

Frontal Crash Protection for Bus Drivers

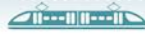
Simulation-Based Assessment of Test Methods and Structural Countermeasures

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- Current bus front structures and regulatory tests do not provide adequate driver protection in frontal collisions.
- This study investigates structural countermeasures and representative test methods to improve driver protection, using finite element simulations.
- We develop new test methods that better reproduce real-world intrusion patterns and energy concentration than current regulatory tests.
- Based on the results, we design a reinforced driver crash box to enhance protection in frontal collisions.
- Simulations show that the crash box reduces steering column intrusion in the driver area with about 50-60% in the simulated frontal impact collisions.

Due to the absence of crumple zones in bus fronts, the lack of mandatory EU crashworthiness standards focusing on bus drivers, and the low seating position of drivers in many buses, bus drivers are more exposed in frontal collisions than drivers of passenger cars and trucks. This has been demonstrated in several serious bus accidents in Norway over the past decade, where drivers have been killed or severely injured despite relatively low impact speeds. In one head-on collision investigated by the Accident Investigation Board, one driver was killed and the other critically injured at an impact speed of just over 30 km/h. Comparable collisions between modern passenger cars at similar speeds would be unlikely to result in fatal injuries due to advanced crashworthiness systems.

While vehicle safety has improved significantly for passenger cars and trucks through stricter regulations, safety requirements for buses have developed more slowly. Truck cabs are subject to crashworthiness standards under UN Regulation R29.03, and passenger cars must meet comprehensive frontal impact requirements, whereas no EU-wide crashworthiness standards specifically address frontal protection for bus drivers. Norway's adoption of UN R29.03 for buses in 2023 represents an important step, but the regulation was developed for trucks and may not fully account for bus-specific design characteristics. This underscores the need to study bus driver crash protection and to develop targeted solutions for frontal collisions.



The overall aim of this study is therefore to establish a technical basis for improved design solutions that can enhance the protection of bus drivers in frontal collisions, as well as for the development of test procedures for assessing the passive safety of bus drivers, with relevance for future regulatory development.

Our evaluation of existing international passive safety regulations demonstrates that current (UNECE) requirements do not adequately represent frontal collision conditions for buses. Regulations addressing rollover protection do not load the front structure, while cab strength tests developed for trucks (e.g. UN R29.03) apply impact energies that are far below those observed in real bus accidents.

To address these limitations, our report develops and investigates alternative frontal impact test configurations, including narrow rigid barrier and pole impact tests. The results show that such localized impact tests better reproduce the energy concentration, deformation patterns, and intrusion levels observed in real bus accidents than current regulatory tests, such as UN R29.03, which is mandatory for buses in Norway. As a result, these test configurations emerge as more suitable candidates for future bus-specific frontal impact assessment. The development and demonstration of these new tests is a key contribution of the report, which can inform future work in this area, including efforts to develop new voluntary or mandatory standards for collision safety in buses.

Another key contribution of the report is new simulation-based evidence on how bus drivers can be better protected in frontal collisions. The study develops and evaluates a reinforced driver crash-box as a targeted structural countermeasure for increased bus driver safety in frontal collisions. The simulations show that the implementation of a driver crash box reduces steering column intrusion in the driver area from approximately 600–730 mm in the baseline configuration to about 260–330 mm, corresponding to a reduction on the order of 50–60%, in the simulated 30 km/h frontal impact collisions. This reduction may be large enough to potentially transform many of the simulated scenarios from non-survivable to potentially survivable, provided that adequate restraint systems (seatbelt, airbag) are used. Authorities, companies and stakeholders can use the crash box as an inspiration for future efforts to increase the safety of bus drivers in collisions.

At the same time, the results highlight the need to balance increased structural stiffness with effective energy absorption and the performance of restraint systems. We propose that the crash box should be combined with measures such as airbags and seat belts. This is an important area for future research. Future research should also examine the effect of a small deformable zone in front of the crash box, as well as the effects of combinations of passive and active safety measures.