# Large Vehicles and Roadside Safety Considerations

JARVIS D. MICHIE

## ABSTRACT

Because three-quarters of highway traffic is composed of passenger sedans, most current roadside hardware has been designed to interact with this vehicle type because of technical and economic restraints. Recent trends in national data indicate that the percentage of vehicles larger than passenger sedans is increasing. In addition, as a result of the Surface Transportation Assistance Act of 1982, large trucks are expected to become wider and longer. The import of these trends is examined with respect to roadside safety considerations, in particular to the roadside features and hardware that may need to be upgraded.

Until the mid-1970s about 80 percent of all vehicle miles of travel in the United States was done by automobiles; the remaining 20 percent was attributed to (a) motorcycles, (b) buses, (c) large and small trucks, and (d) special vehicles such as concrete trucks. Roadside safety research concentrated primarily on the passenger automobile because it was the principal risk. Specifically accommodating any or all of the remaining 20 percent of the other vehicle types was considered technically and economically questionable. (Even within the passenger vehicle segment of the traffic stream, drastic downsizing has occurred since 1974 and has necessitated design modification to roadside hardware.)

The proportion of vehicles heavier than the 4,500-lb passenger sedan in the traffic stream has increased in the past 10 years with an attendant increase in roadside accidents involving larger vehicles. In response, more roadside safety research has been directed to the large vehicle problem by state and federal agencies. With the passage of the Surface Transportation Assistance Act (STAA) of 1982, there is concern about the effects that the longer and wider trucks permitted by the act will have on roadside safety.

The questions that are addressed here are (a) how serious is the large vehicle-roadside safety problem? (b) is the problem becoming more critical? and (c) what, if anything, can be done to lessen the problem?

## BACKGROUND

Although several state and private agencies performed some full-scale crash testing of roadside hardware before 1960, it was in September 1962 with the publication of Highway Research Board Circular 482 (1) that vehicle crash test procedures (and roadside safety research) were formalized. It is noteworthy that a 4,000-lb passenger sedan was indicated as the only test vehicle. In 1974 NCHRP Report 153 (2) presented more in-depth methods of evaluating highway appurtenances by vehicle crash testing and these methods were further refined in 1978 (3). However, only passenger sedans were specified as the test vehicles. It was not until NCHRP Report 230 (4) was published in March 1981 that test vehicles larger than a 4,500-lb passenger sedan were specified; even so, tests with larger vehicles were not considered required experiments but were recommended for use as supplementary experiments.

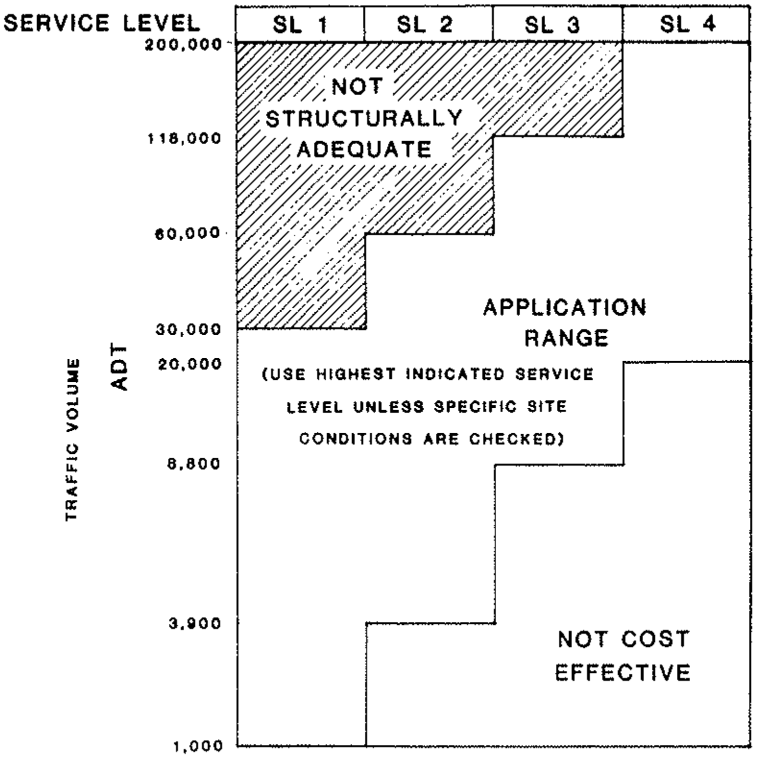
Irrespective of the lack of standardized crash test procedures, the FHWA in the early 1970s began exploring the technical feasibility of developing longitudinal barriers that would contain and redirect large vehicles. In the period 1972-1976 the collapsing ring bridge railing system was developed and evaluated for school bus, intercity bus, and tractor-trailer rig impacts; gross mass of one test vehicle was 70,000 lb (5). Also in 1976 the concrete median barrier was shown to have the capability of redirecting a 40,000-lb intercity bus (6). Early on, it was recognized that the high-performance barriers would have a premium cost compared with barriers designed to redirect only passenger sedans and could not be economically justified for general use. Instead, application of these special barriers would be limited to a few high-risk sites. A benefit-to-cost method was used in developing a multiple service level approach to warranting bridge rail systems (7).

As shown in Figure 1, traffic volume is the principal warranting factor for the four levels of service based on a benefit-to-cost analysis. Recently, other overriding factors have been proposed for an expanded array of bridge rail systems including the "tall wall" and "super tall wall" developed by Hirsch et al. at the Texas Transportation Institute (TTI) (8,9); sites for such high-performance barriers will probably be justified on the basis of "unacceptable consequences, regardless of the improbable risk of occurrence, of a heavy vehicle and/or its cargo penetrating the bridge rail." Examples of such sites might include a bridge that spans a critical water supply, a petrochemical plant, or a pedestrian mall.

Two large-vehicle accidents occurred in 1976 and focused national attention on the limited collision performance capability of bridge rail systems. The first on May 11 in Houston, Texas, involved a tractor-tanker carrying anhydrous ammonia that penetrated an overpass bridge rail and fell on freeway traffic. The second on May 24 involved a school bus that failed to negotiate an off-ramp curve in Martinez, California, penetrated the bridge rail, and resulted in 28 occupant fatalities. Although the FHWA had recognized the growing need for high-performance barriers, these two incidents focused national attention on large-vehicle safety and galvanized support for accelerated roadside safety research.

---

Dynatech Engineering, Inc., 301 South Frio, San Antonio, Tex. 78207.



*SL3 eliminated in NCHRP Report 230 and SL4 becomes a "new" SL3.

FIGURE 1 Traffic volume and bridge railing service level category summary (7).

TRAVEL GROWTH OF LARGE VEHICLES

During the period of 1970 to 1982 overall vehicle exposure measured in vehicle miles of travel (VMT) grew from 1.12 x $10^9$ to 1.59 x $10^9$ VMT or a 42 percent increase (10). This is shown in Figure 2. The passenger automobile part of this total travel grew from 0.9 x $10^9$ to 1.1 x $10^9$ VMT or 22 percent. The largest growth area was in the vehicle segment denoted as "single unit trucks," which more than doubled from 0.17 x $10^9$ to 0.38 x $10^9$ VMT.

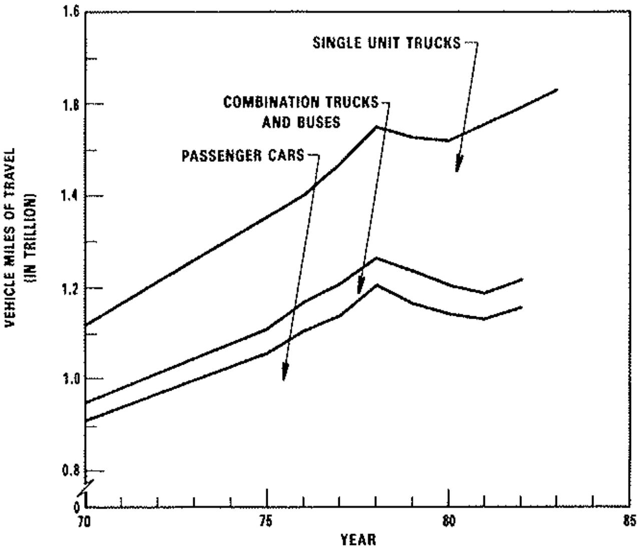


FIGURE 2 Travel growth by vehicle size.

This trend is further analyzed in Table 1. Findings of interest are

- Although passenger automobile travel continued to increase, its percentage of all travel decreased from 78.9 to 72.1 percent;
- Single-unit truck travel increased in both magnitude (i.e., 218.9 x $10^6$ to 376.7 x $10^6$ VMT) and percentage (i.e., 16.5 to 23.6 percent); and
- The combination truck and bus segment exhibited little travel growth and a decrease in percentage of overall travel.

From these statistics, it appears that the single-unit truck is the rapidly growing part of the traffic stream and there is little if any change in the combination truck and bus segment. Even with the effect of the STAA of 1982, the author speculates that the 4 to 5 percent of travel of combination trucks will not change significantly during the next decade. These are, of course, national averages and may not reflect local conditions. Specific routes such as the New Jersey Turnpike are used by a disproportionate amount of truck travel and would not be properly represented by these statistics.

The single-unit truck not the combination truck may represent the most important vehicle with regard to roadside safety. Insight into the type of vehicles that comprise the single-unit-truck segment can be obtained from Table 2 (10,p.17). Of the 2.7 million trucks sold in 1983, about one-half had a mass in the 0- to 6,000-lb range. Although it cannot be deduced from the figures in Table 2, it is judged that about 0.5 million of these vehicles have mass less than 4,500 lb and fall within the passenger vehicle test matrix of NCHRP Report 230. The conventional pickup and van probably represent the major

TABLE 1 Billions of Vehicle Miles of Travel *(10)*

| | Passenger Automobile Travel | | Single-Unit Truck[a] Travel | | Combination Truck and Bus Travel | | All Motor Vehicle Travel | |
|---|---|---|---|---|---|---|---|---|
| Year | VMT | Percentage | VMT | Percentage | VMT | Percentage | VMT | Percentage |
| 1975 | 1,050.5 | 78.9 | 218.9 | 16.5 | 60.7 | 4.6 | 1,330.1 | 100.0 |
| 1980 | 1,129.9 | 74.3 | 324.6 | 21.3 | 66.4 | 4.4 | 1,520.9 | 100.0 |
| 1982 | 1,148.9 | 72.1 | 376.7 | 23.6 | 66.9 | 4.2 | 1,592.5 | 100.0 |

[a] Principally vehicles weighing less than 10,000 lb also denoted as "light trucks and vans."

TABLE 2 Retail Sales of New Trucks by Franchised Dealers of U.S. Manufacturers *(10)*

| | Year | | | | | |
|---|---|---|---|---|---|---|
| Gross Vehicle Weight | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
| 0-6,000 lb | | | | | | |
| Utility | 79,588 | 74,878 | 50,842 | 36,389 | 50,735 | 253,823 |
| Car-type pickup | 83,522 | 77,094 | 49,696 | 37,080 | 25,305 | 26,170 |
| Compact pickup | | | | | | |
| Domestic | – | 78 | 25,525 | 59,431 | 359,177 | 433,167 |
| Import | 140,736 | 225,410 | 228,878 | 159,551 | 95,277 | 55,143 |
| Van | 126,072 | 110,393 | 78,871 | 74,983 | 74,546 | 67,299 |
| Mini van | – | – | – | – | – | 18 |
| Conventional pickup (includes extended and crew cabs) | 904,002 | 783,035 | 544,959 | 520,180 | 485,977 | 445,370 |
| Station wagon (truck chassis) | – | – | – | – | – | 8,394 |
| Mini passenger carrier | – | – | – | – | – | 8,174 |
| Passenger carrier | 472 | 439 | 6,446 | 8,333 | 10,608 | 16,364 |
| Total 0-6,000 lb | 1,334,392 | 1,271,327 | 985,217 | 895,947 | 1,101,625 | 1,313,922 |
| 6,001-10,000 lb | | | | | | |
| Utility | 275,790 | 205,181 | 107,541 | 70,938 | 76,457 | 84,493 |
| Van | 471,334 | 331,848 | 172,045 | 168,469 | 207,466 | 311,207 |
| Van cutaway chassis | 76,277 | 43,797 | 19,918 | 21,662 | 30,951 | 45,228 |
| Conventional pickup (includes extended and crew cabs) | 1,171,257 | 884,551 | 545,720 | 468,730 | 484,909 | 573,918 |
| Station wagon (truck chassis) | 100,395 | 73,294 | 38,807 | 37,564 | 54,517 | 68,844 |
| Passenger carrier | 6,398 | 4,792 | 65,917 | 56,964 | 74,992 | 76,985 |
| Multi-stop | 38,193 | 30,816 | 24,867 | 25,622 | 31,771 | 45,924 |
| Total 6,001-10,000 lb | 2,139,644 | 1,574,279 | 974,815 | 849,949 | 961,063 | 1,206,599 |
| 10,001-14,000 lb | 73,119 | 15,408 | 3,510 | 748 | 1,062 | 145 |
| 14,001-16,000 lb | 5,792 | 2,686 | 195 | 12 | 9 | 2 |
| 16,001-19,500 lb | 2,699 | 2,952 | 2,309 | 1,916 | 1,434 | 1,159 |
| 19,501-26,000 lb | 155,616 | 145,977 | 89,764 | 71,993 | 44,214 | 46,532 |
| 26,001-33,000 lb | 41,032 | 49,623 | 58,436 | 51,402 | 62,488 | 59,383 |
| 33,001 lb and more | 161,608 | 173,543 | 117,270 | 100,334 | 75,777 | 81,647 |
| Total | 3,913,902 | 3,235,795 | 2,231,516 | 1,972,301 | 2,247,672 | 2,709,389 |

part of vehicles in this group with mass greater than 4,500 lb. Even so, most of these vehicles would be at least marginally addressed by the NCHRP Report 230 procedures.

Vans and conventional pickups comprise a large part of the 1.2 million vehicles in the 6,001- to 10,000-lb mass range. It is unknown what part of the 200,000 odd vehicles with mass greater than 10,000 lb is combination trucks; regardless, it is less than 10 percent of the total 2.7 million vehicles.

The most important factors are that (a) about one-half of the truck population (i.e., that which weighs less than 6,000 lb) is at least grossly addressed by current NCHRP Report 230 test conditions; (b) another 45 percent of the total truck population weighs between 6,000 and 10,000 lb and is composed chiefly of conventional pickups and vans; and (c) the remainder, less than 10 percent of all trucks, have mass that extends from 10,000 lb to more than 33,000 lb. This last segment will include the new wider and longer vehicle provided by STAA of 1982 although it will be several years before there are significant numbers in the vehicle fleet.

## SAFETY ASSESSMENT

Roadside safety research addresses mainly the single-vehicle, ran-off-the-road accident scenario. This scenario begins with an inadvertent encroachment and concludes with either an unreported "drive-away" or a reported accident. Inadvertent encroachments have been the subject of extensive research in the past 20 years; findings indicate that highway geometrics (e.g., curves, grade, number of lanes) and traffic volume are the two main factors that affect the number of errant vehicles that leave the traveled way. With regard to traffic volume, accident statistics indicate that the number of each type of vehicle involved in roadside collisions is roughly proportional to its portion of the traffic stream.

An analysis of highway accidents for each major vehicle type is presented in Table 3 (10-12). Vehicles in accidents and vehicles in fatal accidents are compared with billion miles of travel for each vehicle type. Numbers of fatal accidents are reported events whereas the National Accident Sampling System (NASS) accident numbers are projected to a national basis from a scientifically controlled sample of 15,000 events. Table 3 includes multiple- as well as single-vehicle events. Findings of interest are that automobiles are overrepresented in accidents and underrepresented in fatal accidents. Light trucks and vans are underrepresented in both accidents and fatal accidents. Buses are representative in both. Heavy trucks are representative in acci-

TABLE 3 1982 Data on Accidents by Vehicle Type Compared with Exposure *(10-12)*

| | Exposure | | NASS-Projected Vehicles in Accidents | | Vehicles in Fatal Accidents | |
|---|---|---|---|---|---|---|
| Vehicle Type | Billion Vehicle-Miles | Percentage | No. (1,000) | Percentage | No. | Percentage |
| Passenger automobiles | 1,133.9 | 71.2 | 7,715.0 | 78.1 | 33,955 | 60.4 |
| Motorcycles | 15.0 | 0.9 | 177.0 | 1.8 | 4,420 | 7.9 |
| Special vehicles and unknown | | | 17.0 | 0.2 | 2,884 | 5.1 |
| Buses | 6.6 | 0.4 | 51.0 | 0.5 | 286 | 0.5 |
| Light trucks and vans[a] | 376.6 | 23.7 | 1,571.0 | 15.9 | 10,057 | 17.9 |
| Heavy trucks[b] | 60.3 | 3.8 | 344.0 | 3.5 | 4,588 | 8.2 |
| Total | 1,592.5 | 100.0 | 9,875.0 | 100.0 | 56,190 | 100.0 |

dents but overrepresented in fatal accidents. The seriousness of heavy-truck accidents may be attributed to the mismatch of the large truck mass compared with the smaller vehicle mass of other traffic, to the propensity of large trucks to jackknife, and to the longer distance required to decelerate heavy trucks.

A further analysis of types of vehicles in accidents is given in Table 4. The 9.8 million accidents that were extrapolated by NASS in 1982 are summarized by single-vehicle and miltiple-vehicle types, and then the single-vehicle accidents are examined for noncollision, fixed object, and other object. With regard to single-vehicle, fixed-object accidents, automobiles and heavy trucks are slightly overrepresented and light trucks and vans are underrepresented. It is noted that rollover or overturn accidents involving heavy trucks as well as jackknifing (i.e., other noncollision) are overrepresented with respect to exposure measure. With the projected increase in the number of double- and triple-trailer combinations that result from the STAA of 1982, the author speculates that these heavy-truck rollover and jackknifing types of accidents will increase. Moreover, the seriousness of these accidents in terms of property damage, injuries, and fatalities will probably also increase. On a national scale where heavy trucks represent only 3.8 percent of the traffic stream, it may not be cost-effective to provide high-performance roadside safety design to accommodate special requirements of the large mass vehicles. On the other hand, on specific routes where heavy-truck traffic greatly exceeds the 3.8 percent national average, the highway design engineer can and should take measures to minimize the occurrence and consequences of roadside excursion events.

As an independent check on the findings for light trucks and vans, insurance claim frequencies were examined for 1981-1983 for vans, pickups, and utility vehicles and these claim frequencies are shown in Table 5 (13).

It is clear that vans, pickups, and some utility vehicles are not involved in as many accidents as is the traffic fleet in general. The reason for this underinvolvement is not clear, but it may be attributable to travel patterns and driver profiles associated with this type of vehicle. Thus it is seen that while the volume of light truck and van traffic is increasing, this segment is relatively safe and is underinvolved in accidents.

## ROADSIDE DESIGN REQUIREMENTS FOR LARGE VEHICLES

In some cases vehicles larger than passenger sedans exhibit more demanding performance requirements for roadside appurtenances. In other cases, roadside interactions with these larger vehicles are less critical.

Specifically, breakaway structures such as sign and luminaire supports, which are usually designed for small automobile impacts, cause a lesser velocity change in the larger mass vehicles and are therefore less hazardous from that standpoint. On the other hand, the sign blank missile hazard to truck occupants may be another problem. Mounting height of the sign blank should be developed with regard to truck compartment geometry as well as to impact trajectory after passenger automobile impacts. These safety considerations are in addition to sign visibility and readability, which are also a function of mounting height.

Crash cushions are generally designed for two

TABLE 4 1982 Data on Single- and Multiple-Vehicle Accidents by Vehicle Type *(10,11)*

| | | | Single Vehicle | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exposure | | Noncollision | | | | | | | | | | | |
| | | | Rollover/Overturn | | Other[a] | | Fixed Object[b] | | Other Object[c] | | Multiple Vehicle | | Total Accidents | |
| Vehicle Type | Billion Vehicle-Miles | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| Passenger automobiles | 1,133.9 | 71.2 | 77,150 | 39.6 | 77,150 | 51.2 | 694,350 | 77.5 | 231,450 | 81.9 | 6,634,900 | 79.5 | 7,715,000 | 78.1 |
| Motorcycles | 15.0 | 0.9 | 49,560 | 25.5[d] | 1,770 | 1.2 | 19,470 | 2.1 | 7,080 | 2.5 | 99,120 | 1.2 | 177,000 | 1.8 |
| Special vehicles | | | 170 | | | | | | 340 | 0.1 | 16,490 | 0.2 | 17,000 | 0.2 |
| Buses | 6.6 | 0.4 | | | 500 | 0.3 | | | 1,500 | 0.5 | 49,000 | 0.6 | 51,000 | 0.5 |
| Light trucks and vans[e] | 376.6 | 23.7 | 47,130 | 24.2 | 47,130 | 31.3 | 141,390 | 15.8 | 31,420 | 11.0 | 1,303,930 | 15.6 | 1,571,000 | 15.9 |
| Heavy trucks | 60.3 | 3.8 | 20,640 | 10.6 | 24,080 | 16.0 | 41,280 | 4.6 | 10,320 | 3.5 | 247,680 | 2.9 | 344,000 | 3.5 |
| Total | 1,592.5 | 100.0 | 194,650 | 100.0 | 150,630 | 100.0 | 896,490 | 100.0 | 282,110 | 100.0 | 8,351,120 | 100.0 | 9,875,000 | 100.0 |

[a] Jackknifing of combination units, explosions, immersion, gas inhalation, etc.
[b] Buildings, bridge abutments, poles, trees, etc.
[c] Animals, trains, etc.
[d] Motorcycle overturning accidents are different in nature from rollover of other vehicles because of the inherent instability of two-wheeled vehicles.
[e] Vehicles less than 10,000 lb.

TABLE 5 1981-1982 Insurance Claim Frequency for Light Trucks and Vans (13)

| Make | Relative Claim Frequency | Exposure (vehicle-years) |
|---|---|---|
| All passenger automobiles | 100 | 4,696,446 |
| All vans | 64 | 133,267 |
| Small pickups | 86 | 245,250 |
| Standard pickups | 60 | 380,858 |
| Small utility vehicles | 97 | 24,434 |
| Intermediate utility vehicles | 58 | 51,081 |
| Large utility vehicles | 43 | 10,837 |

conflicting conditions: softness and stroke efficiency. For softness, a low-level interaction force must be maintained to protect occupants in small-vehicle collisions. For larger automobiles, the crash cushion must have sufficient stroke to absorb the kinetic energy yet be compact in size to adapt to most sites. Crash cushions are generally staged with a soft nose and a crush stiffness that increases along its length. Labra (14) examined the feasibility of extending crash cushion design capability to include large vehicles. Two vehicle properties limit this application. First, semitractor-trailer rigs are inherently unstable vehicles and will readily jackknife after even a minor collision or sudden maneuver. Second, cargo restraints, especially for flatbed trailers, are designed for braking forces (about 1 g) and are inadequate for normal crash cushion forces of 8 to 10 g's. Under crash cushion collision conditions, a cargo would readily break loose from the tie-down restraint and move forward crushing the driver cab. For these reasons, it is judged impractical to develop crash cushions for very large trucks. On the other hand, it would be practical to develop crash cushions for light trucks and vans with mass of up to 10,000 lb.

A roadside feature that is specially designed for very large trucks is the escape ramp. These features are situated at the bottoms of long, steep inclines where trucks are likely to loose their brakes and require emergency assistance in stopping. Several techniques have been successfully used among which are elongated beds of loose gravel and a reverse incline. These designs are contained in current standard design specifications and will not be discussed further here.

In the past 15 years research has been directed to longitudinal barriers designed to contain large 80,000-lb vehicles. Such barriers are not insignificant because they must accommodate kinetic energy levels 40 times that of small 2,000-lb passenger sedans. Two principal factors govern performance of a longitudinal barrier: height to interact with a substantial structural element of the vehicle and structural strength to sustain the impact force. It is noted that the tractor-trailer rig has two separate components that must be redirected. Barrier height must be sufficient to interact with major structural elements of both the tractor and the trailer. For van-type trailers, a height of 5.5 ft has been shown to be adequate. On the other hand, the midheight of a tanker trailer is about 84 in., and an adequate barrier height is about 90 in. Hirsch (9) has recently developed and demonstrated two high-performance bridge rail systems to contain and redirect 80,000-lb tractor-trailers. Hirsch determined that critical barrier loading occurs when the rear tandem axles of the tractor rotate into the barrier with a 50-ms peak acceleration of 5.5 to 6.0 g's. Coupled with local vehicle mass of 34,000 lb, the applied horizontal loading is about 200,000 lb. It is speculated that the 200,000-lb force will not be exceeded by the longer and wider vehicle permitted by the STAA of 1982.

With the exception of the concrete safety shape (i.e., New Jersey) barrier and the recently developed SERB system, most current guardrail and median barrier operational systems cannot contain or redirect large trucks and buses including the wider and longer vehicles that are being introduced into the traffic stream. Benefit studies reveal that high-performance longitudinal barriers are generally too costly for highways with only 3.8 percent heavy-vehicle traffic but may be justified for those sites where the truck traffic exceeds 25 percent of the total traffic stream.

## SUMMARY

Key findings developed in this paper with regard to large vehicles and roadside safety are

1. Travel growth
   - Single-unit truck travel is increasing both in VMT and as a percentage of all VMT.
   - Combination truck and bus travel is static and is decreasing as a percentage of all VMT. Local traffic properties may differ markedly from these national averages.
   - A large part of the single-unit truck segment is composed of pickups and vans that weigh less than 10,000 lb. Only about 8 percent of all 1983 truck sales were trucks weighing more than 10,000 lb.
2. Accident experience
   - Light trucks and vans are underrepresented in (a) total, (b) single-vehicle, (c) single-vehicle and fixed-object, and (d) fatal accidents. On the other hand, the number of noncollision rollovers or overturns is representative of the total traffic mix.
   - Heavy trucks are representative in (a) total, (b) single-vehicle and fixed-object, and (c) multivehicle accidents but overrepresented in (a) overturn or rollover, (b) jackknifing, and (c) fatal accidents.
3. Roadside design requirements
   - Breakaway structures such as signs and luminaire supports do not pose a severe hazard to the large vehicle if the sign blank missile hazard is properly treated.
   - Crash cushions are not technically feasible for heavy trucks. However, designs to accommodate light trucks (i.e., up to 10,000 lb) should be considered.
   - Longitudinal barriers such as bridge rails, guardrails, and median barriers are being designed to accommodate the largest vehicles but are relatively expensive and therefore sites must be carefully selected.
   - Shoulder sideslope may need to be examined with regard to truck overturns and rollovers.

## REFERENCES

1. Full-Scale Testing Procedures for Guardrails and Guide Posts. Highway Research Board Circular 482. HRB, National Research Council, Washington, D.C., Sept. 1962.
2. M.E. Bronstad and J.D. Michie. Recommended Procedures for Vehicle Crash Testing of Highway Appurtenances. NCHRP Report 153. TRB, National Research Council, Washington, D.C., 1974, 19 pp.
3. Recommended Procedures for Vehicle Crash Testing of Highway Appurtances. Transportation Re-

search Circular 191. TRB, National Research Council, Washington, D.C., Feb. 1978, 27 pp.
4. J.D. Michie. Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances. NCHRP Report 230. TRB, National Research Council, Washington, D.C., March 1981, 42 pp.
5. C.E. Kimball et al. Development of a Collapsing Ring Bridge Railing System. Final Report. FHWA, U.S. Department of Transportation, 1976.
6. M.E. Bronstad et al. Concrete Median Barrier Research. Final Report FHWA-RD-77-4. FHWA, U.S. Department of Transportation, June 1976.
7. M.E. Bronstad and J.D. Michie. Multiple Service-Level Highway Bridge Railing Selection Procedures. NCHRP Report 239. TRB, National Research Council, Washington, D.C., Nov. 1981.
8. J.D. Michie, M.E. Bronstad, and L.R. Calcote. Proposed Performance Standards for Bridge Rails. Task A Interim Report. FHWA, U.S. Department of Transportation, April 1984.
9. T.J. Hirsch and W.L. Fairbanks. Bridge Rail to Contain and Redirect 80,000-lb Tank Trucks. In Transportation Research Record 1024, TRB, National Research Council, Washington, D.C., 1985, pp. 27-34.
10. MVMA Motor Vehicle Facts & Figures '84. Motor Vehicle Manufacturers Association, Detroit, Mich., 1984.
11. National Accident Sampling System 1982. NHTSA, U.S. Department of Transportation, 1982.
12. Fatal Accident Reporting System 1982. National Center for Statistics and Analysis, NHTSA, U.S. Department of Transportation, 1982.
13. Insurance Losses--Personal Injury Protection Coverages, 1981-1983 Models. Research Report HLDI 183-1. Highway Loss Data Institute, Washington, D.C., Sept. 1984.
14. J.J. Labra. Impact Attenuators for Heavy Vehicles--A Feasibility Study. Phase 1 Final Report. FHWA, U.S. Department of Transportation, Aug. 1980.

---

# Longitudinal Barriers for Buses and Trucks

**T. J. HIRSCH**

## ABSTRACT

In May 1976 two significant accidents occurred involving traffic bridge rails. An ammonia truck in Houston, Texas, struck a bridge rail leaving 11 dead, 73 hospitalized, and causing 100 other injuries for a total of 184 casualties. In Martinez, California, a school bus struck a bridge rail and left 29 dead and 23 injured. As a result of these accidents, an extensive effort has been made to develop longitudinal traffic barriers or rails capable of restraining and redirecting buses and large trucks. The results of 34 crash tests conducted using automobiles and mostly buses and trucks on 16 different traffic rails were obtained from the references. Vehicles represented are 4,500-lb passenger automobiles, a 4,000-lb van or light truck, 20,000-lb school buses, 32,000- to 40,000-lb intercity buses, and 40,000- to 80,000-lb tractor-trailer trucks. Results of these crash tests are summarized. Theory and crash test results are presented to demonstrate the magnitude of the impact forces these traffic rails must resist and how high they must be to prevent vehicle rollover. Typical designs of longitudinal barriers that have been successfully crash tested in accordance with recommended procedures are presented.

In May 1976 two significant accidents involving traffic rails occurred. An ammonia truck in Houston, Texas, struck a bridge rail and fell on traffic below leaving 11 dead and 73 hospitalized and causing 100 other injuries for a total of 184 casualties. In Martinez, California, a school bus struck a bridge rail and fell upside down leaving 29 dead and 23 injured. As a result of these accidents, an extensive effort has been made to develop longitudinal traffic barriers or rails capable of restraining and redirecting buses and large trucks.

Before 1956, when the Interstate Highway Act was passed by Congress, most highway bridges crossed rivers, streams, or other natural features. Few highways had traffic lanes divided or separated by median barriers. Longitudinal barriers such as bridge rails, median barriers, and guardrails were designed only to restrain and redirect passenger automobiles. It was the general attitude that buses and trucks were driven by trained, skilled, professional drivers, and sensational traffic barrier accidents with buses and trucks were rare.

Since 1956 tens of thousands of miles of divided traffic lane Interstate highways, urban expressways, and freeways have been built. Most of the bridges

---

Texas Transportation Institute, Texas A&M University, College Station, Tex. 77843.