REPORT SUMMARY

FTA Report No. 0247
June 2023

FTA RESEARCH
FEDERAL TRANSIT ADMINISTRATION

LRV BUMPER SAFETY TECHNOLOGY DEPLOYMENT

Background

Most crashes with a Light Rail Vehicle (LRV) involve motor vehicles and cyclists/pedestrians. These crashes result in large crush intrusions into the automobile, causing injury and fatalities. When override occurs, automobile occupants may be more seriously injured and there is increased potential to produce extensive damage to the LRV. This greatly increases the repair costs and time before the vehicle is put back in service. Therefore, there is a recognized need to investigate methods for improving the crash safety in these collisions.

Recent research evaluated the potential for mitigating injuries in crashes between LRVs and automobiles. The combined research showed marked improvements in automobile passenger safety for a variety of automobile types and collision scenarios. Following this research, the ASME RT-1 Safety Standard for Structural Requirements for Light Rail Vehicles and Streetcars included crash safety design criteria for new LRVs that requires enclosed front ends, or bumpers. As a result, the inclusion of bumpers on new LRV designs is now common practice in the U.S. However, existing LRVs will continue to operate for decades without these crash safety features. The number and severity of injuries caused by continued operation of these vehicles, as well as the ongoing costs to vehicle operators from crashes, can be significantly reduced by retrofitting these vehicles with bumpers that comply with the current RT-1 standard.

Objectives

The objective of this project was to design, build, and test a prototype LRV end enclosure, or bumper, as a retrofit to an existing LRV operated in the U.S. to reduce (1) the potential for injury to automobile occupants, (2) damage to the LRV, and (3) costs to operators from crashes. Three transit agencies provided significant contributions to the project and a complete prototype design was developed and tested for the Siemens SD660 operated by TriMet (Type 2 and Type 3 LRVs).

Findings and Conclusions

This project demonstrates the feasibility of retrofitting existing LRVs with front enclosures, resulting in potential benefits that include improving crash energy management, reducing injuries, lowering risks, reducing repair costs, and reducing system and equipment down times.

The project consisted of the following development steps: (1) retrofit design, (2) fabrication, (3) operational testing on LRVs, and (4) crashworthiness testing. The design process consisted of geometric and mechanical design, design of hydraulics, envelope analysis, and nonlinear dynamic finite element crash analyses. Side and oblique impact simulations were performed when impacting a high and heavy SUV (2003 Ford Explorer) and low and light sedan (2010 Toyota Yaris). The two most common crash conditions were considered: a normal (90˚) impact representative of a street crossing and an oblique (45˚) impact representing a car turning in front of an LRV. Injuries due to collisions were evaluated using a model of the ES-2re Side Impact Dummy (SID). Injuries were calculated for the head, chest, abdomen, and neck using the Abbreviated Injury Scale (AIS).

Simulations were performed for LRV impact speeds of 20 mph against the automobiles. For this speed, the bumper is designed to remain usable in service. Adding the bumper to the collision interface significantly reduced the potential for serious injuries in all the collision scenarios evaluated. For example, the 2003 Explorer injuries were reduced from an AIS3+ (serious) chest injury probability of 48.5 percent without bumper to 21.8 percent with the bumper when considering normal (90°) side impact. For the 2010 Yaris, injuries were reduced from 100 percent AIS6+ (fatal) injury probability (due to head impact against the LRV anti-climber) to 12.4 percent.

The bumper was also designed to be functional and remain in service for LRV-to-LRV crash speeds of 5 mph. To protect against LRV collisions at higher speeds, the bumper side panels break away at 11 mph, and the existing LRV crash energy management performance is unaffected.

Once a prototype was manufactured, operational testing was conducted with an enclosure mounted to a TriMet Type 3 (SD660) LRV. The objective of these tests was to demonstrate compatibility with operational vehicles and to gather feedback from TriMet operators and maintenance staff. Testing of both powered and unpowered function was performed to raise and lower the front enclosure and coupling to another LRV. Operations went smoothly with no interference with car geometry. Moving operation was also performed to demonstrate compatibility with trackside structures. No issues were noted and good clearance with track-side equipment was recorded with video.

All three crash tests were successful in achieving the desired crash conditions. Both tests with the automobiles resulted in minimal damage to the enclosure, consisting only of scratches to the paint. There was no permanent deformation to the structure. The front enclosure was retracted and deployed after each crash test with no loss in function. In the breakaway test, the side panels sheared back as designed and the front enclosure pushed back beneath the anti-climber. In this way, the anti-climber is not obstructed for LRV-LRV collisions. Crash test results were consistent with pre-test crash simulations. In particular, the automobile deformation compares well with measurements. This agreement provides a partial validation of the analysis methods used to determine the reduction in injuries predicted from the matrix of crash simulations.

Benefits

Two case studies were considered to quantify the benefit of bringing existing LRVs up to current crash safety standards with regard to automobile and pedestrian safety. There was not a complete dataset in either case, but the light rail collision analysis performed by Valley Metro in Phoenix, AZ provides what is believed to be a lower bound on the cost of automobile and pedestrian collisions. The following items were considered in the cost analysis: (1) repair costs to LRVs, (2) loss of LRV use, and (3) value of statistical life (VSL). Using these costs as a lower bound, even a modest reduction in damage costs, loss of life, and injuries warrants the cost of retrofit.

Although the prototype bumper was designed specifically for the Siemens SD660 LRV in this study, the approach and structures were designed with the objective of being readily adapted for other LRV designs. There would likely be specific changes needed to attach the linkage mounts, for example, and/or changes to accommodate different front geometries. However, these changes could be more easily accomplished now that this prototype bumper has been designed and validated.

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Project Information

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