

Crashworthiness for Transit Bus



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Outline

- Needs Assessment
- Existing Standards
- Guidelines and Recommended Practices
- NTSB Recommendations
- Gap Analysis
- Findings

Needs Assessment

- An analysis of the National Transit Database (NTD) Safety and Security 40 (S & S 40) major incidents database indicates
 - 411 fatal transit bus involvements occurred between 2011 through 2015
 - Resulting in 427 fatal injuries
 - Demand response buses (typically cutaway vehicles) accounted for 32 of the 411 fatal transit bus involvements
- During that same timeframe, there were over
 - 21,500 total collision events involving buses
 - Resulting in more than 40,600 non-fatal injuries

Existing Standards – Federal Standards

- Title 49 CFR 571 sections 201-404 including, but not limited to:
 - §571.204 “Steering control rearward displacement”
 - §571.205 “Glazing materials”
 - §571.213 “Child restraint systems”
 - §571.217 “Bus emergency exits and window retention and release”
 - §571.302 “Flammability of interior materials”
- Some apply only to the driver’s seat, such as:
 - Title 49 CFR §571.207 “Seating systems”
 - §571.208 “Occupant crash protection”
 - §571.209 “Seat belt assemblies”
 - §571.210 “Seat belt assembly anchorages”
- Some applicability is dependent on gross vehicle weight rating (10k lbs. or less)
 - §571.201, “Occupant protection in interior impact”
 - §571.214, “Side impact protection”

Existing Standards – Federal Standards

- **Altoona Bus Research and Testing – Safety Tests**
 - The **Handling and Stability Test** ensures the operator can maneuver the bus through a double lane change at a speed of 45 miles per hour
 - The **Braking Performance Test** subjects the bus to a series of brake stops from specified speeds, in addition to the evaluation of the parking brake performance on a twenty percent grade for a five-minute time period
- While these tests are necessary, they do not confirm or establish the crashworthiness of the bus

Existing Standards – Federal Standards

■ Altoona Bus Research and Testing

- Safety benefits from other Altoona bus tests include detecting defects that are directly related to safety:
 - Bus fires
 - Cracked CNG cylinder support brackets
 - CNG fuel system cracks/leaks
 - Fuel tank leaks
 - Fire detection/suppression system failures
 - High current electrical short circuits
 - Broken steering/suspension components



Existing Standards – State Standards

- Some states have adopted FMVSS for vans or buses manufactured or operated in their state
 - **Minnesota** Administrative Rules, Chapter 8840.5940(1) Rollover Protection, calls applicability of FMVSS 49 CFR Part 571.216 or 220 to all vans and buses
 - **Wisconsin** Administrative Code, Chapter Trans 330.10 (12) Frame, calls applicability of 49 CFR §393.20, (20) Seating, and (30) Windows and Windshields
 - Chapter 14-90, **Florida** Administrative Code, Vehicle Equipment Standards and Procurement criteria – FMVSS 49 CFR Part 571, Sections 102, 103, 104, 105, 108, 207, 209, 210, 217, 302, 403, and 404 and criteria for (8) emergency exits, (12) seat belts, and (13) safety equipment

Existing Standards – Standards Outside the U.S.

- United Nations Economic Commission for Europe Regulations
 - UNECE R-14: Seat belt anchorages and ISOFIX anchorages
 - UNECE R-16: Seat belt restraint systems
 - UNECE R-17: Seat anchorages (covers M₃ vehicles not covered in UNECE R-80)
 - UNECE R-25: Head restraints (headrests)
 - UNECE R-34: Prevention of fire risks (collision related testing)
 - UNECE R-36: General vehicle construction (load distributions and survivable space)
 - UNECE R-43: Glazing materials
 - UNECE R-66: Residual space available after rollover test
 - UNECE R-80: Seats and seat anchorages
 - UNECE R-114: Airbag replacement
 - UNECE R-135: Pole Side Impact performance*

Existing Standards – Standards Outside the U.S.

■ Australian Design Rules

- ADR Standard 3/03: Seats and seat anchorages
- ADR Standard 4/05: Seatbelts
- ADR Standard 5/05: Anchorage for seatbelts
- ADR Standard 8/01: Safety glazing material
- ADR Standard 34/02: Child restraint anchorages & anchor fittings
- ADR Standard 42/04: General safety requirements (includes external or internal protrusions)
- ADR Standard 59/00: Standards for omnibus rollover strength
- ADR Standard 68/00: Occupant protection in buses (seat performance)

Guidelines and Recommended Practices

- **SAE Recommended Practice J2249_199901:** Wheelchair tie-down and occupant restraint systems for use in motor vehicles) – technically focuses on requirements for vehicles that weigh less than 15,432 lbs. (7,000 kg) and notes that it may be possible to comply with desired results in larger vehicles without following the recommended practice.
- **FTA Vehicle Design Guidelines for low-floor vehicles:** suggests buses operating in BRT environments provide adequate protection in the associated higher speeds.
- **APTA Procurement Guidelines: Section 6 – Technical Specifications 23.2: Crashworthiness** (Note: Guidelines scheduled for review in FY 2018)

NTSB Recommendations

- NTSB does not typically get involved in transit bus collisions
- This 2016 NJ Transit crash between two buses, which resulted in 2 deaths and 17 injuries did not spur NTSB involvement



NTSB Recommendations (cont'd)



Dolan Springs, AZ

January 2009

7 passenger fatalities



Davis, OK

September 2014

4 fatalities



Concan, TX

March 2017

13 fatalities – bus driver
and 12 passengers

Name of Crash	Location	Date of Event	Type of Vehicle	General Description	Fatalities/Injuries	Findings
NTSB/HA R-10/01	Dolan Springs, Arizona	1/30/09	2007 Chevrolet/Starcraft 29-passenger medium-size bus	Bus rolled 1.25 times as a result of overcorrection and subsequent loss of control	7 fatalities, 10 injuries	Limitations of medium sized bus to retain and protect passengers in a rollover, and need for EDR device
NTSB/HA R-15/03	Davis, Oklahoma	9/26/14	2008 Champion Defender 32-passenger medium-size bus	Bus rolled onto side following an impact with a truck-tractor which had crossed the median, resulting in passenger ejections	4 fatalities, 11 injuries	Lack of; passenger restraint system use, crashworthiness side impact standards, and event data recording device
NTSB/HA R-19-XX	Concan, Texas	3/29/17	2004 Ford E350 cutaway chassis with 13-passenger Turtle Top Vanterra medium-size bus body	Front left corner collision with pickup truck that crossed the center line	13 fatalities, 1 injury	Bus was not equipped with passenger lap/shoulder belts which would have provided a greater level of protection and mitigated injuries for passengers seated in the rear of the bus

NTSB Recommendations

- **Dolan Springs, AZ – HAR 10/01**
 - H-10-2: develop regulatory definitions and classifications for each of the different bus body types
 - H-10-3: improve roof strength, occupant protection, and window glazing standards, **include ALL buses with a GVWR above 10,000 pounds** through rulemaking
 - H-10-5 -6: develop and require stability control system performance standards for new buses with a GVWR above 10,000 pounds
- **Davis, OK – HAR 15/03**
 - H-15-40: develop side-impact protection standard for all newly constructed medium sized buses, regardless of weight
 - H-15-42 (Supersedes H-97-2): requires primary enforcement of the use of seat belts for all passengers
 - Reiterates: H-99-50 -51: develop and require roof strength performance standards
 - Reiterates: H-10-3: described above
- **Concan, TX – NTSB/HAR-19-XX**
 - Install lap/shoulder belts as standard, rather than optional, equipment on buses

Gap Analysis

- Paratransit trips are often
 - Longer trips
 - Operating in rural environments
 - On two-lane highways
 - With higher traveling speeds
- Rural statistics
 - US population: 19%
 - VMT: 30%
 - Bus miles traveled: 37%
 - Fatalities: 53%
 - Share of fatally injured due to rollover: 39%
(24% for urban)
- NHTSA reports that rural roads consistently have more annual fatalities and higher fatality rates per miles traveled than urban roads

Gap Analysis – Rollover

- Dynamic (R-66) versus quasi-static (FMVSS 220)
 - UNECE R-66 adequately address the shortcoming of the FMVSS 220 standard test (Cichocki & Wekezer, 2007)
 - “quasi-static load resistance testing of the roof structure does not give sufficient indication on how the structure will behave during a rollover accident.” (Gepner et al., 2010)
 - Testing paratransit buses to the FMVSS 220 standard may lead to erroneous conclusions regarding bus strength and structural integrity (Bojanowski et al., 2011)
 - the structural steel strain rate has no significant effect on the UNECE R-66 rollover test... the current quasi-static experimental approach used to investigate rollover crashworthy structural performance of paratransit buses is well grounded (Gepner et al., 2016)

Gap Analysis – Florida Standard

- Florida Standard requires cutaway vehicles be tested via FE model development, verification, experimental validation, final check using full scale rollover test, and calibration, with an additional requirement of an acceptable range for the **Deformation Index** which represents un-intruded residual space (FDOT, 2007)



Figure 3. Deformation of the paratransit bus after the roadside accident (left), is very consistent with the deformation of the paratransit bus observed during F.E. analysis of the rollover performed following the requirements of the FDOT Standard (right).

Gap Analysis – Florida Standard

- July 2014 crash in Florida involving an aging passenger in paratransit bus resulted in minor injuries to the passenger and no injuries to the driver. The passenger compartment of the bus was proven to be safe. Compared to typical crashes, the reduced injuries in this case can be attributed to the improved design of paratransit buses



Gap Analysis – Data Difficulties

- Size and weight compatibility and operating environments make body-on-chassis medium sized bus occupants more susceptible to the possibility of injury or fatality when involved in a collision
- FMVSS, FHWA Highway Statistics Series, and FARS fail to classify paratransit or cutaway vehicles leaving them in an “other” category, resulting in scarce data availability of cutaway collisions

Gap Analysis – Secondary Impacts

- Secondary impacts: injury findings and recommendations from reviewed literature
 - Frontal collisions – neck flexion or extension due to the lack of restraints and low seatback designs
 - Compartmentalization designs and higher seatbacks
 - Side-impacts – head-to-head and head-to-body contacts and femur injuries of passengers seated on side facing seats
 - Avoid side facing seating designs
 - Rear-impacts – neck extension due to low seatback
 - Higher seatback designs
 - Mandate 3 point seat-belt system

Findings

- With limited data available to prove the necessity of structural and secondary impact crashworthiness standards for general transit buses, voluntary guidance is recommended
- Supplemental data supports the need to expand crashworthiness standard applicability to include body-on-chassis buses (medium-sized coaches)
- Additional detailed data collection and analyses will be required to support future rulemaking, given the lack of classification of body-on-chassis buses in currently available safety related databases

Findings

- Transit agencies may benefit by following procurement guidance established by APTA and applicable standards contained within the Federal Motor Vehicle Safety Standards, specifically FMVSS 214
- Transit agencies may consider requiring innovative interior vehicle designs, including passenger seating devices, attachments, and tracking/anchorage, and seatback designs, as examples to address injuries and fatalities that have occurred as a result of secondary impacts associated with collision events

Questions or Comments

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