ventilation system on while passenger conversations took place in the background. Since a municipal by-law placed a whistling ban in effect for the crossing between the hours of 2000 and 1200 (noon) daily, the locomotive horn was not activated on the approach to the crossing, and the LE did not have time to activate the train horn.

However, for comparison, the investigation evaluated the ability of a driver to hear an activated high-level emergency passenger locomotive horn, and an activated freight locomotive horn, under similar circumstances.

The SNR of a high-level emergency passenger locomotive horn was only 15 dB(A) above typical background noise within a bus with a train located 100 feet (30.5 m) from a bus. For the same circumstances, the SNR of a freight locomotive horn was only 1 dB(A) above typical background noise within a bus.

The alerting level of an auditory stimulus, or the point at which a driver would first become aware of its presence, typically occurs when the sound rises to at least 10 dB(A) above any background noise level.

Having a vehicle door open when stopped at a crossing can increase the perceived loudness of an activated train horn by between 20 and 30 dB(A), which would make a horn audible to the vehicle driver. Therefore, for pedestrians, cyclists, railway trackside workers and vehicles that are required to stop at railway crossings and open their doors, the sounding of a locomotive horn can still be a useful defence.

Since sound must be at least 10 dB(A) above any background noise in order to be audible and the SNR for a high-level emergency passenger locomotive horn was only 15 dB(A) with a train located 100 feet (30.5 m) from a bus, the remaining available SNR was calculated to be only 5 dB(A). Therefore, from a distance of 100 feet (30.5 m), a high-level emergency passenger train horn would have been barely audible to a driver and may not have prompted a response even if the horn had been activated at the time of the accident, whereas a freight train horn would have been inaudible to a driver.

2.12 Requirement for buses to stop at level crossings

In this accident, the crossing AWDs were activated and properly functioning at the time, and the bus drove into the side of the train. However, there have been other crossing accidents where a bus stopped at a protected crossing then drove into the path of an oncoming train. This demonstrates that crossing accidents can occur whether a bus stops at a crossing or not.

Although the practice of stopping at all railway crossings is widespread for school buses, there is no comprehensive study that specifically deals with the risks associated with buses stopping at railway crossings. However, a 1985 FHA study suggested that not mandating stops at railway crossings protected with AWDs when the AWDs were not activated would result in a net annual decrease in train-involved accidents for hazardous material transporters, school buses, and passenger buses. This study did not specifically include transit buses as many of the observations dealt with tractor-trailers hauling hazardous materials and which have different characteristics compared to transit and school buses.

The MMM Group Limited (MMM) study, highlighting some of the advantages and disadvantages of this practice, attempted to answer specific questions posed by the City and provide a framework for reference. However, even this study was not comprehensive enough to draw meaningful conclusions. The MMM study recommended that flashing lights, bells, and gates (FLBG) be installed at all rail crossings that are used by OC Transpo buses. As the accident occurred at the Transitway crossing, which was already equipped with AWD protection that included FLBG and constant warning time (CWT) track circuits, the MMM study recommendation would have not prevented this accident. Also, none of the studies identified how many times a crossing accident was prevented by a bus stopping at a crossing. Consequently, transit and provincial authorities must make their own decisions, resulting in practices that vary across the country.

In this occurrence, the bus struck the side of the train while the crossing AWDs were activated. Had a requirement been in place for all buses to stop at the Transitway crossing, the risk of a crossing accident may have been reduced. However, there have also been cases where the bus stopped at a protected crossing and then drove into the path of an oncoming train. If there is no clear guidance to determine whether buses should stop at railway crossings even when the AWDs are not activated, there is a risk that railway crossing safety may not be optimized.

2.13 OC Transpo organizational issues

2.13.1 Driver performance review

Driver performance monitoring issues were unlikely to have played a contributory role in the accident. However, an organizational review identified deficiencies related to some of the metrics used in the OC Transpo driver performance monitoring process.

The aim of the demerit point system is to encourage drivers to improve their driving performance and to protect other road users from unsafe drivers. OC Transpo’s periodic review of drivers’ abstracts was focused primarily on flagging drivers who had received demerit points on their driver’s licence and / or accumulated the maximum number of demerit points (15).

OC Transpo policies and procedures required that the Training Department contact the driver’s section head in the Operations Department if a driver had received 6 demerit points or more since the last review or was approaching the maximum number of demerit points. The section head was required to look at the type of infraction(s), identify the likely driving issue that led to the demerit points and invite the driver to a meeting to discuss the behaviour and potential ways to improve it. However, it was only voluntary for a driver to attend the meeting. Reprimands or suspensions based on demerit points were rarely issued.

OC Transpo had no demerit point threshold that would prompt additional driver training. The Training Department and Operations staff had limited understanding of the demerit point system in place and did not know when or at what point a driver who had acquired demerit points should be contacted. If staff tasked with managing drivers and reviewing driver abstracts do not fully understand the company’s driver performance monitoring process, unsafe driving behaviours may not be identified and addressed in a timely manner, increasing the risk of roadway accidents.

A central aspect of an organization's approach to safety management is the identification of operational hazards in order to take action to mitigate the risks associated with those hazards. To assist in identifying operational hazards, OC Transpo Transit Operations maintained the Riskmaster collision database of accident and incident reports involving drivers while they were on duty. While the section heads had access to the database and the information was contained in the driver's employee file, the Training Department did not have access to the data, nor was the information included in the driver's training file. As a result, up-to-date driver information regarding driver accidents and incidents was not monitored by the Training Department, nor was it used to develop or modify driver training for emerging issues.

Accident history, number of traffic citations and risky driving behaviours are highly predictive of a driver's potential for a future accident. Research has shown that specialized advanced driver training can lead to modest decreases in crash risk. If driver accident and incident data are not available and reviewed by the training staff, existing or emerging driver deficiencies may continue unchecked, increasing the risk that the requisite training will not be modified to correct unsafe practices.

2.13.2 Driver behaviour and on-time performance

For public transit agencies, it is important that buses run on time. OC Transpo's operational focus on on-time performance is not unreasonable. In this occurrence, the bus was almost 4 minutes behind schedule upon departure from the OC Transpo Fallowfield Station, although OC Transpo considered that departing no more than 5 minutes after the scheduled time to be on-time performance. Being a dedicated roadway for buses, the Transitway was commonly used by drivers to make up time.

There were a number of other organizational factors that may also increase the pressure for an operator to speed. The collective agreement with the City required a guaranteed 5% minimum recovery time between trips. While drivers were not provided with break time during their work day, they could use the recovery time to take care of personal needs, to arrive at the beginning of a subsequent route or to return to the garage at the end of a shift.

OC Transpo's route scheduling system used several inputs to generate the most efficient transit network possible. One of these inputs was historical GPS travel time data from buses that had previously travelled the route. However, these data may have included buses travelling above the posted speed limit. Within the driver station, the scheduling information was visually displayed by the TCH schedule adherence bar, which provided the driver with a graphical representation of on-time performance while the bus was in motion. The TCH display was another factor that could contribute to a driver experiencing increased pressure to speed in order to stay on schedule.

OC Transpo management was aware of the route timing issue and encouraged drivers to drive at posted speed limits so that future route times could be as realistic as possible. While

OC Transpo's Service Improvement Request (SIR) process helped to identify routes in need of adjustment and some changes could be introduced quickly, it could take up to 6 months to make a change to a route that was scheduled with inadequate time. In the meantime, inadequate time may increase a driver's subjective, internal pressure to speed to stay on schedule.

If bus transit companies do not consider the factors that may influence driver behaviour, the drivers may engage in unsafe practices, increasing the risk of accidents.

2.14 Driver training related to crossing safety

Effective, practical training in vehicle operations is important for professional drivers to acquire the knowledge and skills that are necessary to safely and effectively perform their work. Driving regularly also allows commercial drivers to practise what they have learned and to improve their proficiency. Regular evaluation of driving skills is necessary to ensure that drivers practise what they have learned, and that the knowledge and driving skills they have developed is maintained.

OC Transpo had a comprehensive 6-week (30-day) New Bus Operator Training (NBOT) program for new drivers and the Pro-in-Motion recurrent training program that drivers were required to attend every 3 years. The recurrent training focused on efficient, safe driving techniques linked to previously learned defensive driving skills with an emphasis on smooth braking to enhance passenger comfort and safety.

Although various points related to crossing safety were discussed and practised during training, the crossing safety curriculum was not as comprehensive as that available through Operation Lifesaver (OL).

2.14.1 Crossing education and enforcement

The *Railway Safety Act* Review Committee acknowledged that an educational component was an integral part of a multi-faceted approach to rail safety. The Committee noted that technology alone was not sufficient to solve existing crossing safety problems, but must be coupled with education programs and an understanding of human behaviour.

OL is a national public awareness program aimed at educating Canadians about the hazards surrounding rail property and trains. OL had developed a number of educational tools that detailed the risks associated with level grade crossings. The program targeted high-risk locations and also responded to individual requests from interested parties for targeted presentations. OL published tips for drivers to improve safety in the vicinity of level crossings and had developed a module specifically for school bus drivers that could have been modified for transit operations. OL efforts have contributed to reducing railway crossing accidents.

As highlighted by OL, there are 3 elements that are necessary to improve crossing safety:

- *Engineering* to improve crossing protection,
- *Education* for vehicle drivers on risks associated with railway crossings, and
- *Enforcement* of crossing violations to reinforce safe driving habits.

A weakness in one or more of these elements can increase the risk of a crossing accident.

For this occurrence, with respect to the 3 elements, it was noted that:

- The Transitway crossing was equipped with one of the highest levels of AWD protection currently in use in Canada.
- The OC Transpo training crossing safety curriculum was not as comprehensive as that available through OL.

OC Transpo special constables periodically conducted speed testing, but there was little follow-up and no adverse consequence for a speeding violation on the Transitway. The City by-law had no specific requirements to deal with distracted driving, vehicles that did not stop at an activated railway crossing signal, and vehicles being driven around or under activated crossing gates. As the Transitway was considered a private roadway, these violations were not enforceable on the Transitway under the OHTA.

Two of the 3 elements necessary to improve crossing safety (i.e., education and enforcement) were not being addressed by OC Transpo oversight. If bus drivers do not receive targeted railway crossing safety education, and if driver compliance with the rules of the road is not actively enforced, railway crossing safety will not be optimized, increasing the risk of a crossing accident.

2.15 Crossing signal light misalignment

Both Woodroffe Avenue and the Transitway crossings were equipped with light-emitting diode (LED) signal light technology, which provided improved conspicuity of active signal lights. When compared to conventional incandescent lighting, LED lights are typically brighter and have a wider dispersion pattern, which reduces the risk in cases where the lights may be slightly misaligned.

By design, crossing back lights (short) mounted on a stanchion are intended to provide warning for drivers stopped at or near the crossing when the lights are activated. The front lights (long) are intended to provide advance warning for drivers approaching from a distance. The design is also based on the premise that the vehicle driver will be paying attention and will take appropriate action, such as slowing for or stopping at a crossing. As one set of lights is intentionally aimed short and the other set is aimed long, when approaching the level crossing from a distance, it is normal for crossing back lights (short) to be visible, but not as bright as the front lights (long), which are aimed further down the road.

During the TSB accident re-enactment, while proceeding northward approaching the crossing, the Transitway front lights (long) were highly visible while the back lights (short) were visible but not as bright. The activated crossing lights on Woodroffe Avenue were also visible from the Transitway.

For a road speed of 60 km / h (Transitway limit), the short lights (back lights located on the north stanchion) should have been aimed at a location 50 feet (15.2 m) south of the northbound lane (accident lane) stop line at the crossing, at the driver position, 5.25 feet (1.6 m) off the road surface. The long lights (front lights located on the south stanchion) should have been aimed at a location about 280 feet (85.3 m) south of the northbound lane stop line (accident lane).

The TSB site examination determined the following:

- Although the crossing lights were clearly visible to roadway vehicles, the Transitway lights facing southward were misaligned for northbound traffic approaching the crossing.
- The west light of the south-side front lights (long) was properly aligned at 280 feet (85.3 m) while the east light was aimed 50 feet (15.2 m) to the west at the 280-foot (85.3 m) mark.
- Because the northbound bus collided with and broke the south crossing gate and a northward impact on the south crossing gate could turn the light to the west, the east front light misalignment likely occurred as a result of the accident. As such, the front lights (long) were likely properly aligned at the time of the accident.
- The east light of the north-side back lights (short) were aimed at 62 feet (18.9 m) on the northbound lane while the west light was aligned about 50 feet (15.2 m) to the east, 62 feet (18.9 m) from the south stop line. However, although misaligned, the east short light aimed at 62 feet (18.9 m) on the northbound lane would have been even more salient to the driver than if it had been aimed as required (50 feet or 15.2 m).

The bus was travelling at 67.6 km / h (42 mph) and was 116.8 feet (35.6 m) away from the point of collision when braking was initiated. A perception reaction time of 2.5 seconds is generally accepted as the time required for a driver to respond to a visual stimulus, and at 67.6 km / h (42 mph), a vehicle travels 18.78 m / s (61.6 feet / s). This would suggest that the driver first became aware of the activated crossing AWD signals 270.8 feet (82.5 m) in advance of the crossing, which is approximately where the long (front) lights were aimed. Although the north-side back LED lights (short) of the Transitway crossing were slightly misaligned, they were intended for vehicles stopped at the crossing, and the misalignment likely did not play a role in this accident.

2.16 Emergency response

The City responded and coordinated activities in accordance with its established emergency plans. The Ottawa Police Service, Ottawa Fire Services and Ottawa Paramedic Service responded quickly and effectively upon notification of the accident. Due to the location of the accident and proximity to the Transitway level crossing, the site was accessible for emergency responders, who were on the scene within minutes following the accident. An incident command post was established and a unified command structure was put in place.

The most seriously injured were triaged and transported to hospital within 35 minutes following the accident. Given the circumstances of the accident, the emergency response was well coordinated between the attending agencies with appropriate and effective measures taken to protect the site and to ensure passenger and public safety.

2.17 Unrelated Barrhaven crossing automatic warning device activations

While crossing AWD protection is generally highly reliable, it can periodically experience unwanted activations as a result of the fail-safe design or other issues. Repeated unwanted AWD activations for any reason are considered to be nuisance operation that can negatively affect vehicle driver behaviour and can also lead the general public to question the overall safety of the crossing AWD protection.

From 18 September 2013 to May 2015, there were 5 reports of an OC Transpo bus travelling over the Transitway crossing while the lights and bells of the AWD protection were activated.[163] In 1 of the 5 cases, OC Transpo reported an unwanted activation of Transitway crossing AWDs.[164] With no railway track protection in place, 3 OC Transpo buses traversed the crossing while at least 1 transit supervisor accessed the crossing and manually tried to lift the south gate while the crossing AWDs were activated. If vehicle drivers are repeatedly exposed to unwanted crossing AWD activations, there is an increased risk that drivers will develop an expectation that no train is present at the crossing when the AWDs are activated and may circumvent the crossing protection.

Between January 2014 and April 2014, a series of unwanted crossing AWD activations occurred at 6 VIA crossings within the Barrhaven area. Although not reportable to the TSB, the TSB followed up as part of this investigation and reviewed a total of 20 crossing AWD trouble calls. A review of a series of unwanted AWD activations of the Barrhaven crossings in early 2014 determined that, although disruptive, there was no systematic failure of the crossing protection system, and the parties involved (TC, VIA and the City) took appropriate steps to resolve the issues.

2.18 Synchronization of crossing signal bungalow timing

Although it did not affect the performance of the AWDs, the internal clocks used in the 2 signal bungalows for the adjacent crossings on Woodroffe Avenue and the Transitway were not synchronized. The time stamp event data had to be realigned, delaying the analysis of the data and could have resulted in some confusion while reviewing the data. As the 2 crossings were located in close proximity, and work together as 1 unit, synchronization of the internal clocks for event logging and analysis of data would have been preferable. This has presented challenges in correlating data from the LER, wayside detection systems, signal

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163 Transportation Safety Board of Canada, Rail Safety Advisory 01/14, R13T0192 – OC Transpo buses traversing crossings with activated AWD protection.

164 Transportation Safety Board of Canada, Rail Safety Advisory 02/14, R13T0192 – Reported malfunction of Transitway automatic crossing protection.

indications and crossing signal bungalows in other in TSB investigations.[165] Given advancements in technology, it may be feasible to establish common time stamps for all railway operating electronic logs within each company. If railway electronic log time stamps are not synchronized, operational analysis of safety-critical data may be difficult, increasing the risk of delays in the analysis and of misinterpretation of the data.

2.19 Other potential driver-related factors

During the investigation, a number of driver-related factors were considered and reviewed, but were determined not to have played a role in the accident.

2.19.1 Driver fitness for duty

“Fitness for duty” refers to an individual’s physical, mental, and emotional status with respect to being able to safely perform the essential functions of their job. As such, the driver’s health, work and sleep history, including any potential impact of split shift work, were examined as part of the investigation.

The driver was fully qualified and fit for duty at the time of the accident. There was no medical illness involved and there were no traces of drugs or alcohol in the driver’s system.

2.19.2 Red-green colour vision defect

The driver had a congenital, red-green colour vision defect that had been identified during his 2005 OC Transpo pre-employment medical exam. Based on the screening test results, there was a greater than 90% probability that the driver had a deutan colour vision defect. Although the driver had a red-green colour vision defect, it was unlikely that this colour vision defect played a role in the accident as the driver had near-to-normal brightness sensitivity to the red flashing lights at the crossing.

2.19.3 Effect of driver’s sunglasses

At the time of the accident, the driver was wearing polarized sunglasses with a dark vermillion (reddish-brown) tint. The potential effect of the polarized sunglasses on the conspicuity of the crossing LED signal lights and the driver’s perception of liquid crystal display in-vehicle screens, monitors and controls was assessed.

As the crossing signal lights were not polarized, their visibility to the driver was not affected by the polarization property of the sunglasses. The vermillion tint of the sunglasses would have absorbed the least amount of light from the red region. Variation in light absorption properties would have increased the brightness contrast of the red crossing signal lights viewed against a blue background (i.e. the sky), or a green background (i.e. the surrounding brush) because of the higher absorption in the green and blue regions of the spectrum. In addition, the in-vehicle display screens/monitors were clearly visible through the

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165 TSB railway investigation reports R07D0111 and R12T0038.

sunglasses. The driver's sunglasses enhanced the conspicuity of the crossing signal lights and did not play a role in the accident.

2.19.4 Previous neck injury

The driver sustained a neck injury in July 2007 and worked part-time until January 2009 when the driver was deemed medically fit to return to work full-time. Although the driver had a mild flare-up of the injury in January 2012, he had been healthy since that time. As the driver was not experiencing any significant ongoing pain or discomfort and he had full range of motion for at least 18 months preceding the accident, the driver's previous neck injury did not play a role in the accident.

2.19.5 Diabetes

The driver had Type 2 diabetes, which had also been reported to the MTO on the driver's most recent (March 2010) medical report. The report indicated that the diabetes was being treated with diet alone and that the driver had never experienced hypoglycemia or loss of consciousness due to hypoglycemia. Although the driver subsequently had been prescribed medication (metformin) to help manage the disease, the driver remained qualified to drive commercially in Ontario, as he had never experienced any complications that adversely affected his driving ability.

The driver did not show any signs of incapacitation or unconsciousness in the moments leading to the accident. There was no indication that the driver was hyperglycemic or had suffered an episode of hypoglycemia before the crash. Therefore, although the driver had Type 2 diabetes, it had been managed appropriately and there was no indication that the disease played a role in the accident.

2.19.6 Fatigue

There is no rigid formula that can be applied to the fatigue factors to test for the existence of fatigue. Both the magnitude and the number of risk factors must be considered. In this occurrence, there are 2 possible risk factors that may have existed—acute and chronic sleep disruption.

The acute sleep disruption may have existed because the driver had shortened sleep on 2 out of 3 nights (6.6 and 6.2 hours of sleep) prior to the accident, and there was a potential concern about the quality of the sleep. The chronic sleep disruption may have existed because the driver had a small sleep debt (-1.3 hours) at the time of the accident and because of the concern about the quality of the sleep. However, these factors were offset by the short period of continual wakefulness (3.7 hours) prior to the accident. In addition, the time of day and the driver's sleep patterns were not of concern in relation to circadian rhythm effects.

In this occurrence, the driver not stopping for the flashing signals and gates that were activated at the time of the collision was related to a performance impairment that falls into the category of attention or vigilance. While there are a number of research studies that support a connection between fatigue and attention, the effect of fatigue was considered unlikely for the following reasons:

- The driver had only been awake for a few hours.
- The accident occurred at a favourable circadian point in the day.
- The driver had a small sleep debt of only 1.3 hours.
- The driver had 2 full days off followed by only 2 of 3 nights with slightly less than desirable sleep.
- The driver was performing a job that was not monotonous in nature.

Based on the review of the driver's work-rest history and related sleep patterns, driver fatigue did not likely play a role in the accident.

2.20 Other factors considered

2.20.1 Red flashing lights on crossing gates

The 3 lights affixed to each crossing gate were 4-inch LED fixtures, with maximum luminous intensity readings of approximately 160 candelas at 60 feet (18.3 m). The gates are intended as a barrier to cars within the immediate vicinity of the crossing and the lights are intended to identify the position of the gates in situations where there is inadequate light (i.e. dusk or night time).

During the accident re-enactment, when the gates were activated (down), the horizontal gate and flashing gate lights were positioned directly in line with the horizon beyond the crossing. The crossing gate blended into the background, and the sunshine on the day of the accident diminished the visibility of the gate lights. Consequently, the crossing gate and lights were not very conspicuous from a distance, nor were they designed to be.

2.20.2 Stopped vehicles on roadways

Stimuli other than designated warnings can act as cues to drivers that indicate expected, or appropriate, behaviour. The AWDs for both the Woodroffe Avenue and the Transitway crossings were activated before the bus departed from the OC Transpo Fallowfield Station. In the seconds leading up to the accident, there were a number of northbound and southbound vehicles stopped at the Woodroffe Avenue crossing for the activated crossing AWDs, prior to the train arriving. However, there were no other buses on the Transitway travelling in either direction in the immediate vicinity of the bus prior to the accident.

As the stationary vehicles at the adjacent crossing on Woodroffe Avenue were obscured by trees, shrubs and foliage on the Transitway right-of-way, they were not conspicuous enough to alert the driver to the activated crossing protection.

2.20.3 The approaching train

For a northbound driver looking ahead toward the tangent point (the inside) of the road as the bus exited the left-hand curve of the Transitway toward the crossing, a train approaching from the east would be in the driver's peripheral vision or obscured by trees shrubs, foliage and the bus side pillars. The relatively similar approach speeds of the bus and of the train toward the crossing likely made it difficult for the driver's peripheral vision to detect the presence of the train.

2.20.4 Bells at the crossing

The primary purpose of crossing bells is to warn pedestrians and other non-vehicle road users of an approaching train. The crossing bells at the accident crossing were active at the time of the accident, and were first activated at the same time as the warning lights.

The sound level of the crossing bells would not likely have been detected above the ambient noise levels within the bus.

3.0 Findings

3.1 Findings as to causes and contributing factors

1. Although the crossing protection was activated, the bus did not stop as required and struck the train as the train entered the crossing.

2. Locomotive VIA 915's lead truck followed the main track while its rear truck derailed on the Transitway crossing when the locomotive was contacted by the bus chassis. Then, the rear truck of locomotive VIA 915, along with the lead truck of the first car (VIA 3455), took a diverging route into the VIA Rail Canada Inc. siding.

3. As locomotive VIA 915 and car VIA 3455 jackknifed, the lateral restraint capacity of both tracks was exceeded as the rail on both tracks spread out of gauge and rolled to the field side, resulting in the derailment of the remaining passenger cars.

4. As it was common for drivers to use the section of the Transitway immediately following the crossing to make up time, and because the driver did not expect to encounter a train, the bus was accelerated beyond the posted speed limit.

5. The bus speed of 42 mph (67.6 km / h) exceeded the posted speed limit of 60 km / h by 7.6 km / h just prior to the initial brake application, which increased the stopping distance required.

6. The driver did not initially fully apply the brakes, which increased the bus stopping distance.

7. OC Transpo's training on brake application, which focused on smooth braking to minimize passenger discomfort, may have contributed to the driver not initially applying maximum braking force in an emergency situation.

8. OC Transpo speed monitoring and enforcement activities on the Transitway in the vicinity of the crossing were not sufficient to prevent drivers from exceeding posted speed limits when approaching the crossing, in contravention of recommended safe driving practices.

9. The driver was likely visually distracted by looking at the video monitor during the critical driving sequence of negotiating the left-hand curve and approaching the crossing.

10. Conversations between the driver and a passenger and among passengers near the driver, as well as the perceived need to make an announcement to passengers standing on the upper deck, created a situation where the driver was likely cognitively distracted in the seconds before the accident.

11. OC Transpo did not identify or mitigate the risks arising from driver attention being inappropriately directed at the video monitor when the bus was in motion and from

the need to make announcements if passengers were observed standing on the upper deck.

12. The trees, shrubs, foliage, and roadway signage on the Transitway right-of-way, as well as the bus front corner and window pillars, obstructed the driver's view of the activated automatic warning devices until the bus was 122.5 m (402 feet) from the crossing, a distance that was slightly less than the recommended stopping sight distance of 130 m (426.5 feet).

13. In addition to distractions that likely influenced the driver, the additional driver workload associated with negotiating the left-hand curve on approach to the crossing likely decreased the driver's ability to detect the activated automatic warning devices.

14. Although the crossing automatic warning devices (AWDs) had been activated before the bus departed from the station, the view of the activated AWDs was obstructed and there was no active advance warning of the train's approach available to the driver.

15. Although not required by regulation, a more robust front structure and crash energy management design may have reduced the damage to the bus and prevented the loss of a protective shell for the occupants.

3.2 Findings as to risk

1. If officials tasked with the enforcement of traffic violations on the Transitway are not provided adequate enforcement tools, there is an increased risk for a related vehicle accident to occur.

2. If mitigating strategies are not put in place to address driver distraction, bus drivers may not always remain focused on the driving task and on the roadway ahead, increasing the risk of a roadway accident.

3. If active advance warning signs interconnected with railway crossing signals are not installed on roadways with a significant curve near a crossing or at locations with inadequate stopping sight distances, drivers may not have sufficient time to react to an approaching train, increasing the risk of a crossing accident.

4. If the stopping sight distance is not periodically checked by road authorities, especially along roadways with trees and other growing vegetation, the view of the crossing from the roadway may become obstructed over time, increasing the risk of a crossing accident.

5. If vehicle safety standards for transit buses do not include requirements for enhanced crashworthiness, there is an increased risk of injury to vehicle occupants in the event of an accident.

6. If buses are not equipped with crashworthy event data recorders, the circumstances and factors contributing to a bus accident may not be fully understood and appropriate safety action may not be implemented, increasing the risk that other similar bus accidents will occur.

7. If bus companies do not have access to or do not use available technology and event data recorder data for proactive safety analysis, there is an increased risk that opportunities to improve operational safety will not be identified.

8. If the need for grade separation is not periodically reconsidered, changes in the risk factors may not be identified in a timely manner, increasing the risk that existing crossing protection may no longer be adequate to address increases in train and roadway vehicle traffic.

9. For grade crossings that require increased driver workload, if vehicle drivers do not fully understand crossing automatic warning device protection, interconnected traffic signals, visual cues, approach signage and roadway markings, the risk of a crossing accident is increased.

10. If there are no guidelines established for when a grade separation should be constructed, level crossings with elevated risk factors can remain in place, increasing the risk of a crossing accident.

11. If there is no clear guidance to determine whether buses should stop at railway crossings even when the automatic warning devices are not activated, there is a risk that railway crossing safety may not be optimized.

12. If staff tasked with managing drivers and reviewing driver abstracts do not fully understand the company's driver performance monitoring process, unsafe driving behaviours may not be identified and addressed in a timely manner, increasing the risk of roadway accidents.

13. If driver accident and incident data are not available and reviewed by the training staff, existing or emerging driver deficiencies may continue unchecked, increasing the risk that the requisite training will not be modified to correct unsafe practices.

14. If bus transit companies do not consider the factors that may influence driver behaviour, the drivers may engage in unsafe practices, increasing the risk of accidents.

15. If bus drivers do not receive targeted railway crossing safety education, and if driver compliance with the rules of the road is not actively enforced, railway crossing safety will not be optimized, increasing the risk of a crossing accident.

16. If vehicle drivers are repeatedly exposed to unwanted crossing automatic warning device (AWD) activations, there is an increased risk that drivers will develop an

expectation that no train is present at the crossing when the AWDs are activated and may circumvent the crossing protection.

17. If railway electronic log time stamps are not synchronized, operational analysis of safety-critical data may be difficult, increasing the risk of delays in the analysis and of misinterpretation of the data.

3.3 Other findings

1. The automatic warning device crossing protection for both the Woodroffe Avenue and the Transitway crossings operated as designed with no malfunctions.

2. The ADL E500 double-decker bus met or exceeded all required air brake system criteria for operation in Canada. There was no indication of any pre-accident conditions or deficiencies with the air brake system mechanical and pneumatic components that would have precluded normal operation of the brake systems.

3. While it was possible to construct roadway overpass grade separations for Woodroffe Avenue, the Transitway, and Fallowfield Road, the need to reopen the environmental assessments, the possible loss of Millennium funding and the clear preference for the roadway underpass alternative demonstrated by both the public and the National Capital Commission limited the grade separation options considered by the City of Ottawa in 2004.

4. From a distance of 100 feet (30.5 m), a high-level emergency passenger train horn would have been barely audible to a driver and may not have prompted a response even if the horn had been activated at the time of the accident, whereas a freight train horn would have been inaudible to a driver.

5. Although the north-side back LED lights (short) of the Transitway crossing were slightly misaligned, they were intended for vehicles stopped at the crossing, and the misalignment likely did not play a role in this accident.

6. The emergency response was well coordinated between the attending agencies with appropriate and effective measures taken to protect the site and to ensure passenger and public safety.

7. A review of a series of unwanted automatic warning device activations of the Barrhaven crossings in early 2014 determined that, although disruptive, there was no systematic failure of the crossing protection system, and the parties involved (Transport Canada, VIA Rail Canada Inc. and the City of Ottawa) took appropriate steps to resolve the issues.

8. The driver was fully qualified and fit for duty at the time of the accident.

9. There was no medical illness involved and there were no traces of drugs or alcohol in the driver's system.

10. Although the driver had a red-green colour vision defect, it was unlikely that this colour vision defect played a role in the accident as the driver had near-to-normal brightness sensitivity to the red flashing lights at the crossing.

11. The driver's sunglasses enhanced the conspicuity of the crossing signal lights and did not play a role in the accident.

12. As the driver was not experiencing any significant ongoing pain or discomfort and he had full range of motion for at least 18 months preceding the accident, the driver's previous neck injury did not play a role in the accident.

13. Although the driver had Type 2 diabetes, it had been managed appropriately and there was no indication that the disease played a role in the accident.

14. Based on the review of the driver's work-rest history and related sleep patterns, driver fatigue did not likely play a role in the accident.

15. The crossing gate and its lights were not very conspicuous from a distance, nor were they designed to be.

16. As the stationary vehicles at the adjacent crossing on Woodroffe Avenue were obstructed by trees, shrubs and foliage on the Transitway right-of-way, they were not conspicuous enough to alert the driver to the activated crossing protection.

17. The relatively similar approach speeds of the bus and of the train toward the crossing likely made it difficult for the driver's peripheral vision to detect the presence of the train.

18. The sound level of the bells would not likely have been detected above the ambient noise levels within the bus.

4.0 Safety action

4.1 Safety action taken

4.1.1 Follow-up after TSB accident re-enactment

On 11 October 2013, the Transportation Safety Board of Canada (TSB) met with the City of Ottawa (City), Transport Canada (TC) and VIA Rail Canada Inc. (VIA) to share the observations compiled following the accident re-enactment on the Transitway. The observations included comments on various sightlines, on the configuration of the crossing, and on various elements of the automatic warning device (AWD) crossing protection.

Following the meeting, the City initiated the following safety actions:

- The trees, shrubs and foliage in the vicinity of the Transitway crossing area were trimmed or removed.
- The speed in both directions approaching the crossing was reduced to 50 km / h.
- The signage in the vicinity of the crossing was enhanced:
  - revised “Railway Crossing Ahead” warning signs were installed on the approaches to the southwest Transitway crossing, in accordance with the new 50 km / h speed limit;
  - revised “Curve Ahead” warning signs were relocated on the approaches to the curve south of the Transitway crossing, in accordance with the new 50 km / h speed limit;
  - “Chevron Alignment” warning signs were installed south of the crossing for both northward and southward traffic along the curve; and
  - white delineators were installed on the guide-rails on either side of the Transitway, north and south of the crossing.
- The City installed an active advance warning sign (AAWS), with a light that continuously flashes, in advance of the crossing for northbound traffic. The flashing light was not interconnected to railway crossing signals.
- The OC Transpo Fallowfield Station signage was relocated.

Following the meeting, VIA undertook a safety blitz to verify the accuracy of the light unit alignment on all of the crossings on VIA track that are protected by AWDs and maintained by VIA (including the Alexandria Subdivision, Beachburg Subdivision, Smiths Falls Subdivision and Chatham Subdivision). VIA maintains 131 public crossings equipped with AWDs and 3 private crossings equipped with AWDs (1 of which is the Transitway). Of these 134 crossings, 20 of 1300 crossing lights were realigned.

4.1.2 TSB Rail Safety Advisory 01/14

On 25 February 2014, the TSB issued Rail Safety Advisory (RSA) 01 / 14, entitled *OC Transpo buses traversing crossings with activated AWD protection*, to the City.

The RSA indicated that, since the accident on 18 September 2013, there were 4 reports of an OC Transpo bus travelling over a crossing while the lights and bells of the AWD crossing protection were activated. The RSA suggested that the City may wish to put appropriate measures in place to ensure that buses are able to stop safely in advance of an activated railway crossing signal.

In response to RSA 01/14, the City initiated the following safety actions:

- On 23 April 2014, Transit by-law 2007-268, which governs the operation of vehicles on the Transitway, was amended to prohibit
  - vehicles from crossing at a railway crossing when warning of an approaching train is given;
  - drivers from driving through, around or under a crossing gate; and
  - drivers from using hand-held communications and entertainment devices or viewing video display screens unrelated to the driving task.
- An external review was undertaken of current OC Transpo operating practices at railway crossings. The engineering report concluded that OC Transpo's current operating practice at protected railway crossings is appropriate and suggested that 4 existing rail crossings be modified. The engineering work associated with modifying the crossings is underway.

OC Transpo and the Amalgamated Transit Union 279 jointly issued written directives to operators reminding them to

- follow the *Ontario Highway Traffic Act* (OHTA) and exercise safe and defensive driving practices;
- watch for railway crossing flashing lights (signals). If the lights are flashing, stop safely and well before the railway tracks;
- always follow the posted speed limits and, when approaching the railway crossings, slow down, hover over the brake pedal and watch for train movement in both directions of the railway tracks. Proceed with caution; and
- always be prepared to stop.

OC Transpo broadcasts daily internal radio announcements to drivers to remind them to exercise caution when approaching a railway crossing, and to adhere to the posted speed limits.

4.1.3 TSB Rail Safety Advisory 02/14

On 25 February 2014, the TSB issued RSA 02/14, entitled *Reported malfunction of Transitway automatic crossing protection*, to the City.

The RSA indicated that, on 11 February 2014, OC Transpo had reported a malfunction of the VIA crossing AWD protection at the Transitway crossing. During this incident, 3 OC Transpo buses had traversed the crossing while the AWDs were activated. The RSA suggested that the City and VIA may wish to develop and implement standard operating procedures to ensure safe operations when unusual activations or malfunctions of crossing automated protection occur.

In response to RSA 02/14, the City initiated the following safety action:

- The City and VIA developed and implemented joint standard operating procedures to better ensure safe operations during a railway crossing malfunction. These procedures include a joint communications protocol to ensure that both organizations are aware of an unplanned malfunction of the railway company's devices and are better communicating with each other.
- For any crossing incident, reporting protocols are clearly established so that staff in the OC Transpo control room has direct contact with VIA and its contractor, RailTerm, in order to respond appropriately.

4.1.4 TSB Rail Safety Advisory 10/14

On 24 September 2014, the TSB issued RSA 10/14, entitled *Video monitoring system on OC Transpo double decker buses*, to the City.

The RSA suggested that, given the importance of minimizing driver distraction, the City may wish to review the procedural/operational aspects of the video monitor on double-decker buses to ensure that safe bus operation is always maintained.

In response to RSA 10/14, the City initiated the following safety action:

- The City tasked expert traffic safety engineering and ergonomic consultants from MMM Group Limited (MMM) and their subcontractor Human Factors North (HFN) to review driver workload and other ergonomic aspects of OC Transpo bus operation.
- In July 2015, HFN recommended that
  - the video monitor within the driver's station of all OC Transpo ADL E500 buses be reconfigured to display only the interior view of the upper deck of the bus at all times; and
  - since the video monitor was required to maintain the operator's visibility of the upper deck in order to monitor passenger safety, the best location for the monitor is to the left of the rear-view mirror, which provides the same function for the lower deck.
- By the end of September 2015, the video monitor display within the driver station of all OC Transpo ADL E500 buses had been reconfigured to display only the interior view of the upper deck of the bus at all times.
- OC Transpo and Alexander Dennis Limited (ADL), the manufacturer of the ADL E500, are discussing the engineering and safety requirements incorporated into the design and specifications of the driver's video monitor on the ADL E500, and exploring further changes to its location, operation and use.
- OC Transpo staff are reviewing standard operating procedures and training curriculum related to the driver's responsibility to ensure that passengers are safely seated on the upper deck and are not standing in the stairwell. Staff will ensure that

this direction is consistent with the instructions and curriculum related to avoiding distracted driving, and will make any necessary changes to ensure that these instructions are unambiguous, clear, and consistently applied.

- OC Transpo installed information labels on the upper deck of double-decker buses to advise passengers that standing is not permitted.

4.1.5 TSB Rail Safety Advisory 12/14

On 24 September 2014, the TSB issued RSA 12/14, entitled *Braking analysis and bus speed approaching crossings*, to the City.

The RSA suggested that the City may wish to implement additional measures to monitor and control bus speed, particularly in the vicinity of railway crossings.

In response to RSA 12/14, the City initiated the following safety action:

- A Transitway Radar Enforcement Unit was created and deployed. The Unit, including transit special constables and transit supervisors, will operate 7 days a week to monitor, assess, and enforce speeds on the Transitway. Monitoring will focus on the Transitway, including in the vicinity of the crossings at Woodroffe Avenue and Fallowfield Road.
- OC Transpo staff are reviewing best practices at transit agencies across Canada and in the United States, by which speed limits are enforced among transit staff, including approaches to employee supervision, the use of global positioning system (GPS) and other technologies.
- The City Public Works and OC Transpo are evaluating engineering solutions to ensure compliance with posted speed limits approaching the crossing. Peripheral transverse pavement markings, rumble strips, and post-mounted delineators have been identified as physical means that can be both effective and practical. These measures will be tested at other locations on the Transitway.

4.1.6 Additional measures taken by the City of Ottawa

Since the accident, the following additional safety measures have been taken by the City or by OC Transpo:

- The City is installing gates at railway crossings used by OC Transpo buses.
- OC Transpo has been involved with Operation Lifesaver (OL). OL was consulted and involved in the development of an OC Transpo railway safety video that illustrates safe driving practices on the approach to railway crossings. By the end of 2013, OC Transpo had trained 11 employees to deliver OL training material.
- All new OC Transpo vehicle specifications will involve input from all front-line staff, including mechanics and drivers.
- OC Transpo is updating the GPS Mapper on the transit control head (TCH).
- OC Transpo will be implementing driving simulators for enhanced driver training.
- The OC Transpo general manager delivered safety messages personally to all drivers at all Pro-in-Motion sessions.

- OC Transpo New Bus Operator Training (NBOT) and the recurrent Pro-in-Motion training were revised to include additional in-depth training related to risks associated with safely negotiating a railway crossing. Additional training material now includes the following information:

Railway crossings

- All railway crossings on roads and the Transitway are marked with large red and white "X" signs called cross bucks. Watch for these signs and always be prepared to stop safely.

  You may also see large “X” pavement markings or yellow advance warning signs ahead of some railway crossings.
- Most railway crossings over which OC Transpo operates have red flashing warning lights and some also have gates to remind drivers not to cross the tracks because a train is coming.

  A train travelling at 60 km/h takes up to 2 km to stop under full emergency braking and so trains always have the right-of-way at all railway crossings.
- Some other vehicles are required by law to stop at railway crossings whether or not the warning signals are activated – watch for these vehicles and be prepared to stop behind them.

At active railway crossings (with signals and gates):

- Adjust your speed to the road conditions and always follow posted speed limits
- When approaching crossings, slow down
- Hover over the brake pedal as you approach, be prepared to stop
- Determine the decision point
- Look both ways and listen to make sure the way is clear before crossing the tracks
- Proceed with caution, maintain vehicle speed

If the warning devices are activated:

- Stop your vehicle at the marked stop line
- Stop at least 5 metres (15 feet) from the nearest rail or gate
- If there are red flashing warning signal lights, wait until they stop flashing and, if the crossing has a gate, wait until it is fully in the upright position before you safely cross the tracks
- Do not cross the track until you are sure the train has passed

At passive railway crossings (no warning devices) follow the Highway Traffic Act:

- Stop at least 5 metres back from nearest rail
- Open door, look both ways and listen for trains

- Proceed with caution when clear

For Safety:

- **Never stop on the railway tracks**; for example, in heavy traffic, make sure you have enough room to cross the tracks completely before you begin.
- **If you get trapped** on a crossing, whether or not you see or hear a train coming, immediately get everyone out to a location at least 50 metres away from the tracks. Contact the [OC Transpo] Control Centre immediately.
- **Do not attempt to cross tracks when flashing signal lights and barriers are activated.** If in doubt, contact your controller (MSG 9) [the OC Transpo Control Centre] immediately.
- **Never drive around, under or through a railway gate** while it is down, being lowered or being raised. Never lift or tamper with a gate and never walk onto the railway tracks except to cross where the way is marked for pedestrians.
- **Never touch or manipulate the gates**, signals or any other warning device at the railway crossing.
- **Do not proceed if the signal remains active**, unless instructed to do so only by an official railway personnel or the Ottawa Police Service.
- If you arrive at any railway crossing and notice an abnormal condition such as a **malfunctioning signals or barriers**, do not cross the tracks, secure your vehicle at a safe location before the tracks, activate your hazard lights and immediately inform the [OC Transpo] Control Centre.

Tracks on Fallowfield Road Eastbound

The traffic signals at the intersection of Fallowfield Road eastbound at the rail crossing and the Transitway are uniquely designed, and include the following features:

1. […] There are two sets of traffic signals that are coordinated with the level crossing.
2. The traffic signals are in addition to the standard features of this type of active level crossing (flashing lights, bells, and gates):
   - Traffic signal A is before the rail tracks.
   - Traffic signal B is at the intersection with the Transitway.

During a Transitway crossing, Traffic Signal A will turn red prior to Traffic Signal B. This ensures that vehicles have enough time to clear both intersections.

During a railway crossing, Traffic Signal A will turn red while Traffic Signal B will remain green for at least 34 seconds longer, prior to turning amber then red.

This ensures that traffic that has passed the railway line can clear the intersection completely.

> **Note:** Traffic Signal B is slightly angled downward. This limits visibility of that signal until drivers have past [*sic*] Traffic Signal A.

- The City has created and staffed the position of Chief Safety Officer, who will be responsible for providing leadership and strategic direction to the Transit Safety, Compliance, Training, and Emergency Management Branch, as well as the department-wide safety management system. The Chief Safety Officer will also be responsible for regulatory compliance for all modes of transportation (bus, Para Transpo, diesel and electric rail) as well as departmental training activities, health and safety, annual rail auditing, environmental auditing, and emergency preparedness.
- In 2014, OC Transpo established a formal program with the objective of enhancing the City's Commercial Vehicle Operators Registration (CVOR) rating with respect to vehicle collisions, convictions and inspections. The program focussed on OC Transpo's safety culture and collision prevention, improving and standardizing collision response process, on-scene data collection, investigations, collision-prevention training and performance management. As a result of this program, the following has occurred:
  - The use of Riskmaster was expanded to include the collection of collision data, investigation tracking documentation, trend analysis for transit training and performance management.
  - Documentation for post-collision interviews, investigations and skills-based training was improved.
  - Reporting and trend analysis was improved to support the continued development of training content and safety awareness campaigns.
- OC Transpo completed an ergonomic assessment and changed the location of the radio handset on the ADL E500 in consultation with its Health and Safety Committee.

4.1.7 Additional measures taken by VIA Rail Canada Inc.

VIA instructed its maintenance-of-way contractor, RailTerm, to synchronize the Woodroffe Avenue, Transitway, and Fallowfield Road crossing signal logs.

VIA initiated the process, and is developing an engineering plan, to have the City AAWS, which was installed in advance of the Transitway crossing, interconnected with the crossing signal. With this modification, the AAWS lights would begin to flash once the Transitway crossing AWDs were activated by an approaching train and would shut off once the AWDs were deactivated. However, the City has not yet made a decision whether or not to modify the existing AAWS, which flashes continually and is not interconnected with the crossing signal.

Following an increase in the reporting of fail-safe activations of 6 crossings equipped with AWDs in the Barrhaven area, VIA implemented enhancements and corrective actions to augment the performance of the AWD protection.

4.1.8 Employment and Skills Development Canada

Pursuant to the *Canada Labour Code,* Part II, Employment and Skills Development Canada (ESDC) – Labour Program conducted a concurrent investigation related to workplace health and safety.

On 19 November 2013, ESDC issued a *Direction to the Employer under Subsection 145(1)* of the *Canada Labour Code,* Part II, indicating that some provisions of the *Canada Labour Code,* Part II, had been contravened.

The ESDC direction indicated that the employer did not identify and assess the hazards including ergonomic-related hazards at all railway crossings where its bus operators are required to work. OC Transpo was directed to terminate the contravention and to take steps to ensure that the contravention does not continue or recur.

On 14 February 2014, OC Transpo responded to the ESDC direction that it will continue its work through the Workplace Health and Safety Committee and Policy Health and Safety Committee to review and update the Transit Services' Hazard Prevention Program. To assist with this process, OC Transpo contracted safety engineering consultants from MMM to assess ergonomic considerations for transit operators at railway crossings in conjunction with current OC Transpo operating procedures and to define assessment methods that can be used consistently in the future. ESDC will continue to monitor progress with respect to the hazards identified during its investigation.

4.2 Safety action required

The issue of railway crossing safety remains on the TSB *Watchlist*. Despite more recent (2010 to 2015) improvements in crossing safety made in the busy Québec–Windsor corridor, the number of level crossing accidents in the rest of Canada had not decreased substantially over the past 10 years (i.e. 2004 to 2013). During this period, there were 1865 train-vehicle crossing collisions, with 165 fatalities and 271 serious injuries outside the corridor. Consequently, the Board concluded that the risk of trains and vehicles colliding at crossings remains too high.

Warning signs at both public and private crossings are the first line of defence to help reduce risk, by making drivers aware of railway crossings. Approximately one-third of public crossings in Canada have automatic warning device (AWD) protection, which includes either flashing lights and bells or flashing lights, bells and gates. In this accident, even though the crossing lights, bells and gates were activated, a professional bus driver did not stop the bus as required and struck a train as the train entered the crossing, resulting in 6 fatalities, 9 serious injuries and about 25 reported minor injuries.

This investigation has identified numerous factors that either caused or contributed to this crossing accident, or increased the risk of such accidents. Despite the presence of AWDs, serious collisions between vehicles and trains continue to occur at railway crossings, for various reasons. This suggests that more needs to be done to reduce the risk to the travelling public.

4.2.1 Distracted driving guidelines

All Alexander Dennis Limited (ADL) double-decker buses are equipped with a video monitor that provides the driver with interior views and exterior views of the bus. Within the driver workstation, the video monitor is located on the left side of a forward panel above the driver seat. The video monitor measures 6 inches (15.2 cm) wide by 3¾ inches 9.5 cm) high. The monitor is divided into 4 quadrants, each measuring 3 inches (7.6 cm) wide by 1⅞ inches (5 cm) high. Each quadrant shows a view from 1 of 4 on-board video cameras and the 4 views are continuously displayed. The location and angle of the video monitor are not adjustable and the driver is not able to turn the display off or change the camera views. The location of the video monitor creates a significant upward viewing angle for the driver (i.e. 30 to 40 degrees from the horizontal). The screen's position, far away (22 inches or 56 cm) from the driver seat, makes the image appear very small to the driver.

At station stops and while in service, OC Transpo drivers were required to view the monitor to ensure that upper deck passengers were seated. If passengers were seen to be standing on the upper deck, drivers were required to make an announcement to inform the passengers that standing was not permitted on the upper deck or in the stairwell. However, to find available seating after boarding a double-decker bus, some passengers would remain moving or standing on the upper deck after the bus was in motion. OC Transpo administrative procedures indicate that drivers should not stare at the video monitor while the bus is in motion even though the video display remains active. But, it is human nature for a driver to periodically glance at the screen while the bus is in motion to monitor the small image displaying the upper level.

In this occurrence, there were 2 types of driver distraction that likely contributed to the accident:

- Visual distraction arising from the use of the in-vehicle video monitor;
- Cognitive distraction arising from
  - a requirement to monitor the upper deck for standing passengers even when the bus was in motion;
  - a conversation between the driver and a passenger about seating availability prior to the bus departing from the OC Transpo Fallowfield Station; and
  - conversations regarding available seating on the upper deck among lower deck passengers who were near the driver following departure from the OC Transpo Fallowfield Station.

Following the accident, the City engaged expert traffic safety engineering and ergonomic consultants from MMM Group Limited (MMM) and their subcontractor Human Factors North (HFN) to review driver workload and other ergonomic aspects of OC Transpo bus operations. Subsequently, HFN recommended that

- the video monitor within the driver's station of all OC Transpo ADL E500 buses be reconfigured to display only the interior view of the upper deck of the bus at all times;

- the video monitor within the driver workstation be relocated to the left of the large rear-view mirror located to the right of the driver.

While these changes may improve monitoring of the video display, there would still be an upward viewing angle to the right of the driver and the potential for distraction would still exist as the single image of the upper deck is constantly displayed even when the bus is in forward motion. Furthermore, since these suggested changes only apply to OC Transpo buses, other transit authorities that operate ADL double-decker buses would then have different configurations of the video monitor, which could present other risks for distraction.

All provinces have some form of distracted driving legislation in place. With the rapid development of technology and in-vehicle displays, distracted driving is an emerging safety issue. For example, the Ontario Provincial Police (OPP) notes that distracted driving is the number one killer on roads, and statistics show that more people in Ontario died in distracted driving-related crashes in 2013 than in any other type of crash.[166]

At the time of the accident, the location of the video monitor on OC Transpo's ADL E500 buses and OC Transpo's use of the video monitor within the driver station were not consistent with driver distraction guidelines published by the American Public Transportation Association (APTA) in 2009 and the United States Department of Transportation (DOT) National Highway Traffic Safety Administration (NHTSA) in 2013. These guidelines were based on the fundamental principle that a driver's eyes should be looking at the road ahead rather than at an in-vehicle device. In particular, the NHTSA guidelines encouraged automakers to forego in-vehicle systems that require the manual input of data while a vehicle is in motion, or that require unreasonably long glances away from the forward visual scene. The NHTSA guidelines recommended

- disabling certain in-vehicle system operations unless the vehicle is stopped and in "PARK";
- locking out video displays and making them inaccessible to the driver while driving; and
- positioning any active displays as close as practicable to the driver's forward line of sight, with a maximum viewing angle of 30 degrees downward from horizontal.

Many jurisdictions, including the Province of Ontario, also have laws in place to limit the potential for driver distraction. However, for the OC Transpo double-decker bus, the video monitor was deemed to be necessary for the safe operation of the bus and was therefore exempt from the *Ontario Highway Traffic Act* (OHTA) restricting the use of display screens.

In Canada and the United States, the federal government is responsible for establishing, maintaining and enforcing minimum motor vehicle safety standards. The placement of in-vehicle displays, which are included as original equipment by the manufacturer, would fall

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166 CBCnews (on line), *OPP calls distracted driving 'number one killer on roads'*, March 2014, available at: http://www.cbc.ca/news/canada/kitchener-waterloo/opp-calls-distracted-driving-number-one-killer-on-roads-1.2557892 (last accessed 28 September 2015).

under the *Canada Motor Vehicle Safety Standards* (CMVSS) in Canada and the *Federal Motor Vehicle Safety Standards* (FMVSS) in the United States. Vehicle / driver licensing and enforcement falls under provincial and state jurisdiction, respectively. Vehicles must therefore meet the federal safety standards in addition to any provincial or state requirements for a province or state to license the vehicles. Activities related to distracted driving fall under provincial or state jurisdiction and as such can vary between provinces and / or states.

The United States has recognized the importance of federal guidelines to provide a consistent framework to assist the federally regulated industry as well as state regulators in addressing the emerging issues related to distracted driving. When all is considered, there is no similar or consistent guidance with regards to the installation and use of video monitors in motor vehicles operated in Canada.

Despite jurisdictional issues, it is important for Transport Canada (TC) to take a leadership role and develop a framework that provides consistent guidance to both the industry and provinces to address the emerging issues related to distracted driving. The Board considers this framework to be an important element in mitigating the associated risks, particularly with regards to railway crossing safety. In order to minimize any potential distraction while driving a vehicle, the Board recommends that

> The Department of Transport, in consultation with the provinces, develop comprehensive guidelines for the installation and use of in-vehicle video monitor displays to reduce the risk of driver distraction.
>
> **TSB Recommendation R15-01**

4.2.2 Bus crashworthiness

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.

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 ADL E500 buses were designed in accordance with, and were fully compliant with, the legislative requirements of the FMVSS 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 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) 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 NHTSA,[167] the NTSB outlined the findings from its special investigation,[168] 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.

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 recommends that

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

4.2.3 Vehicle event data recorders

The ADL double-decker buses were equipped with a video monitor that provides the driver with interior views and exterior views of the bus. However, the system monitoring the video cameras installed on the bus did not have recording enabled, and no video information was recovered from the system.

Each of the rail, air and marine modes of transportation require locomotives and many commercial aircraft and vessels to be equipped with event data recorders (EDRs) that record a number of specified elements. In contrast, the CMVSS contain no requirements for buses

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

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

(including school, transit and inter-city) to be equipped with an on-board crashworthy EDR. While nothing precludes an operator from installing such technology on its fleet, OC Transpo had no such requirement. As a result, the occurrence bus was not equipped with a crashworthy EDR (i.e. black box) to record and store vehicle operation data that occurred prior to and during the accident sequence. Consequently, 8 electronic units that contained non-volatile memory (NVM) were recovered and analysed.

Of the 8 units recovered, only the engine control module (ECM) retained useful data. The ECM is programmed to automatically record a sudden deceleration event when the bus decelerates at greater than 9.0 mph / s (14.5 km / h / s). Had the bus decelerated at less than 9.0 mph / s (14.5 km / h / s), the ECM would have contained no data at all. While, in this case, the recovered ECM data were useful, when compared to locomotive event recorder (LER) data, the ECM data lacked sufficient detail to conduct a meaningful analysis. Specifically,

- there was no meaningful time stamp;
- no distance travelled was recorded;
- the recorded time interval of 1 second was not sufficient for detailed analysis;
- the operation of the anti-lock brake system and emergency brake was not identified;
- the ECM data indicated that the brakes had been applied, but no other meaningful braking information was recorded; and
- there was no brake line air pressure recorded to determine the amount of force applied to the brakes.

Consequently, a detailed braking analysis had to be performed to determine event timing, braking distance and amount of braking force applied by the bus during the accident. The complexity of this work added a number of months to the investigation process. In comparison, comprehensive data from the LER were available for review the next day. The LER data clearly identified the operating parameters of the train and actions of the train crew, which permitted investigators to make informed decisions as to the direction of the investigation and turn their attention to the condition and operation of the bus.

In the United States, the NTSB has recommended EDRs for buses since 1999. While progress has been made, the use of EDRs remains voluntary for roadway vehicles, and the NTSB has classified the related safety recommendations as “Open—Unacceptable Response” because the NHTSA has not required the use of EDRs on buses.

Through years of experience with EDRs in the air, rail and marine modes of transportation, the TSB, the NTSB and the transportation industry have learned a great deal about the effective use of recording technology. Establishing industry standards for recording in these modes has been critical to effective implementation of EDRs by ensuring consistency in the recorded data in standardized formats.

Railway companies routinely use LER data in conjunction with operator (driver) proficiency testing to identify potential areas of improvement within the context of a railway company’s safety management system (SMS).

EDRs have been commonly used by over 100 United States jurisdictions to manage school bus fleets. Studies have determined that, when integrated into a company's safety program, the review of EDR data has led to operational safety improvements for vehicle fleets. A sampling and review of EDR data can identify emerging driver trends, and modifications to company training and / or employee mentoring can be made to improve safety accordingly. Such reviews can also be used to identify and reinforce positive and safe driver behaviour. This demonstrates that EDR information can be used in a non-punitive way as a tool for monitoring driver behaviour and performance in conjunction with a transportation company's safety program that can further reduce risk and improve safety before an accident occurs.

Although accidents involving transit buses at level crossings are rare, they are considered to be high-risk events due to the number of passengers transported in each bus and the potential for injury to the travelling public. When these accidents occur, it is imperative that all investigators have access to real-time recorded data that are consistent and meaningful to quickly identify safety deficiencies and prevent recurrence. Understanding driver behaviour and identifying the related human factors are critical to understanding why accidents happen.

All safety, regulatory, law enforcement and company accident investigations benefit from the efficient, timely and accurate collection, assimilation and analysis of available information. In many cases, EDRs provide and validate much of this valuable information. Early recovery of the information can also result in more timely communication of safety deficiencies and accident reports to industry, regulators and the public, which in turn can result in the implementation of measures to prevent a recurrence. Considering that today's vehicles are capable of supporting crashworthy technology that has the capacity to record safety-critical information that enables safety improvements as well as comprehensive and timely accident investigation, the Board recommends that

> The Department of Transport require commercial passenger buses to be equipped with dedicated, crashworthy, event data recorders.
>
> **TSB Recommendation R15-03**

4.2.4 Grade separation guidelines

Woodroffe Avenue and Fallowfield Road are major arterial roads that service the area and, along with the Transitway, cross railway tracks used daily by numerous VIA passenger and some freight trains. The VIA Fallowfield Station (Mile 3.57) is located between the Woodroffe Avenue / Transitway and the Fallowfield Road level crossings (Mile 3.28 / 3.30 and 3.88 respectively) and adjacent to the OC Transpo Fallowfield bus station. Each of the crossings is equipped with AWDs, which include flashing lights, bells, gates and constant warning time track circuits. The railway signalling system throughout this area is complex with a number of additional built-in safety features.

While the signalling system was generally reliable, with the additional features and programming, additional potential points of failure were introduced. During the course of this investigation, the TSB reviewed a number of other OC Transpo bus incidents at these crossings, as well as a number of reported trouble calls concerning the AWDs.

When one or more components or systems fail, the crossing protection enters the fail-safe mode and remains activated. While this is a designed safety feature, such repeated activations are categorized as nuisance operations that can impose significant delays to roadway users and erode public confidence in the system.

With recent improvement in technology, additional crossing warning systems may be available, including the following:

- Talking GPS systems have become quite advanced and can be programmed to alert drivers to an upcoming crossing and the need to slow down approaching the crossing.
- Other train detection technologies (e.g., GPS, radar, wheel sensors based on magnetic flux) can be used to provide low-cost active warning sign alternatives.
- Collision avoidance technologies for the automobile industry, which include blind spot detection, vehicle spacing, speed control and automated emergency braking, have been developed and / or implemented.

However, these technologies and applications do not specifically include systems for detecting and automatically responding to a potential collision with a train approaching from the side. While these technologies may be helpful, they may also increase driver workload, especially when approaching and traversing a crossing.

Ultimately, the safety of a crossing is dependent on a roadway vehicle driver making appropriate decisions based on the information displayed and responding appropriately to any additional warnings. Consequently, the only way to ensure that similar accidents do not occur at such high-traffic locations is to physically separate the roadway from the railway though grade separation.

Cross-product has always been one of the primary criteria used to assist in identifying potential grade separation projects. Historically, a cross-product (number of trains X number of vehicles per day) of 200 000 was the accepted threshold used by TC and industry for considering grade separation. However, there was no indication of when, why or how the 200 000 threshold was established and no research to support it.

The new *Grade Crossings Standards* identify cross-product thresholds at which AWD protection is required. Part C, Section 9, outlines warning systems specification and states in part:

> 9.1 The specifications for a public grade crossing at which a warning system without gates is required are as follows:
>
> a) where the forecast cross-product is 2,000 or more
>
> […]
>
> 9.2 Specifications for a public grade crossing at which a warning system with gates is required are as follows:

> 9.2.1 a warning system is required under article 9.1 and;
>
> (a) the forecast cross-product is 50,000 or more.

While TC does regulate as to when a crossing at-grade is not permitted, there is no requirement outlining when a grade separation should be considered. In Canada, there are no guidelines and no specific cross-product value at which grade separation should be built. In comparison, the United States Department of Transportation (DOT) Federal Highway Administration (FHA) *Railroad-Highway Grade Crossing Handbook* (2007) provides specific guidance as to when grade separation should be considered. Chapter V, Part A, Section 6, Grade Separation, states in part:

> […]
>
> b. Highway-rail grade crossings should be considered for grade separation across the railroad right-of-way whenever the cost of grade separation can be economically justified based on fully allocated life-cycle costs and one or more of the following conditions exist:
>
> […]
>
> viii. Crossing exposure (the product of the number of trains per day and AADT [average annual daily traffic]) exceeds 500,000 in urban areas or 125,000 in rural areas; or
>
> ix. Passenger train crossing exposure (the product of the number of passenger trains per day and AADT) exceeds 400,000 in urban areas or 100,000 in rural areas.

Considering the 2013 train and traffic volume cross-product values of Woodroffe Avenue (699 108) and Fallowfield Road (406 592), both roads met the United States FHA cross-product criteria for grade separation. If occupant cross-product is also considered, the Transitway (532 703) would also meet the FHA cross-product criteria.

It is recognized that federal guidelines are generally not enforceable, particularly in other jurisdictions. However, the Board considers that guidance similar to that contained in the United States DOT FHA *Railroad-Highway Grade Crossing Handbook* would be a useful framework that provides consistent guidance on issues related to grade separation for the industry as well as federal, provincial and municipal road authorities. Since Canada has no such guidelines for grade separation, the Board recommends that

> The Department of Transport provide specific guidance as to when grade separation should be considered.
>
> **TSB Recommendation R15-04**

4.2.5 Grade separation of Woodroffe Avenue, the Transitway, and Fallowfield Road

Originally, grade separations had been planned for Woodroffe Avenue, the Transitway, and Fallowfield Road. The plans were based on environmental assessments (EAs) conducted in the late 1990s. At that time, members of the public were opposed to any roadway overpass structure, and the National Capital Commission (NCC) supported the public position. Consequently, overpass options were not considered as part of the EAs. The original plan then focused on the preferred option of open-cut roadway underpass grade separations for each location. However, by February 2003, subsurface testing had determined that the conditions were not suitable for the construction of underpasses. Due to unexpected subsurface conditions, the estimated cost to construct the open-cut roadway underpasses increased from 40 million dollars to more than 100 million dollars. Noting that this option also presented significant risks, the underpass alternatives were not pursued.

Roadway overpass alternatives were then reconsidered. Although the soils in the area were determined to have limited load-bearing capacity, it was noted that roadway overpass structures could have been built using light approach fills and multiple bridge spans. However, construction of any of the roadway overpass options would have required reopening the EAs that had been previously undertaken. The time required to redo the EAs would further delay completion of the project beyond the time constraints imposed through Millennium funding (end of March 2006). This would have resulted in the loss the Millennium funding, which accounted for approximately 70% of the original estimated project cost.

While it was possible to construct roadway overpass grade separations for Woodroffe Avenue, the Transitway, and Fallowfield Road, the need to reopen the EAs, the possible loss of Millennium funding and the clear preference for the roadway underpass alternative demonstrated by both the public and the NCC limited the grade separation options considered in 2004. Once the preferred option of open-cut roadway underpasses was no longer available, it was decided in 2004 to forego grade separations and install the level crossings with enhanced AWD protection. This decision was based on the following considerations:

1. Population for the south end of Ottawa was approximately 100 000.
2. There were only 10 trains per day.
3. The train / vehicle cross-products were less than the 200 000 commonly used as a threshold for grade separation to be considered for both Woodroffe Avenue and Fallowfield Road. Furthermore, the Transitway had not yet been constructed.
4. All passenger trains were stopped at the VIA Fallowfield Station.
5. All trains were restricted to 20 mph over both the crossings.

Once the crossings were constructed, the need for grade separation at Woodroffe Avenue, the Transitway, and Fallowfield Road was not formally reviewed or reconsidered, nor was it required to be.

By 2013, the following changes had occurred:

1. The population for the south end of Ottawa had increased to 145 062 (45% increase) and was projected to grow to 171 000 by 2020.
2. The number of trains had increased to 23 trains per weekday (130% increase). Any future increase in train traffic on this corridor would further increase the risks associated with the crossings.
3. The cross-product had increased to 699 108 (285% increase) for Woodroffe Avenue and 406 592 (116% increase) for Fallowfield Road. Similarly, the Transitway cross-

product had increased from 0 in 2004 to 23 161 in 2013, with a corresponding train / vehicle / occupant cross-product of 532 703.

4. While all VIA passenger trains continued to stop at the VIA Fallowfield Station, some VIA passenger trains were now traversing the crossings at 40 to 60 mph.

Grade separation projects usually involve multiple jurisdictions with funding provided by the railways, the respective road authority and the federal government. The decision to proceed with level crossings was based on known risk factors in 2004. Since that time, changes have occurred in the risk factors such as area population, number of trains, train speed, the number of vehicles, the resulting cross-product and the average number of vehicle occupants. These risk factors will continue to increase with further urban and potential railway development in the area with a commensurate risk that existing level crossing protection may no longer be adequate. Therefore, the Board recommends that

> The City of Ottawa reconsider the need for grade separations at the Woodroffe Avenue, Transitway, and Fallowfield Road level crossings.
>
> **TSB Recommendation R15-05**

4.3 Safety concern

4.3.1 Buses stopping at railway crossings

In this accident, the crossing automatic warning devices (AWDs) were activated and properly functioning at the time and the bus drove into the side of the train. Had a requirement been in place for all buses to stop at the Transitway crossing, the risk of a crossing accident may have been reduced. However, there have also been cases where a bus stopped at a protected crossing and then drove into the path of an oncoming train. This demonstrates that crossing accidents can occur whether a bus stops at a crossing or not.

The practice of stopping at all railway crossings is widespread for school buses while OC Transpo buses operating in Ottawa are not required to stop at railway crossings protected with AWDs when the AWDs are not activated. In contrast, transit buses that operate in the Province of Quebec must stop at all railway crossings in accordance with the requirements of the Quebec *Highway Safety Code*. Ultimately, there is no comprehensive study that specifically deals with the risks associated with all buses stopping at all railway crossings. Consequently, school bus transportation companies, as well as transit, municipal and provincial authorities must make their own decisions, and practices vary across the country.

The study most often cited with regards to requirements for stopping at railway crossings is a 30-year-old (1985) United States Department of Transportation (DOT) Federal Highway Administration (FHA) study. The FHA study suggested that not mandating stops at railway crossings protected with AWDs when the AWDs were not activated would result in a net annual decrease in train-involved accidents for all vehicles. However, many of the observations of the study dealt with tractor–trailers hauling hazardous materials that have different characteristics and require a longer period of time to negotiate a crossing than modern transit and school buses. In addition, since the study was conducted, vehicle technology and efficiency has greatly improved.

Following the accident involving the OC Transpo bus, the City commissioned a study to review the advantages and disadvantages of buses stopping at all railway crossings. The study attempted to answer specific questions posed by the City and provide a framework for future reference. However, the study was not comprehensive enough to draw meaningful conclusions and had several gaps. Specifically, the study

- did not consider the possibility of OC Transpo buses stopping at select crossings protected with AWDs (i.e. the Transitway) when the AWDs are not activated;
- did not identify that only buses, maintenance and emergency vehicles use the Transitway and, if all buses were required to stop at the Transitway crossing, the risk of rear-end collisions as a result of vehicles stopping at the crossing would be reduced;
- did not identify other factors that could affect the ability of a transit bus to safely negotiate a level crossing such as approach gradient, the type and condition of the roadway surface and weather conditions at the time;
- recommended that flashing lights, bells and gates be installed at all railway crossings that are used by OC Transpo buses. Since the accident occurred at a crossing that was already equipped with AWDs that included flashing lights, bells and gates and constant warning time track circuits, the recommendation would have not prevented this accident.

Moreover, none of the studies referenced identified or estimated how many times a crossing accident was prevented by a bus stopping at a crossing.

It is recognized that requirements for a bus to stop at a railway crossing falls under provincial, municipal, and in some cases, transportation company jurisdiction. However, the studies used to support decision making made on this issue are out of date, incomplete and limited in scope. The absence of good guidance can lead to ill-advised or misinformed decisions that could in turn result in wasted investments that do not effectively mitigate the safety risks and that give people a false level of confidence in the safety of particular practices. Under these circumstances, more up-to-date guidance, based on research and science, would be useful for all jurisdictions. The Board is concerned that, given there is no recent comprehensive study that specifically deals with the risks associated with all buses stopping at all railway crossings, decision makers may not make the best choices possible to ensure an adequate level of safety.

This report concludes the Transportation Safety Board's investigation into this occurrence. The Board authorized the release of this report on 10 November 2015. It was officially released on 2 December 2015.

Visit the Transportation Safety Board's website (www.tsb.gc.ca) for information about the TSB and its products and services. You will also find the Watchlist, which identifies the transportation safety *issues that pose the greatest risk to Canadians. In each case, the TSB has found that actions taken to date are inadequate, and that industry and regulators need to take additional concrete measures to eliminate the risks.*

Appendices

Appendix A – VIA locomotive event recorder data

Time	Cali Mile	Speed (mph)	BP (psi)	BC (psi)	EOT (psi)	Throttle position	DB	Horn	Bell	Emer brake	AB Hdl	Events/ Comments
0831:57	0.149	0	100	1	100	1	OFF	OFF	ON	no	Rel	Departure Mile 0.149
0832:14	0.156	2	100	0	100	2	OFF	OFF	ON	no	Rel	Thtl 2
0832:25	0.172	6	100	0	100	1	OFF	OFF	ON	no	Rel	
0832:44	0.216	9	100	0	100	Idle	OFF	OFF	ON	no	Rel	Idle/cruise
0833:06	0.273	9	100	0	100	1	OFF	OFF	OFF	no	Rel	Thtl 1
0833:30	0.336	9	100	0	100	Idle	OFF	OFF	OFF	no	Rel	Idle/cruise
0833:31	0.339	10	100	0	100	Idle	OFF	OFF	OFF	no	Rel	
0833:45	0.378	9	100	0	100	1	OFF	OFF	OFF	no	Rel	Thtl 1/cruise
0834:46	0.569	12	100	0	100	2	OFF	OFF	OFF	no	Rel	Thtl/speed increase
0834:57	0.611	13	100	0	100	3	OFF	OFF	OFF	no	Rel	Thtl 3
0835:39	0.876	29	100	0	100	2	OFF	OFF	OFF	no	Rel	Thtl decrease
0835:45	0.925	29	100	0	100	Idle	OFF	OFF	OFF	no	Min	Min/Service brake
0835:53	0.987	26	93	14	100	Idle	ON	OFF	OFF	no	Min	DB for 2 seconds
0836:04	1.063	22	90	0	100	Idle	OFF	OFF	OFF	no	Rel	Air brake released
0836:09	1.093	21	100	0	100	1	OFF	OFF	OFF	no	Rel	Thtl increase
0836:18	1.148	21	100	0	100	2	OFF	OFF	OFF	no	Rel	
0836:34	1.249	22	100	0	100	3	OFF	OFF	OFF	no	Rel	
0837:23	1.620	30	100	0	100	2	OFF	OFF	OFF	no	Rel	
0837:35	1.723	30	100	0	100	3	OFF	OFF	OFF	no	Rel	
0837:49	1.846	32	100	0	100	3	OFF	OFF	ON	no	Rel	Thtl release from 3
0837:50	1.855	32	100	0	100	2	OFF	OFF	ON	no	Rel	
0837:51	1.864	32	100	0	100	Idle	OFF	OFF	ON	no	Rel	Idle/cruise
0838:07	2.002	29	100	0	100	1	OFF	OFF	ON	no	Rel	Thtl increase
0838:15	2.064	27	100	0	100	2	OFF	OFF	ON	no	Rel	
0838:36	2.228	28	100	0	100	3	OFF	OFF	OFF	no	Rel	
0838:46	2.313	32	100	0	100	4	OFF	OFF	OFF	no	Rel	
0839:04	2.492	37	100	0	100	4	OFF	OFF	OFF	no	Rel	Thtl decrease from 4
0840:04	3.180	40	92	1	100	Idle	OFF	OFF	OFF	no	Min	Min brake
0840:09	3.234	38	93	11	100	Idle	ON	OFF	OFF	no	Min	DB ON
0840:30	3.430	29	98	0	100	Idle	OFF	OFF	ON	no	Rel	BC 0 / DB OFF

Time	Cali Mile	Speed (mph)	BP (psi)	BC (psi)	EOT (psi)	Throttle position	DB	Horn	Bell	Emer brake	AB Hdl	Events/ Comments
0840:37	3.486	28	100	0	100	2	OFF	OFF	ON	no	Rel	Thtl increase
0840:48	3.573	28	100	0	100	4	OFF	OFF	OFF	no	Rel	
0841:05	3.711	30	100	0	100	5	OFF	OFF	OFF	no	Rel	
0841:35	4.015	41	100	0	100	4	OFF	OFF	OFF	no	Rel	Thtl decrease
0841:57	4.278	44	100	0	100	3	OFF	OFF	OFF	no	Rel	
0841:59	4.302	43	100	0	100	2	OFF	OFF	OFF	no	Rel	
0842:00	4.315	43	100	0	100	1	OFF	OFF	OFF	no	Rel	Thtl 1/cruise
0842:23	4.586	41	100	0	100	2	OFF	OFF	OFF	no	Rel	
0842:25	4.609	41	100	0	100	3	OFF	OFF	OFF	no	Rel	
0842:44	4.824	40	100	0	100	1	OFF	OFF	OFF	no	Rel	
0843:04	5.044	38	100	0	100	2	OFF	OFF	OFF	no	Rel	
0843:07	5.076	38	100	0	100	3	OFF	OFF	OFF	no	Rel	
0843:28	5.302	39	100	0	100	1	OFF	OFF	OFF	no	Rel	
0843:29	5.313	40	100	0	100	2	OFF	OFF	OFF	no	Rel	
0843:38	5.412	39	100	0	100	Idle	OFF	OFF	OFF	no	Rel	
0843:41	5.445	39	100	0	100	Idle	OFF	OFF	OFF	no	Serv	Service brake
0843:46	5.499	39	92	15	100	Idle	ON	OFF	OFF	no	Serv	DB ON
0844:11	5.713	23	99	0	100	Idle	OFF	OFF	OFF	no	Rel	BC 0 / DB OFF
0844:14	5.732	23	100	0	100	2	OFF	OFF	OFF	no	Rel	Thtl increase
0844:18	5.758	23	100	0	100	3	OFF	OFF	OFF	no	Rel	
0844:34	5.865	25	100	0	100	2	OFF	OFF	OFF	no	Rel	
0844:43	5.932	26	100	0	100	3	OFF	OFF	OFF	no	Rel	
0844:49	0.006	27	100	0	100	4	OFF	OFF	OFF	no	Rel	Mile 5.97 / Mile 0.0
0845:00	0.096	29	100	0	100	5	OFF	OFF	OFF	no	Rel	
0845:16	0.247	36	100	0	100	6	OFF	OFF	OFF	no	Rel	
0845:42	0.567	50	100	0	100	7	OFF	OFF	OFF	no	Rel	
0846:51	1.850	80	100	0	100	7	OFF	OFF	OFF	no	Rel	Thtl reduce from 7
0846:55	1.939	80	100	0	100	5	OFF	OFF	OFF	no	Rel	
0846:56	1.962	82	100	0	100	5	OFF	OFF	OFF	no	Rel	
0846:57	1.985	81	100	0	100	3	OFF	OFF	OFF	no	Rel	
0847:01	2.076	81	100	0	100	2	OFF	OFF	OFF	no	Rel	
0847:04	2.144	82	100	0	100	1	OFF	OFF	OFF	no	Rel	
0847:05	2.167	82	100	0	100	Idle	OFF	OFF	OFF	no	Rel	Highest speed: 82
0847:06	2.190	81	100	0	100	Idle	OFF	OFF	OFF	no	Min	Service brake
0847:13	2.347	80	93	14	100	Idle	ON	OFF	OFF	no	Serv	DB ON / BC 14

Time	Cali Mile	Speed (mph)	BP (psi)	BC (psi)	EOT (psi)	Throttle position	DB	Horn	Bell	Emer brake	AB Hdl	Events/ Comments
0847:22	2.540	75	93	6	100	Idle	ON	OFF	OFF	no	Serv	DB ON / BC 6 cruise slow down
0848:04	3.275	47	78	6	100	Idle	ON	OFF	ON	EIE	Emer	EIE initiation and bell ON / BC 6
0848:05	3.288	46	31	6	100	Idle	ON	OFF	ON	EIE	Emer	Last record before collision / speed: 46
0848:06	3.300	43	1	13	100	Idle	ON	OFF	ON	EIE	Emer	Collision and power off / speed: 43

Appendix B – VIA trains per day over crossings

Trains over Woodroffe–Transitway crossing								Trains over Fallowfield Road crossing							
Train	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Train	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.
30	1	1	1	1	1			30							
32	2	2	2	2	2			32							
37	2	2	2	2	2			37							
39	2	2	2	2				39							
40	1				1	1	1	40	1				1	1	1
41	1	1	1	1	1			41	1	1	1	1	1		
42	1	1	1	1	1			42	1	1	1	1	1		
43	1	1	1	1	1			43	1	1	1	1	1		
44	1	1	1	1	1	1	1	44	1	1	1	1	1	1	1
45	1				1	1	1	45	1				1	1	1
46	1	1	1	1	1		1	46	1	1	1	1	1		1
47	1	1	1	1	1	1	1	47	1	1	1	1	1	1	1
48	1	1	1	1	1	1		48	1	1	1	1	1	1	
50	1	1	1	1	1	1		50	1	1	1	1	1	1	
51	1	1	1	1	1			51	1	1	1	1	1		
52	1	1	1	1	1	1	1	52	1	1	1	1	1	1	1
55	1	1	1	1	1		1	55	1	1	1	1	1		1
56	1	1	1	1			1	56	1	1	1	1			1
57	1	1	1	1	1		1	57	1	1	1	1	1		1
59	1	1	1	1	1	1	1	59	1	1	1	1	1	1	1
641						1		641						1	
643						1	1	643						1	1
646					1			646					1		
648							1	648							1
Freight		2				2		Freight		2				2	
Total	23	23	21	21	21	12	12	Total	16	16	14	14	16	12	12

Appendix C – Distances referenced in Figure 7 (TSB re-enactment)

Position	Description	Distance from stop sign (feet)	Distance from stop sign (metres)	Distance from intersection (metres)
0	Stop sign (origin)	0	0.000	0.000
1	Stop line across Transitway	81	24.689	12.344
2		812 (748 feet from crossing)	247.498 (228 m from crossing)	235.153
3		866 (694 feet from crossing)	263.957 (211.5 m from crossing)	251.612
4		1158 (402 feet from crossing)	352.958 (122.5 m from crossing)	340.614
5	Bumper (front)	1547	471.526	459.181
6	Crossing stop line 1	1555	473.964	461.620
7	Crossing gate 1	1560	475.488	463.144
8	Centre of track	1577	480.670	468.325
9	Crossing gate 2	1593	485.546	473.202
10	Crossing stop line 2	1598	487.070	474.726
11	Speed sign (90 km/h begins)	2462	750.418	738.073
12	Speed sign (90 km/h)	3278	999.134	986.790

Appendix D – Canada Motor Vehicle Safety Standards*: applicable crashworthiness standards*

CMVSS	Standard Title	Application	Description	Tests
201	Occupant Protection	Passenger cars, multi-purpose passenger vehicles, trucks and buses with a GVWR of 4536 kg or less.	Sets requirements for various interior components that an occupant's head could contact during a collision. Components covered within the standard include the instrument panel, arm rests and sun visors for front occupants and seat backs for rear occupants.	The area determined to be contactable in a collision must be constructed so that a headform's deceleration during an impact of 24 km/h (19.3 km/h if an airbag is present) does not exceed 80 g continuously for more than 3 ms.
203	Driver Impact Protection and Steering Control System	All vehicles.	The steering system must be designed so that no component or attachment is capable of catching the driver's clothing or jewelry during normal driving manoeuvres.	No specific test criteria.
		Passenger cars and three-wheeled vehicle and every multi-purpose passenger vehicle, bus and truck — other than a walk-in van — with a GVWR of 4536 kg or less.	Test to ensure that the forces transferred to the body by the steering system in an impact are not excessive.	The system shall be impacted by a body block at a relative velocity of 24 km/h. The force on the body block shall not exceed 11 120 N. ** A vehicle meeting the crash test requirements of CMVSS 208 does not need to perform this test.
204	Steering Column Rearward Displacement	Passenger cars and three-wheeled vehicle and every multi-purpose passenger vehicle, bus and truck, other than a walk-in van, with a GVWR of 4536 kg or less.	Test to ensure the steering column does not move rearward excessively into the driver in a collision.	Vehicle is impacted into a fixed barrier at 48 km/h. The steering column and shaft in the vehicle shall not be displaced more than 127 mm in a horizontal rearward direction. ** A vehicle meeting the crash test requirements of CMVSS 208 does not need to perform this test.

208	Occupant Protection in Frontal Impacts	1. Seat belt requirements for all vehicles (seat belt strength requirements are part of CMVSS 209 and the installation requirements are part of CMVSS 210). 2. Frontal crash testing requirements for passenger cars, trucks, buses and multi-purpose passenger vehicles (other than a walk-in van), with a GVWR of 3856 kg or less and an unloaded vehicle weight of 2495 kg or less.	1. Seat belt requirements include which designated seating positions must be equipped with seat belts, and which types of seat belts are allowable or required in those locations – i.e. lap-only belt or lap/shoulder belt. 2. Full frontal rigid barrier crash test – Vehicle is crashed into a rigid wall to ensure that the seat belts and air bags provide protection to (dummy) occupants in a collision. 3. Offset deformable barrier – Vehicle is crashed into a barrier with a 40% overlap of the front of the vehicle. The barrier has a deformable face to simulate the slower crush during a vehicle to vehicle collision (as compared to a rigid barrier test). This test is designed to test the proper functioning of the air bag system. 4. Out-of-position requirements – To ensure air bags are not overly aggressive to a short-statured female driver dummy or to various sized child front passenger dummies.	1. Seat belt strength is not tested as part of CMVSS 208. Seat belt webbing strength and the buckle performance is required to meet CMVSS 209 and the seat belt anchors are required to meet CMVSS 210. 2. Full frontal rigid barrier test – Vehicle is impacted into a fixed barrier at 56 km/h. Must not exceed specified performance injury criteria for head, chest, neck and femur. 3. Offset deformable barrier – Vehicle is impacted into a deformable barrier at 40 km/h. Must not exceed specified performance injury criteria for head, chest, neck, femur. 4. Out-of-position component test requirements – Low-risk deployment to ensure the air bag is not overly aggressive for a short-statured adult lying over the steering wheel air bag at the time of a collision; the 5th percentile female dummy is placed out-of-position on the steering wheel and the air bag is deployed. Low-risk deployment or suppression requirements for children, which is tested using several sizes of child dummies that are placed out-of-position at the time of a test. The air bag must either not deploy or deploy with minimal force, thus no injury should occur for a child.
214	Side Door Strength	Every side door that is designed to be used for the egress of occupants from a truck, multi-purpose passenger vehicle or bus with a GVWR of 4536 kg or less or from a passenger car or three-wheeled vehicle.	A push test on doors of vehicles to reduce the risk of intrusion into the vehicle compartment when the vehicle is in a side-impact collision.	The following resistances, calculated in accordance with Test Method 214, Side Door Strength (14 November 1996), when tested in accordance with those test methods with the seats removed or installed, at the option of the manufacturer: (a) when tested with the seats removed, (i) an initial crush resistance of not less than 10.01 kN, (ii) an intermediate crush resistance of not less than 15.57 kN, and (iii) a peak crush resistance of not less than 2 times the curb mass of the vehicle or 31.14 kN, whichever is the lesser; or (b) when tested with the seats installed, (i) an initial crush resistance of not less than 10.01 kN, (ii) an intermediate crush resistance of not less than 19.46 kN, and (iii) a peak crush resistance of not less than 3.5 times the curb mass of the vehicle or 53.38 kN, whichever is the lesser.

N/A	Side Impact Memorandum of Understanding	Side impact protection applicable to passenger cars, multi-purpose passenger vehicles, trucks and buses with a GVWR of 2722 kg (6000 pounds) or less, except for walk-in vans and certain other special-purpose vehicles.	Written agreement between vehicle manufacturers and Transport Canada to have vehicles meet the side-impact protection requirements of the United States (FMVSS 214), Moving Deformable Barrier, and pole test or United Nations (R95), Moving Deformable Barrier. All tests are to protect occupants in the event of a side-impact collision.	FMVSS 214-1 – 1361 kg moving deformable barrier test: 54 km/h angled at 63 degrees to the impacted vehicle. Must meet the dummy injury criteria of: Front – HIC (36) 1000 (Head Injury Criterion), chest deflection – 44 mm, abdominal force – 2500 N, pelvic force – 6000 N. Rear – HIC (36) 1000, lower spine – 82 g, pelvic force – 5525 N. 2. Pole test: Vehicle impacts a 254 mm pole at 75 degrees at 32 km/h. Must meet the dummy injury criteria of: Male – HIC (36) 1000, chest deflection – 44 mm, abdominal force – 2500 N, pelvic force – 6000 N. Female – HIC (36) 1000, lower spine acceleration – 82 g, pelvic force – 5525 N. R95 – 950 kg moving deformable barrier test 50 km/h at 90 degrees to the impacted vehicle. Must meet the dummy injury criteria of HIC 1000, rib deflection – 42 mm, soft tissue – 1 m/s, abdominal force – 2500 N, pelvic force 6000 N. Transport Canada is in the process of mandating the United States requirements into the Canadian regulations.
N/A	Compatibility Memorandum of Understanding	Passenger cars and light trucks, with a GVWR less than 3856 kg (8500 pounds).	Written agreement between vehicle manufacturers and Transport Canada to have vehicles meet the side-impact protection requirements that are used by the Insurance Institute for Highway Safety (IIHS).	1500 kg moving deformable barrier test: 50 km/h at 90 degrees to the impacted vehicle. Must meet the dummy injury criteria of: HIC (15) 779, no direct head contact with moving deformable barrier.
216	Roof Crush Resistance	Passenger cars, multi-purpose passenger vehicles, trucks and buses, other than school buses, with a GVWR of 2722 kg or less.	Roof strength requirements to limit crush in the roof over the front seat area during rollover crashes.	A 762 mm x 1829 mm test plate is oriented over the roof with its long dimension parallel to a vertical plane, passing through the longitudinal centreline of the vehicle, and tilted forward at a 5-degree angle. Its short dimension is tilted outward on its longitudinal axis at a 25-degree angle so that its outboard side is lower than its inboard side. The initial contact point with the vehicle roof is on the test plate's longitudinal centreline, 254 mm rearward of the front edge. The test plate is pushed downward perpendicular to its surface until a load of 1.5 times the unloaded vehicle weight, or for passenger cars, a maximum force of 22 240 N has been applied. The roof must prevent the test plate from moving downward more than 127 mm (5 inches).

		(Starting 31 August 2016) Same classes of vehicles with a GVWR greater than 2722 kg and up to 4536 kg. Vehicles built in 2 or more stages or that have altered roof lines can meet CMVSS 220 instead of CMVSS 216.		Increased force applied from 1.5 to 3.0 times the GVWR for vehicles lower than 2722 kg; vehicles with a GVWR of between 2722 kg and 4536 kg are tested to 1.5 times the GVWR. Maximum force of 22 240 N removed. Vehicles to be tested on both sides, not just driver's side. No force greater than 222 N is permitted to be applied to a headform located at the head position of a 50th percentile adult male.
220	Rollover Protection	Applies mainly to (all) school buses, but buses described in CMVSS 216 (e.g., pop-up walk-in van conversion type vehicles) can optionally perform CMVSS 220.	Roof strength requirements to limit the possibility of a school bus roof collapsing in a rollover.	A test plate, which is sized based on the size of the roof of the vehicle, is positioned perpendicular to the vertical plane in contact with the roof. The test plate is pushed downward with a force 1.5 times the GVWR. The roof must prevent the test plate from moving downward more than 130 mm and each emergency exit must remain functional.
221	School Bus Body Joint Strength	Applies only to school buses.	Strength requirements for body joints to ensure that the joints, in the occupant space, do not come apart in the event of a collision causing sharp edges to intrude into the occupant space.	Every body panel joint shall be capable of sustaining, without separation, a tensile force that is equal to 60% of the breaking tensile strength within the weakest body panel component attached by the joint when the ASTM Standard Test Methods for Tension Testing of Metallic Materials is performed on test specimens of the joints.
222	School Bus Passenger Seating and Crash Protection	Applies only to school buses.	Compartmentalization requirements whereby occupants are protected by high seat backs, which are padded with energy-absorbent material and spaced closely together.	Forward performance tests are performed by using 2 loading bars to apply a force to the rear of the seat back. No seat component can separate at an attachment point and its deflection must remain within a zone defined by a force/deflection curve. (per the force/deflection curve: maximum deflection – 356 mm, no part may deflect within 100 mm of another seat, minimum energy absorbed 452 W Nm). Rearward performance test is similar but applied in the rearward direction and is performed with only one loading bar (per the force/deflection curve: maximum force – 9876 N, maximum deflection – 250 mm, no part may deflect to within 100 mm of any part of another seat, minimum energy absorbed 316.4 W Nm). The bench seat cushion cannot separate from the seat when an upward force 5 times the weight of the cushion is applied. Surfaces within the defined head protection zone are tested by head form impact (HIC lower than 1000 at 6.7 m/s, contact area of 1935 mm^2 at 1.5 m/s). Surfaces within the defined leg protection zone are impacted by a kneeform (resisting force of impacted material lower than 2669 N and contact area of knee form of 1935 mm^2 at 4.88 m/s).

Definitions

"passenger car" means a vehicle having a designated seating capacity of 10 or less, but does not include an all-terrain vehicle, a competition vehicle, a low-speed vehicle, a multi-purpose passenger vehicle, an antique reproduction vehicle, a motorcycle, a truck, a trailer, a vehicle imported temporarily for special purposes or a three-wheeled vehicle;

"multi-purpose passenger vehicle" means a vehicle having a designated seating capacity of 10 or less that is constructed either on a truck chassis or with special features for occasional off-road operation, but does not include an air cushion vehicle, an all-terrain vehicle, a golf cart, a low-speed vehicle, a passenger car, a three-wheeled vehicle, a truck or a vehicle imported temporarily for special purposes;

"three-wheeled vehicle" means a vehicle, other than a competition vehicle, an antique reproduction vehicle, a motorcycle, a restricted-use motorcycle, a trailer or a vehicle imported temporarily for special purposes, that (a) is designed to travel on three wheels in contact with the ground, (b) has no more than 4 designated seating positions, and (c) has a GVWR of 1000 kg or less;

"truck" means a vehicle designed primarily for the transportation of property or special-purpose equipment, but does not include a competition vehicle, a crawler-mounted vehicle, a three-wheeled vehicle, a trailer, a work vehicle, a vehicle imported temporarily for special purposes, a vehicle designed for operation exclusively off-road or a low-speed vehicle;

"bus" means a vehicle having a designated seating capacity of more than 10, but does not include a trailer or a vehicle imported temporarily for special purposes;

"school bus" means a bus designed or equipped primarily to carry students to and from school;

"walk-in van" means a van type of truck in which a person having a height of 1700 mm can enter the occupant compartment in an upright position by a front door.

Appendix E – Engine control module data

PowerSpec - Sudden deceleration data report

Time (seconds)	Vehicle speed (mph)	Engine speed (rpm)	Engine load (%)	Throttle (%)	Brake status	Clutch status	Cruise status	Lamp status
-39	0	735	60.2	38.9	-	-	-	-
-38	0	942	48.8	42.1	-	-	-	-
-37	2	1079	65.6	81.8	-	-	-	-
-36	4	1404	71.9	88.9	-	-	-	-
-35	7	1760	85.2	89.0	-	-	-	-
-34	9	1855	84.4	89.0	-	-	-	-
-33	11	1801	85.2	89.1	-	-	-	-
-32	13	1854	84.4	88.9	-	-	-	-
-31	15	1849	84.4	89.1	-	-	-	-
-30	17	1575	88.7	89.1	-	-	-	-
-29	19	1329	93.4	89.1	-	-	-	-
-28	20	1398	93.4	89.1	-	-	-	-
-27	22	1495	91.0	89.1	-	-	-	-
-26	23	1438	91.8	89.1	-	-	-	-
-25	24	1152	99.6	89.1	-	-	-	-
-24	25	1208	98.0	89.1	-	-	-	-
-23	26	1254	95.7	89.1	-	-	-	-
-22	27	1306	93.8	89.1	-	-	-	-
-21	28	1354	93.4	89.1	-	-	-	-
-20	30	1401	93.4	89.0	-	-	-	-
-19	30	1444	92.2	89.1	-	-	-	-
-18	31	1484	91.0	89.1	-	-	-	-
-17	32	1513	89.8	89.1	-	-	-	-
-16	33	1156	98.8	89.1	-	-	-	-
-15	34	1184	99.6	89.1	-	-	-	-
-14	35	1206	98.4	89.1	-	-	-	-
-13	35	1234	96.9	89.1	-	-	-	-
-12	36	1256	95.7	89.1	-	-	-	-
-11	37	1275	94.9	89.1	-	-	-	-
-10	37	1307	93.4	89.0	-	-	-	-
-9	38	1323	85.5	83.2	-	-	-	-
-8	39	1345	65.6	68.8	-	-	-	-
-7	39	1359	66.4	69.4	-	-	-	-
-6	40	1373	92.6	88.4	-	-	-	-
-5	40	1397	92.6	88.6	-	-	-	-
-4	41	1422	92.2	88.7	-	-	-	-
-3	41	1444	91.4	88.8	-	-	-	-

Time (seconds)	Vehicle speed (mph)	Engine speed (rpm)	Engine load (%)	Throttle (%)	Brake status	Clutch status	Cruise status	Lamp status
-2	42	1270	94.5	88.6	-	-	-	-
-1	42	1250	0.0	0.0	-	-	-	-
0	35	1004	0.0	0.0	ON	-	-	-
1	25	708	0.0	0.0	ON	-	-	-
2	5	659	20.3	0.0	ON	-	-	-
3	2	285	0.0	0.0	ON	-	-	ON
4	0	51	0.0	0.0	ON	-	-	ON
5	0	0	0.0	0.0	ON	-	-	ON
6	0	0	0.0	0.0	ON	-	-	ON
7	0	0	0.0	0.0	ON	-	-	ON
8	0	0	0.0	0.0	ON	-	-	ON
9	0	0	0.0	0.0	ON	-	-	ON
10	0	0	0.0	0.0	ON	-	-	ON
11	0	0	0.0	0.0	ON	-	-	ON
12	0	0	0.0	0.0	-	-	-	-
13	0	0	0.0	0.0	-	-	-	-
14	0	0	0.0	0.0	-	-	-	-
15	0	0	0.0	0.0	-	-	-	-

Appendix F – Ergonomic Assessment

<table>
<tr><th rowspan="2">Task</th><th colspan="4">Bus type</th></tr>
<tr><th>ADL E500 (42 feet)</th><th>New Flyer Articulated (60 feet)</th><th>Orion VII Hybrid (40 feet)</th><th>New Flyer (40 feet)</th></tr>
<tr><td>Sitting in usual driving position and fastening the seat belt.</td><td>· Can adjust forward-aft seat movement while bus is in motion.
· Backrest is adjustable – can do when bus is in motion.
· Steering tilt can be changed, but only when stationary.
· Steering column extends and retracts – only when bus is stationary (parking brake ON and bus in NEUTRAL gear).
· Steering wheel also adjustable.
· Seat belt required by law (but not always worn by drivers because uncomfortable over long periods).
· Fit is good for forward-aft position.
· Armrests can be adjusted for height. More drivers use right-hand armrest than left-hand one.</td><td>Same as ADL E500.</td><td>Same as ADL E500.</td><td>Same as ADL E500.</td></tr>
<tr><td>Reaching for the ignition switch.</td><td>Push button located on right of steering wheel.</td><td>Button located left of steering wheel.</td><td>Switch located left of steering wheel.</td><td>Button located left of steering wheel.</td></tr>
<tr><td>Depressing the brake pedal from the foot resting on accelerator pedal.</td><td>· Brake and accelerator pedals equal distance apart.
· Metal heel rest provided below pedals.</td><td>Heel rest similar to ADL E500.</td><td>· Bus retards when foot is taken off accelerator.
· Pedals are similar to ADL E500, but no heel rest.</td><td>· Heel rest similar to ADL E500.
· Pedal shape different from ADL E500 and Orion VII Hybrid.</td></tr>
<tr><td>Reaching for the emergency brake control.</td><td>· Lever positioned to left of steering wheel.
· Used for parking.
· Can also be used in the event that the brake pedal does not work (this aspect is different from other OC Transpo buses).
· Can be applied gradually with air.</td><td>Button located on the floor, left of driver.</td><td>Button located left of steering wheel.</td><td>Button located left of steering wheel.</td></tr>
<tr><td>Looking at destination sign screen.</td><td>· Used to enter destination sign information (front of bus).
· Difficult for drivers who wear bifocals to read.
· Centred above driver’s seat.
· The display and controls are not locked out when the bus is in motion.</td><td>· Same as ADL E500.
· Positioned to the right, above driver.</td><td>· Uses older version of destination sign that is different from ADL E500 (does not include video screen).
· Positioned to the right, above driver.</td><td>· Older version – same as Orion VII Hybrid.
· Different from ADL E500 and articulated bus. Centred above driver.</td></tr>
</table>

Looking at the video monitor.	· Offset to left of centre above driver's seat. · Uses quad split screen (top left-hand = top of stairwell looking down; top right-hand = exterior rear of bus; lower left-hand: interior back door; lower right-hand: upper deck interior view from front of bus). · Drivers used to be able to change the locations of each view. · Drivers indicated that they would prefer to have only 3 screens to have a better view. · Drivers cannot adjust or turn the screen off.	N/A	N/A	N/A
Engaging and picking up the bus radio.	· Telephone-like handset positioned to right of steering wheel. · Extra drivers (drivers who are added to an already busy run) might need to be contacted by radio. · Not often used otherwise.	Same handset and location as ADL E500, but with easier access (reach not as low).	Same handset and location as ADL E500, but with easier access (reach not as low).	Same handset and location as ADL E500, but with easier access (reach not as low).
Looking at the transit control head (TCH) display.	· Screen located to right of steering wheel. · Uses GPS to show a map; also shows fare information. · Shows where bus is and/or highlights the route. · Drivers can select display to show either "North" or "Direction of travel" to point upward. · Display screen becomes inactive when bus is travelling exactly 10 mph (16 km/h) (drivers cannot input anything above this speed).	Same as ADL E500.	Same as ADL E500.	Same as ADL E500.

Appendix G – Video monitoring protocols for other transit companies

GO Transit – Toronto, Ontario

GO Transit (GO) uses a slightly different configuration of the ADL E500 bus for its inter-city coach. This configuration has only one entrance door located at the front of the bus opposite the driver. The video monitor is located in the same location as the OC Transpo ADL E500 bus. The video monitor is similarly divided into 4 views to monitor the upper deck, stairwell, rear exterior of the bus and the lower deck in the area of the front door / wheelchair ramp. In addition, the location and angle of the monitor are not adjustable, there is no sound provided, and the driver is not able to turn the display off or change the camera views. However, GO Transit does record the images.

At the time of the accident, other than identifying the monitor and where the cameras were located, there was no other training material available for GO ADL E500 drivers regarding video monitoring procedures. Following the TSB–issued Rail Safety Advisory 10 / 14, *Video monitoring system on OC Transpo double decker buses*, GO developed a new video monitoring policy and a procedure Systems Bulletin (effective 03 October 2014). The new video monitoring procedures include the following guidance:

- Never stare at the video monitor while driving (2 seconds or more).
- Ensure all upper deck passengers are seated before departing from the stop.
- If any passengers are standing on the upper deck or in the stairwell, make a polite announcement asking them to find a seat for their personal safety.

Strathcona County Transit - Edmonton, Alberta

The video monitor is located in the same location as OC Transpo ADL E500 bus, with the same 4 views. Drivers are trained to check the video monitor prior to departing bus stops to ensure stairwells are clear and that all passengers on the upper deck are seated. During the operation of the bus, drivers can glance at the monitor. Drivers are not to change camera views while driving.

In addition to the 4 cameras displayed on the monitor, Strathcona Transit has 8 additional cameras installed, which cannot be viewed on the monitor. Up to 30 days of video is stored on the recorder. Video from all 12 cameras is recorded when the bus is in operation, but the bus driver is not recorded. The video recorder does capture some bus telemetry, which includes location, speed, and status of all indicator lights such as left and right signal, headlights, and brake lights.

Drivers are not provided any specific training material related to monitoring the screen, and there are no company guidelines for drivers indicating how to use the video monitors safely to prevent distraction.

BC Transit – Victoria, British Columbia

All video monitors on BC Transit (Victoria) ADL double-decker buses are located in the same location as the monitors on the OC Transpo bus and the Strathcona County Transit bus. The views on the video monitor's early double-decker series only show the upper deck. The later series (E500) display the upper deck, the stairwell and the side door. No information is recorded. It is only considered critical that the upper deck monitor is functioning. There is no specific training material regarding the use of the video monitors.

A January 2008 notice was circulated to bus drivers concerning the viewing of video monitors on the ADL double-decker buses. The instructions indicated that the video monitors are designed to act as a rear-view mirror for the upper deck so that customer movements can be observed when the bus is approaching and leaving stops in order to prevent on-board incidents. The notice does not prohibit bus drivers from looking at the monitor while the bus is moving, nor does it provide guidance for glancing at the screen.

Appendix H – American Public Transportation Association bus crashworthiness specifications (May 2013)

Technical Specification (TS)	Requirement
TS 23.2 Crashworthiness (Transit Coach)	"The bus body and roof structure shall withstand a static load equal to 150 percent of the curb weight evenly distributed on the roof with no more than a 6 in. reduction in any interior dimension." "The bus shall withstand a 25 mph impact by a 4000 lb automobile at any side, excluding doorways, along either side of the bus and the articulated joint, if applicable, with no more than 3 in. of permanent structural deformation at seated passenger hip height. This impact shall not result in sharp edges or protrusions in the bus interior."
TS 70.1 Location of Bumpers	"Bumpers shall provide impact protection for the front and rear of the bus with the top of the bumper being 27 in., ±2 in., above the ground."
TS 70.2 Front Bumper	"No part of the bus, including the bumper, shall be damaged as a result of a 5 mph impact of the bus at curb weight with a fixed, flat barrier perpendicular to the bus's longitudinal centerline. The bumper shall return to its pre-impact shape within 10 minutes of the impact."
TS 70.2 Front Bumper	"The bumper shall protect the bus from damage as a result of 6.5 mph impacts at any point by the common carriage with contoured impact surface defined in Figure 2 of FMVSS 301 loaded to 4000 lbs parallel to the longitudinal centerline of the bus." "It shall protect the bus from damage as a result of 5.5 mph impacts into the corners at a 30 deg angle to the longitudinal centerline of the bus."
TS 78.13 Passenger Seating Structure and Design (Transit Coach)	"All transverse objects—including seat backs, modesty panels, and longitudinal seats—in front of forward-facing seats shall not impart a compressive load in excess of 1000 lbs onto the femur of passengers ranging in size from a 5th-percentile female to a 95th-percentile male during a 10g deceleration of the bus. This deceleration shall peak at 0.05 to 0.015 seconds from initiation." "Permanent deformation of the seat resulting from two 95th-percentile males striking the seat back during this 10g deceleration shall not exceed 2 in., measured at the aisle side of the seat frame at height H. The seat back should not deflect more than 14 in., measured at the top of the seat back, in a controlled manner to minimize passenger injury. Structural failure of any part of the seat or sidewall shall not introduce a laceration hazard." "The seat assembly shall withstand static vertical forces of 500 lbs applied to the top of the seat cushion in each seating position with less than ¼ in. permanent deformation in the seat or its mountings." "The seat assembly shall withstand static horizontal forces of 500 lbs evenly distributed along the top of the seat back with less than ¼ in. permanent deformation in the seat or its mountings." "The back of each transverse seat shall incorporate a handhold no less than ⅞ in. in diameter for standees and seat access / egress. The handhold shall not be a safety hazard during severe decelerations." "Seat back handhold and armrests shall withstand static horizontal and vertical forces of 250 lbs applied anywhere along their length with less than ¼ in. permanent deformation. Seat back handhold and armrests shall withstand 25,000 impacts in each direction of a horizontal force of 125 lbs with less than ¼ in. permanent deformation and without visible deterioration."

Appendix I – Other transit authority requirements for buses stopping at crossings

Winnipeg Transit – Winnipeg, Manitoba

Buses are not required to stop at active or passive railway crossings within the boundaries of the City of Winnipeg unless gates are down, lights are flashing, flagmen are on location, the crossing is controlled with a stop sign, or when an approaching train is close enough to pose a hazard to the bus.

As railway crossings can create a bump hazard, to prevent personal injury and equipment damage, drivers are instructed to reduce their speed to 30 km/h when crossing.

Outside the boundaries of the City of Winnipeg, the same procedures apply to crossings with automatic warning devices (AWDs), but drivers must stop at all passive crossings.

Saskatoon Transit – Saskatoon, Saskatchewan
Calgary Transit – Calgary, Alberta
Lethbridge Transit – Lethbridge, Alberta

Buses do not stop at actively protected grade crossings unless the bells/lights and/or gates are activated. These authorities were not aware of any passively protected crossings within city limits.

Edmonton Transit – Edmonton, Alberta

Buses are not required to stop at railway crossings unless the gates are down, the lights are flashing, flagmen are on location, the crossing is controlled with a stop sign, or an approaching train is close enough to pose a hazard to the bus. Drivers are required to slow their bus to one-half of the posted speed limit on the approach to a crossing.

Strathcona County Transit – suburb of Edmonton, Alberta

At controlled railway crossings, buses are required to slow before the crossing and advance at a speed not more than one-half of the posted speed limit.

Appendix J – Other crossing accidents involving a bus

TSB railway occurrence R14T0290 (Mississauga, Ontario)

On 22 October 2014, at 0806 Eastern Daylight Time, eastbound GO Transit train No. 160 (the train) was proceeding at about 20 mph (32.2 km / h) when it struck a southbound school bus (the bus) operated by Switzer-Carty Bus Lines. The bus had stopped just foul of the north track at the Erindale Station Road public railway crossing (the crossing), located at Mile 17.35 of the Canadian Pacific Railway (CP) Galt Subdivision in Mississauga, Ontario. The bus sustained minor damage. Neither the bus driver (the driver) nor the 6 school-age passengers were injured. The bus was not equipped with a dedicated event recorder.

The level crossing was equipped with automatic warning device (AWD) protection, consisting of flashing lights, bell and gates. The crossing, located in the body of a 3-degree left-hand curve, traversed 3 sets of railway tracks at a 30-degree angle. The crossing sightlines in each direction were restricted. The maximum train speed in the vicinity was 65 mph (104.6 km / h), and rail traffic consisted of about 38 trains per day. At this location, an anti-whistling by-law prohibited the use of the locomotive horn.

Prior to the occurrence, the driver had stopped in the curb lane at the stop line on the north approach of the crossing. The driver put the bus in "PARK," opened the driver-side window and the passenger door, and then looked left and right while watching and listening for approaching trains. However, there was no audible locomotive horn because a whistling ban was in effect.

The bus then moved forward slowly while the driver performed a second check for trains. When the crossing bells activated, the driver immediately stopped the bus and backed up in an attempt to safely clear the north track. As the bus was reversing, the crossing gate descended and struck the roof of the bus. The driver stopped the bus. With the bus stationary, but still foul of the north track, the train struck one of its front mirrors.[169]

TSB railway occurrence R14T0081 (Mississauga, Ontario)

On 04 April 2014, at 1456 Eastern Daylight Time, westbound CP freight train 147-04 (the train) was proceeding at about 35 mph (56.3 km / h) when it struck a southbound school bus (the bus), operated by Stock Transportation, that had stopped between the crossing gate and north track at the Queen Street public crossing (the crossing) located at Mile 20.12 of the CP Galt Subdivision. The bus sustained a broken mirror and a damaged bumper on the front passenger-side corner of the bus. Neither the school bus driver (the driver) nor the 3 school-age passengers were injured. The bus was not equipped with a dedicated event recorder.

The level crossing was equipped with AWD protection consisting of flashing lights, bell and gates. The crossing, located in the body of a 4-degree right-hand curve, traversed 2 sets of railway tracks at a 43-degree angle. The crossing sightlines in each direction were restricted.

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169 Transportation Safety Board of Canada, rail safety advisories 17 / 14 and 18 / 14.

The maximum train speed in the vicinity was 50 mph (80.5 km / h), and rail traffic consisted of about 38 trains per day. At this location, an anti-whistling by-law prohibited the use of the locomotive horn.

Prior to the collision, the driver had initially stopped at the stop line on the north side of the crossing. The driver then put the bus in “PARK”, opened the driver-side window and the passenger door, looked left and right, watching and listening for approaching trains. However, there was no audible locomotive horn because a whistling ban was in effect.

With partially restricted sightlines, the driver then slowly moved the bus forward and performed a secondary check for approaching trains. During this second check, the driver saw the crossing gate on the opposite (south) side of the tracks start to descend to the horizontal position. With the crossing protection activated and unable to see a train, the driver brought the bus to an immediate stop just foul of the track, rather than continuing through the crossing, and was struck by the train.[170]

TSB Railway Investigation Report R13W0083 (Carlyle, Saskatchewan)

At about 1515 Central Standard Time on 26 March 2013, Canadian National (CN) freight train L50041-26 was proceeding eastward at 25 mph (40.2 km / h) on the Lampman Subdivision in Carlyle, Saskatchewan, when it struck a southbound school bus (the bus) transporting 7 elementary school children at the 4th Street East crossing (Photo J1). One passenger suffered minor injuries. The train weighed approximately 3000 tons and was about 1800 feet long.

Photo J1. Accident scene looking west (Source: Canadian National)

The bus was a single-axle, model D220 school bus manufactured by International Bus in 2004 and equipped with an automatic transmission. It weighed 12 474 kg (27 500 pounds) and had a capacity of 52 passengers. The bus had a provincial mechanical inspection on 26 October 2012 with no exceptions noted. The bus was equipped with side-view mirrors, which were mounted outside on the pillars at both front corners of the bus. The bus did not have a dedicated event data recorder; therefore, it was not possible to determine the driver’s actions just before or at the time of the accident.

170 Transportation Safety Board of Canada, rail safety advisories 04 / 14 and 07 / 14.

Assuming that the school bus reached a speed of 5 mph (8 km / h), the kinetic energy of both the bus and the freight train was calculated with the following results:

Table J1. Kinetic energy of school bus and train

Vehicle	Mass (kg)	Speed		Momentum (kg·m/s)	Kinetic energy (J)
		mph	km / h		
R13W0083 Bus	12 474	5	8	28 000	31 000
R13W0083 Train	2 727 273	25	40.2	30 480 000	170 321 000

The Province of Saskatchewan considered passive railway crossings equipped with cross bucks and a stop sign to be *controlled* railway crossings. At controlled railway crossings, school bus drivers are not required to open the driver’s side window or the front door to look and listen for a train. This is contrary to other provincial jurisdictions, which require that school buses stop not less than 5 m (16 feet) or more than 15 m (49 feet) from the nearest rail at all railway crossings. In addition, after stopping, the driver must

- fully open the driver’s side window and the front service door;
- look and listen in both directions along the tracks for approaching trains; and
- not proceed unless the action can be completed safely.

In this occurrence, with the bus at low idle and the windows and the front door closed, the train horn could not be heard above the ambient noise level within the bus until the train was about 2 seconds from the crossing.

The investigation determined the following:

- The accident occurred when the driver, unaware of the approaching train, proceeded from a stop onto the crossing, where the bus was struck by the oncoming train.
- Even though sightlines met regulatory requirements, a stationary rail car, as well as the A-pillar and side mirror of the school bus, may have obstructed the driver’s view westward and concealed the train at critical times during the driver’s visual scan.
- The driver’s obstructed view, the expectation that no train would be present, and the lack of contrast between the approaching train and the background environment likely contributed to the driver not detecting the train when looking westward.
- Although the locomotive horn was sounded, with the bus door and window closed, the ambient noise within the bus reduced any meaningful warning that the horn was intended to provide.
- The driver was likely distracted by secondary visual search tasks associated with the road traffic and pedestrian activity in the vicinity of the crossing.
- If school bus drivers are not required to stop at passive railway crossings, open the driver’s side window and front door of the bus to look and listen for a train, the locomotive horn may not be audible to the bus driver, increasing the risk of a crossing accident.

Crossing collision between a GO Transit train and a Toronto Transit Commission bus

At approximately 1645 Eastern Standard Time on 12 December 1975, Toronto Transit Commission (TTC) bus No. 86 (the bus) was on its way from Warden Station to the Metro Zoo. The bus, with about 65 passengers, was proceeding east on St. Clair Avenue East. As required by company policy, the bus stopped at a level crossing that incorporated 5 tracks, just west of Midland Avenue in Scarborough, Ontario. The bus then proceeded onto the tracks where it stalled.

A GO Transit train was proceeding southwest with 6 passenger cars at 70 mph (113 km / h) when the locomotive engineer noticed the bus stalled on the tracks. The train was placed into emergency. The train slowed to 50 mph (80 km / h) when it struck the bus broadside. Nine of the bus passengers sustained fatal injuries and another 20 were injured. There were no injuries among the GO Transit train 3-person crew or its 15 passengers. The bus was not equipped with an event data recorder.

The accident occurred at a location where local politicians and residents had previously requested to have a roadway underpass constructed. In 1977, the level crossing was replaced by a roadway underpass.

Appendix K – Other OC Transpo bus incidents at level crossings

Bus incidents at the Transitway crossing

On 01 October 2013, at about 0745 Eastern Daylight Time, a northbound articulated bus (Route 73), which had departed from the OC Transpo Fallowfield Station, was approaching the crossing when the lights and bells activated. The bus was about 30 feet from the crossing when the driver observed a westbound train about 1 km to the east. As the crossing gate had not yet descended, the driver believed that it was safe to proceed. The driver also believed that the bus could not be stopped without putting passengers at risk, as the bus was full and a number of passengers were standing. The bus proceeded through the crossing while the automatic warning devices (AWDs) were activated.

On 11 October 2013, at about 1848 Eastern Daylight Time, a southbound double-decker bus (Route 77) proceeded through the crossing while the lights and bells were activated as an eastbound passenger train was departing from the VIA Rail Canada Inc. (VIA) Fallowfield Station. At the time, the bus was travelling southbound on the Transitway en route to the OC Transpo Fallowfield Station. The bus approached the crossing at just under 60 km/h when the crossing lights and bells activated. As the bus was about 15 feet from the crossing and the gates had not descended, the driver believed that the bus could not be stopped safely without putting passengers at risk.

On 30 October 2013, at about 1940 Eastern Daylight Time, a southbound bus (Route 95) proceeded through the crossing while the crossing lights and bells were activated as a train approached. The bus was travelling at 58 km/h (8 km/h over the speed limit). OC Transpo indicated that it was not illegal to go through flashing crossing lights. Several days later, an OC Transpo supervisor met with the driver and suggested that the driver “hover” over the brake when approaching a railway crossing and be prepared to stop when the crossing lights are activated.

On 27 January 2014, at about 0745 Eastern Standard Time, it was reported that a southbound OC Transpo bus had proceeded through the crossing while the lights and bells were activated. Follow-up by OC Transpo determined that the bus involved was a northbound bus, travelling at 52 km/h. The bus had been running 27 minutes behind schedule due to poor driving conditions during a winter storm. Believing that the bus could not be stopped safely without putting passengers at risk, the driver proceeded through the crossing while the lights and bells were activated.

On 11 February 2014, OC Transpo reported a malfunction of the crossing AWD protection at the VIA Transitway crossing, which involved 3 OC Transpo buses. At about 2145 Eastern Standard Time, westbound train VIA 39 arrived at the Woodroffe Avenue and Transitway crossings, and the crossing AWD protection was activated. Once VIA 39 cleared the Transitway crossing, the system deactivated and the north gate (southbound lane) went up (recovered), but the south gate (northbound lane) remained down (did not recover). As a result, the crossing protection reverted to fail-safe mode and the lights remained activated as designed.

Shortly thereafter, northbound OC Transpo bus 6364 (1st bus) arrived at the Transitway crossing, and the driver noted that the Woodroffe Avenue crossing protection was deactivated, but the Transitway crossing lights were on with the south gate down and the north gate upright. The driver stopped the bus about 50 feet from the crossing. The driver applied the bus emergency brake, activated the emergency 4-way flashers, reported the situation to OC Transpo control on the radio and waited for OC Transpo supervisors to arrive. OC Transpo control diverted transit traffic to Woodroffe Avenue and dispatched transit supervisors to the site.

Southbound OC Transpo bus 6565 (2nd bus) was already on the Transitway when the driver heard the radio call to OC Transpo control reporting the situation. Approaching the crossing, the driver slowed the bus, stopped at the crossing and activated the bus emergency 4-way flashers. The driver observed that the south gate was down and that bus 6364 (1st bus) was stopped in front of it on the northbound lane. However, the north gate was up, indicating to the driver that it was clear for the bus to cross. Based on previous experience as a school bus driver, the driver opened the bus front door and driver’s side window and looked both ways to confirm that it was safe before proceeding across the track and continuing to the OC Transpo Fallowfield Station.

At about 2151, transit supervisors arrived on scene. Shortly thereafter, southbound OC Transpo bus 5065 (3rd bus) arrived at the crossing. The driver slowed and stopped the bus about 60 feet from the crossing and activated the bus emergency 4-way flashers. The driver observed that the south gate was down, bus 6364 (1st bus) was stopped in front of it on the northbound lane and a transit supervisor was attempting to manually lift the south gate, but could not. The transit supervisors subsequently directed bus 6364 (1st bus) on to the southbound lane, around the south gate, over the crossing and back on to the northbound lane. As the north gate was already upright, the transit supervisors then directed bus 5065 (3rd bus) to proceed over the crossing.

In this incident, the 1st bus driver took appropriate action by stopping the bus, reporting the incident and waiting for assistance. OC Transpo control took a safe course of action by re-routing Transitway traffic until the situation was resolved. However, OC Transpo had no standard operating procedures in place to deal with this type of situation. Consequently, there was no track protection in place and the driver of each bus took a different action to negotiate the crossing.

Bus incidents at the Fallowfield Road crossing

On 25 April 2014, an OC Transpo bus was stopping on Fallowfield Road for a red traffic light due to a bus crossing Fallowfield Road on the Transitway when the driver stopped the bus about 25 feet (7.62 m) beyond the crossing roadway stop line. Subsequently, the crossing AWD protection activated and a gate lowered onto the roof of the bus. The driver reversed the bus, backed up clear of the crossing, and the gate descended into position.

On 28 April 2014, VIA train 59 (VIA 59) met VIA train 44 (VIA 44) at Fallowfield with VIA 44 taking the siding. After VIA 44 arrived, VIA 59 advanced westward to clear the platform for VIA 44. In the process, VIA 59 advanced far enough ahead to activate the crossing circuit for the Fallowfield Road crossing. As VIA 59 did not have the signal to depart, the crossing AWD timed out. At this time, an OC Transpo bus was stopped behind 5 other vehicles on Fallowfield Road for a red traffic light. After the traffic light turned green, the driver followed the flow of traffic until the traffic lights again turned red, and the driver stopped the bus beyond the crossing roadway stop line.

Once VIA 59 was given the signal to depart, the crew activated the crossing AWD protection. A crossing gate descended onto the top of the OC Transpo bus, which was stopped beyond the crossing roadway stop line. As the train was departing, the bus backed up clear of the crossing and the gate descended into position. Once the train cleared the crossing, the gates raised, the traffic lights turned green, but the crossing AWD lights remained activated. With the lights activated, the bus driver proceeded over the tracks with the flow of traffic.

On 06 November 2014, OC Transpo bus No. 8049 was travelling eastbound on Fallowfield Road approaching the VIA Fallowfield Road crossing and the intersection with the Transitway, which runs parallel to the railway tracks and crosses Fallowfield Road. At this location, the Transitway traffic signals are interconnected with the railway crossing AWD protection.

Photo K1. Bus stopped past roadway stop line (Source: social media)

At 0748:08 Eastern Standard Time, the Transitway traffic signal on Fallowfield Road changed from green to amber and then to red at 0748:13. The traffic light remained red until 0748:46 to allow 2 buses to cross Fallowfield Road on the Transitway. The traffic lights then turned green and roadway traffic on Fallowfield Road proceeded in both directions.

At 0749:02, the traffic signal turned to amber and then to red at 0749:07. During this sequence, OC Transpo bus 8049 came to a stop for the traffic light at a location that was about 25 feet (7.62 m) beyond the crossing roadway stop line. At 0749:33, the crossing AWD protection activated for a westbound VIA passenger train (southward at this location). Shortly thereafter (0749:41), a crossing gate lowered onto the roof of the bus (Photo K1). At 0750:14, the train arrived at the crossing. At 0750:44, the train cleared the crossing after which traffic resumed on Fallowfield Road.

Appendix L – Automatic warning device trouble calls: 23 January 2014 to 12 April 2014

Item	Date	Location	Description of event	Action taken/Review	Cause/ Rectification	Category
1	23 Jan.	Woodroffe Avenue (Mile 3.28)	Ottawa Police Service (OPS) reported to the rail traffic controller (RTC) that the automatic warning devices (AWDs) were not working while the train was crossing.	A signal maintainer was sent on site and reviewed the operation history log download. No evidence was found to support this claim.	Depending on the exact train move (backing up, slowing, etc.). AWDs intended operation requirement may have been misunderstood by the police officer.	Normal
2	07 Feb.	Fallowfield Road (Mile 3.88)	On 13 February 2014, at 1840, OC Transpo reported that a train stopped, then the AWDs took approximately 45 seconds to recover, then the AWDs reactivated. The event had occurred on 07 February 2014.	The grade crossing predictor (GCP) historical download was reviewed. VIA initiated an operational blitz during the weekend of 05 April 2014 in reference to event No. 12.	After reviewing the GCP historical download, it was determined that the train crew did not follow the dual-tone multi-frequency (DTMF) activation procedures and instructions.	Normal
3	11 Feb.	Woodroffe Avenue and Transitway (Mile 3.28 and Mile 3.30)	OC Transpo reported that the AWDs were in fail-safe mode (one gate down, lights on, bell ringing).	There was frost on the gate-up motor contact in gate mechanism. The gate-up contact was cleaned, the AWDs were tested and one train was observed over crossing; functioned normally.	The inspection by the signal maintainer sent on site revealed that frost on the gate-up contacts delayed the raising of the gates. The gate recovered by itself prior to the maintainer arriving on site.	Technical issue
4	14 Feb.	Woodroffe Avenue and Transitway (Mile 3.28 and Mile 3.30)	OC Transpo reported that the warning lights were operating and the gates were down, but there was no train. The situation was resolved 5 minutes later.	None. Normal AWD operation due to train operational requirement.	The AWDs deactivated within 5 minutes. The incident was caused by a City of Ottawa snow plow that was stuck on an adjacent crossing. As a result, a VIA train had to stop within the approach circuit of the AWDs, pending RTC instructions and centralized traffic control system signal clearing, thus activating the AWDs.	Normal

Item	Date	Location	Description of event	Action taken/Review	Cause/ Rectification	Category
5	14 Feb.	Transitway (Mile 3.30)	The Transitway was closed in both directions to allow maintenance forces to perform repairs to the roadway/railway crossing surface. During regular scheduled track inspection, an inspector discovered a loose roadway crossing surface panel. For safety concerns, it required immediate attention.	The panel was temporarily secured with lag bolts. Work was stopped by the City of Ottawa because it was not planned work. The panel was permanently secured one week later, on 13 March 2014.	Not an AWD system issue. This was a roadway surface repair required for safety concerns.	N/A
6	21 Feb.	Woodroffe Avenue, Transitway, and Fallowfield, Greenbank, Jockvale and Strandherd roads (Miles 3.28, 3.30, 3.88, 5.10, 5.73 and 6.81)	VIA train No. 30 and OPS reported that the warning lights were activated and the gates were down.	Signal maintenance staff was called on site and found the automatic warning systems in fail-safe activation mode. The system had to be recalibrated.	The extreme fluctuation in ballast conditions resulted in fail-safe AWD track circuit failure caused by water accumulation combined with City-applied salt accumulations in the ballast.	Technical issue
7	22 Feb.	Woodroffe Avenue, Transitway, and Fallowfield, Greenbank, Jockvale and Strandherd roads (Miles 3.28, 3.30, 3.88, 5.10, 5.73 and 6.81)	VIA train No. 44 and OPS reported that the warning lights were activated and the gates were down.	Signal maintenance staff was called on site and found the automatic warning systems in fail-safe activation mode. The AWD operating systems and track circuits were recalibrated to compensate for ballast conditions.	The extreme fluctuation in ballast conditions resulted in fail-safe AWD track circuit failure caused by water accumulation combined with significant City-applied salt accumulations in the ballast.	Technical issue

Item	Date	Location	Description of event	Action taken/Review	Cause/ Rectification	Category
8	28 Feb.	Transitway (Mile 3.30)	At 0928, OC Transpo reported a train sitting at the VIA Fallowfield Station. The AWDs were activated on Woodroffe Avenue but not on the Transitway. At 0931, all warning signals and barriers were functioning normally, including the ones on the Transitway. It is unclear if it was a train conductor or the RailTerm signal maintainer walking in front of the train northbound until it crossed the Transitway.	The signal maintainer reviewed the AWD historical operation download and tested the crossing, which was shown to be working as intended. It may have been a situation of weekly tests and inspection of the AWDs being performed. There are 2 test switches at this location, intended to activate 1 AWD at a time, so as not to disrupt roadway traffic unduly.	Nothing abnormal in the review of the GCP historical activity log.	Normal
9	10-11-12 Mar.	Fallowfield Road (Mile 3.88)	It was reported that the AWDs were activated without any train at different times over a period of several days from the evening of 10 March 2014 to the morning of 12 March 2014.	Signal maintenance forces found that the issue was caused by the City-controlled roadway traffic light synchronization interconnection between the AWD system and the City's roadway traffic light control system. The issue was repaired by City roadway traffic control crews on 12 March 2014 at 1045.	The issue was related to the City roadway traffic controller situated at Fallowfield Road. A recalibration and reset were required on the City side of the system.	Other
10	28 Mar.	Fallowfield Road (Mile 3.88)	OC Transpo reported that the warning lights were activated and the gates were down without any train. The gates were up, allowing road traffic to operate.	Signal maintenance staff was sent on site. Testing and repairs continued for several hours. Eventually, it was found to be a failed limiter diode and a wire shorting out in the signal mast situated near the bell.	There was a wire short circuit, resulting in a blown diode. Grounded operating circuits caused by an accumulation of road salt deposits on all wire terminals were also found in the vicinity of the roadway.	Technical issue

Item	Date	Location	Description of event	Action taken/Review	Cause/ Rectification	Category
11	03 Apr.	Fallowfield Road (Mile 3.88)	Transport Canada audited this crossing and revealed no urgent and no immediate concern, but found high voltage (120 V) being used for interconnect circuits between the City of Ottawa roadway traffic control system and the AWDs. Minor maintenance items were reported such as faded background light, one misaligned light on the pedestrian portion and corrosion on some terminals in a junction box.	On 04 April 2014, VIA notified the City of Ottawa, and VIA has not received any update of when this will be rectified. Other maintenance items will be/have been done. The 120 V AC interconnect is a non-vital application, and is based upon the City traffic standards. The AREMA 24 V application is a suggestion only.	The AREMA-suggested standard identifies low voltage (24 V DC) to be used for interconnected circuits.	Other
12	02 Apr.	Fallowfield Road (Mile 3.88)	At 2154, VIA was advised by the RailTerm RTC that the crossing at Mile 3.88, Smiths Falls Subdivision (Fallowfield Road), had been reported by the City of Ottawa traffic operations control centre to have been in fail-safe mode since 1838. City of Ottawa had been advised by a citizen at 2120 that the AWDs appeared not to be working. The RailTerm RTC had been advised at 2153.	VIA carried out an operational and safety blitz during the weekend of 05 April 2014 and a refresher. Train crews were investigated and assessed.	After reviewing the GCP historical download, it was determined that the train crew did not follow the DTMF activation procedures and instructions.	Normal
13	04 Apr.	Fallowfield Road (Mile 3.88)	It was reported by a RailTerm maintenance employee at 0909 that the AWD gates were going up and down.	The RTC dispatched a signal maintainer who was already on site, and the crossing was cleared for road traffic as of 0925. Repaired by RailTerm as of 1030. New wind brackets are ordered and will be installed.	This was caused by high winds in the area, resulting in moving the gate excessively during ascent and descent, which resulted in the south gate getting caught on the exterior of the wind bracket.	Technical issue

Item	Date	Location	Description of event	Action taken/Review	Cause/ Rectification	Category
14	06-08 Apr.	Strandherd, Jockvale and Greenbank roads (Miles 6.81, 5.73 and 5.10)	It was reported by the City of Ottawa at 2250 that the gates were going up and down at the Standherd Road crossing (Mile 6.81).	The RTC dispatched a signal maintainer to troubleshoot the issue. After troubleshooting and testing, in conjunction with Ottawa Hydro, the problem was determined to be caused by foreign voltage and current induction in the rails from the Ottawa Hydro transmission lines, causing the AWD approach track circuits to fail in safe mode. VIA temporarily modified the AWD track circuit lengths and operating system, which resulted in slower-speed train operation until design modifications by VIA and Ottawa Hydro could be placed into effect. Pending to get a noise filter (90 days' lead time). Hydro Ottawa is aiming to reduce the voltage during the week of 14 April 2014.	There are high-voltage power transmission lines adjacent to and crossing over the track in this vicinity. On Sunday evening, 06 April 2014, Hydro Ottawa increased the transmission levels in these power lines, which resulted in these higher levels inducing stray and foreign voltages and currents into the AWD track circuits, causing fail-safe AWD activations. Hydro Ottawa increased the transmission levels to reduce levels on another transmission line, for a future project.	Technical issue – caused by others
15	06 Apr.	Fallowfield Road (Mile 3.88)	At 2347, the RTC was advised by the assigned employee monitoring the Fallowfield Road crossing that the AWDs were activating sporadically.	The RTC dispatched a signal maintainer who found the main AC power service circuit breaker tripped, causing backup battery supply voltage to fail in safe mode. The main breaker was put back on.	This was caused by a loss of AC power resulting in the backup storage battery bank supply depleting to a level where fail-safe mode took effect (operated as intended).	Technical issue

Item	Date	Location	Description of event	Action taken/Review	Cause/ Rectification	Category
16	08 Apr.	Fallowfield Road (Mile 3.88)	A citizen reported to the RTC that AWD gates were going up and down sporadically.	None. Normal operation for this type of event. Could have been protected by some method (flagman, deactivation). This was caused by tests and calibration taking place at Jockvale and Strandherd roads due to Ottawa Hydro foreign voltage and current induced within the track circuits of the GCPs.	This was caused by the Ottawa Hydro induction resolution work that was being performed to the west (Greenbank, Jockvale and Strandherd roads) in reference to event No. 14. Tests and calibration were being performed west of Fallowfield Road, and because of the overlapping AWD approach track circuits and interconnectivity of the AWDs, recalibration, shunting and testing caused intermittent activations of the AWDs at Mile 3.88 (Fallowfield Road).	False activation - caused by others
17	09 Apr.	Greenbank Road (Mile 5.10)	The media reported that the AWDs did not activate when a train was travelling over the crossing. It was locomotive 905, train No. 55, and it occurred between1528 and 1535. A video was received from the locomotive.	The AWDs were deactivated at the time, as per procedure, and train operations over the crossing were as per CROR Form V (4).	Signal maintainers were performing repairs at Jockvale and Strandherd roads, in reference to event No. 14 (Hydro Ottawa high-voltage issue). To eliminate excessive and unnecessary AWD operation, the AWDs at Greenbank Road were deactivated, as per instruction and procedure.	Non-activation (crossing was deactivated). Train operations over crossing as per CROR Form V (4).
18	10 Apr.	Greenbank Road (Mile 5.10)	The VIA operations control centre received a call from a citizen around 1120 that the gates did not go down during a train passage.	A signal maintainer reviewed the AWD operation history download, which revealed that the AWDs operated as intended. This was also confirmed by the employee stationed at the roadway crossing to report any unnecessary activation.	Public call – misunderstanding and misconception by the public.	Normal

Item	Date	Location	Description of event	Action taken/Review	Cause/ Rectification	Category
19	10 Apr.	Strandherd Road (Mile 6.81)	A dump truck broke the south gate as the AWDs were activated by an approaching train. This was witnessed by the employee stationed at the crossing.	A signal maintainer was dispatched on site and repaired the gate and gate lights.	The truck driver was travelling too fast and went through the gate. OPS incident report No. 14-89317.	Other
20	11-12 Apr.	Woodroffe Avenue (Mile 3.28)	RailTerm reported that the AWDs recovered after a train passed through the crossing (normal operations), then reactivated, with gates beginning descent, but recovering. A video of the event was also taken and it was mentioned in an email dated 12 April 2014.	Signal maintainers have relocated the transmit cable connections on the rails, recalibrated the GCP and tested the system as per Siemens recommendations. It appears to not have worked. Information was sent back to Siemens and Hatch Mott MacDonald for their review.	This seems to be an occurrence of truncated wheel noise generated by the train movement. Issue with the GCP.	Technical issue

Number of events in each category

Normal	7
Technical issue	7
Other	6

Appendix M – List of acronyms and abbreviations

AADT	average annual daily traffic
AAWS	active advance warning sign
AB Hdl	air brake handle
ABS	anti-lock braking system
ADL	Alexander Dennis Limited
APTA	American Public Transportation Association
ASR	anti-slip regulation
ASTM	American Society for Testing and Materials
ATA	American Trucking Association
avg.	average
AWD	automatic warning device
BC	brake cylinder
BP	brake pipe
BTAC	Bus Technical Advisory Committee
BTD	B-train double
C	Celsius
Cali mile	calibrated mile
CCMTA	Canadian Council of Motor Transport Administrators
CCTV	closed circuit television
cd	candelas
CEO	Chief Executive Officer
City	City of Ottawa

cm	centimetres
CMA	Canadian Medical Association
CMVSS	*Canada Motor Vehicle Safety Standards*
CN	Canadian National
CP	Canadian Pacific Railway
CROR	*Canadian Rail Operating Rules*
CSA	Canadian Standards Association
CTC	Canadian Transport Commission
CVOR	Commercial Vehicle Operators Registration
CWT	constant warning time
dB	decibels
DB	dynamic brake
Delcan	Delcan Corporation
DOT	Department of Transportation (United States)
DSA	detailed safety assessment
DTMF	dual-tone multi-frequency
EA	environmental assessment
ECM	engine control module
EDR	event data recorder
EIE	engineer-induced emergency
EOT	end-of-train
ESDC	Employment and Skills Development Canada
E500	Enviro 500 (bus model)

FAST	Fatigue Avoidance Scheduling Tool
FHA	Federal Highway Administration (United States)
FLBG	flashing lights, bells, and gates
FMVSS	*Federal Motor Vehicle Safety Standards* (United States)
ft	feet
GCIP	Grade Crossing Improvement Program
GCP	grade crossing predictor
GCR	*Grade Crossings Regulations*
GE	General Electric
GO	GO Transit
Golder	Golder Associates Limited
GPS	global positioning system
GVWR	gross vehicle weight rating
HFN	Human Factors North
HIC	head injury criterion
hr.	hours
HVAC	heating, ventilation, and air conditioning
ICLE	in–charge locomotive engineer
IEEE	Institute of Electrical and Electronics Engineers
IIHS	Insurance Institute for Highway Safety
in.	inches

ISA	intelligent speed adaptation
IVN	Intelligent Vehicle Network
J	joules
Jock Valley	Jock Valley Engineering Limited
KE	kinetic energy
kg	kilograms
km	kilometres
km/h	kilometres per hour
km/h/s	kilometres per hour per second
kN	kilonewtons
Laidlaw	Laidlaw Incorporated
lb	pounds
LBFTS	looked-but-failed-to-see (human error)
LE	locomotive engineer
LED	light-emitting diode
LER	locomotive event recorder
LRC	Light, Rapid, Comfortable
m	metres
mg	milligrams
mm	millimetres
MMM	MMM Group Limited

mph	miles per hour
mph/s	miles per hour per second
ms	milliseconds
m/s	metres per second
MTO	Ministry of Transportation of Ontario
N	newtons
NATSA	North American Transit Services Association
NBOT	New Bus Operator Training
NCC	National Capital Commission
NDIC	National Diabetes Information Clearinghouse
NHTSA	National Highway Traffic Safety Administration
Nm	newton metre
NTSB	National Transportation Safety Board (United States)
NVM	non-volatile memory
OHTA	*Ontario Highway Traffic Act*
OL	Operation Lifesaver
OPP	Ontario Provincial Police
OPS	Ottawa Police Service
PA	public address
psi	pounds per square inch
RCC	Canada–United States Regulatory Cooperation Council

ROW	right-of-way
RP	recommended practice
rpm	revolutions per minute
RSA	Rail Safety Advisory
RTC	rail traffic controller
RTD 10	*Road/Railway Grade Crossings: Technical Standards and Inspection, Testing and Maintenance Requirements*
SAE	SAE International
SIR	Service Improvement Request
SMS	safety management system
SNR	signal-to-noise ratio
SSD	stopping sight distance
TAC	Transportation Association of Canada
TC	Transport Canada
TCH	transit control head
TCM	transmission control module
TDC	Transportation Development Centre
Thtl	throttle
TS	technical specification
TSB	Transportation Safety Board of Canada
TTC	Toronto Transit Commission
T_v	vehicle departure time
U.S.	United States

V	volts
V AC	volts alternating current
V DC	volts direct current
VIA	VIA Rail Canada Inc.
W	watts