J. Test Requirements for Safety Barriers and Light Poles on Australian Roads
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The design of safety barrier systems should consider characteristics and mass of the vehicle fleet as well as drivers' behaviors and aspirations. The Australian road network and demographic characteristics are described. Accident characteristics that might affect the full-scale testing requirements for safety barriers and lighting luminaries are discussed; the concerns and requests for new hardware made by the Australian road authorities are outlined.

Australian Road Network

The Australian roadways system and demographic conditions are unique. Australia has a population of about 16 million people and an area of 7.6 million km^2. The overall population density is about 2.1 persons/km^2, which is much less than the densities in other developed countries. Australians are becoming progressively more urbanized; some 62 percent of the population reside in capital cities. The population density of the greater part of the rural areas is less than 0.04 persons/km^2.

Australians are very mobile. Vehicle ownership in Australia is about 42 passenger cars per 100 persons. This value is similar to the value of 50 passenger cars per 100 persons in the United States. The average distance traveled in both countries is about 16,500 km per year.

Australia's road network is about 760,000 km in length, giving a road network density of about 0.1 km/km^2, compared with 0.7 km/km^2 in the United States and 1.5 km/km^2 in the United Kingdom. Table 13 also indicates that the length of road per person in Australia is about double that in the United States and about eight times that in the United Kingdom. In 1975, about 115,000 km of the rural road network was used to provide access to major cities and towns. About 0.3 percent of this rural network had separate carriageways for each direction (i.e., divided roads).

In 1983, there were about 1,086 km of divided rural road and about 1,765 km of divided urban road, with a further 177 km of freeway or motorway. Much of the urban divided road system has an arterial road function with considerable access to and from abutting properties and road. Most of these urban arterial roads cannot be conveniently protected with a median barrier. The divided rural road system and the urban freeway system are high-speed facilities and constitute 0.12 percent of the road network. Hence, the Australian high-speed road system consists predominantly of two-lane rural roads with only short lengths of divided road or freeway.

TABLE 13 DEMOGRAPHIC DETAILS

Country	United Kingdom	United States	Australia
Area (10^3 km^2)	224.0	9,373	7,682
Population (10^6 persons)	56.7	243.2	16.0
Population density (persons/km^2)	233	26	2.1
Road length (10^3 km)	351	6,366	790
Road length per person (m)	6.2	26.2	49.3
Motorway (10^3 km)	3.0	69.2	0.79

Since 1983, there has been a reduction in Australian federal government funding, and even if this funding remains static at 1987-1988 levels, there will still be a reduction in the amount of effort in new road works. Therefore, Australia's road network is not expected to be extended significantly in the foreseeable future. However, continued duplication of rural roads is expected, and a median barrier protection may be required on these roads. It is estimated that between 45 and 150 km per year will be duplicated, depending on road funding policies.

Thc traffic carried on these divided roads is expected to increase dramatically. In 1981, the 4 percent of the duplicated national highway carried 26 percent of the traffic. This trend is expected to continue, with the divided road system carrying about 9,600 million vehicle-kilometers in 1991. The road system will continue to have more traffic as the number of vehicles on register and the total distance traveled continue to increase.

A consequence of this increased traffic is the growing need to make the road system safer. It also becomes more cost-effective to install safety barriers. The lack of construction of new roads puts even more pressure on the existing system. There will be a continuing and increasing need for improved safety standards both on rural divided and undivided roads. This need will result in more safety barrier protection on the outer verge and on the median for divided roads. The increase in traffic will also require more traffic lanes. Again, this will put pressure on the road safety system and require the use of safety systems that operate in these locations. Some road authorities have been concerned about the reduction in verge widths, which has virtually eliminated the breakdown lanes adjacent to the median on some roads. If an accident occurs, access becomes severely restricted and travel is hazardous.

Australian Vehicle Fleets

The Australian passenger car vehicle fleet has been changing over recent years. The fuel crisis in the 1970s led to increased sales of smaller vehicles. Since then, the mass of the vehicle fleet has been increasing. Australians now prefer to buy larger cars than they did in the 1970s.

The Australian vehicle manufacturers are now producing world cars. These vehicles are essentially the same as others available in Japan, Europe, or America. This world car concept has caused vehicle fleets to be similar in many parts of the world. Figure 14 shows the proportion of new cars with tare masses less than the values indicated. Although data are only available for seven years, they do indicate that there has been a marginal trend to larger vehicles during this time.

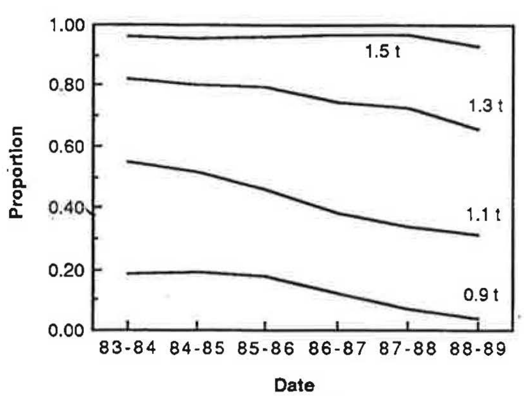

FIGURE 14 Distribution of the tare masses of new passenger cars and station wagons.

Data are not available for the year 1989-1990, but it is expected that these trends would continue. Table 14 presents the approximate median and 85th percentile passenger car vehicle masses. Over the recent 6-year period, the median vehicle mass has increased by 140 kg and the 85th-percentile value by 100 kg. This increase is comparable with the weight of an average occupant. The 95th-percentile value is close to 1.5 tonnes throughout the period. An analysis of the mass of vehicles on register was not able to establish "a significant downsizing effect." This result is contrary to the U.S. scene where there has been significant downsizing.

TABLE 14 VEHICLE MASSES

Year	50th Percentile Tare Mass (t)	85th Percentile Tare Mass (t)
1983-84	1.07	1.34
1984-85	1.09	1.36
1985-86	1.12	1.36
1986-87	1.16	1.39
1987-88	1.18	1.40
1988-89	1.21	1.41

The passenger car vehicle fleet in Australia is similar to that of the subcompact sedan. The smaller (lighter) vehicles may be more frequently involved in overturning accidents. Viner indicates that this increased frequency implies a greater use of safety barriers. Improved guard fence designs may also be required to better redirect these smaller vehicles. The current U.S. barriers performed better with the midsized vehicles.

There were approximately 44,000 heavy vehicles registered in Australia during 1988-1989, and when compared with the 523,000 light vehicles, this number represented less than 8 percent of all vehicles. A subset of heavy vehicles is rigid trucks, which constitute about 3.7 percent of the new vehicle sales. More than 50 percent of the rigid trucks include the 4x4 passenger vehicles. If these vehicles are excluded, then the proportion of rigid trucks in each mass category is shown in Figure 15. The 85th-percentile rigid truck for freight transport weighs about 16 tonnes.

The proportion of articulated vehicles is shown in Figure 16. Almost half of the articulated vehicles were in the over-40-tonne category. Unfortunately, a better breakdown of the figures was not available. In the northwestern part of Australia, large combination vehicles up to 50 m long and with a gross combination mass of 115 tonnes operate. These large combination vehicles have up to three articulated trailers, but although their mass is high they can be redirected reasonably easily. As soon as the prime mover is redirected by a safety barrier, the other units are pulled along or away from the barrier.

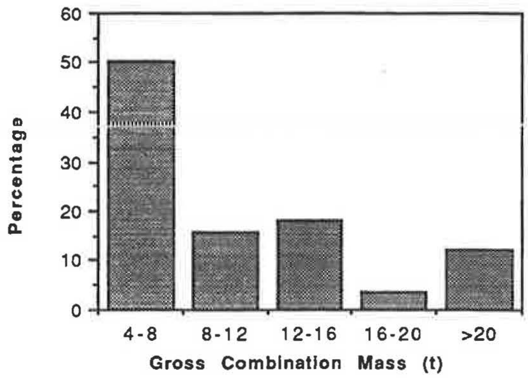

FIGURE 15 Proportion of rigid trucks over 4 tons registered during 1988-1989.

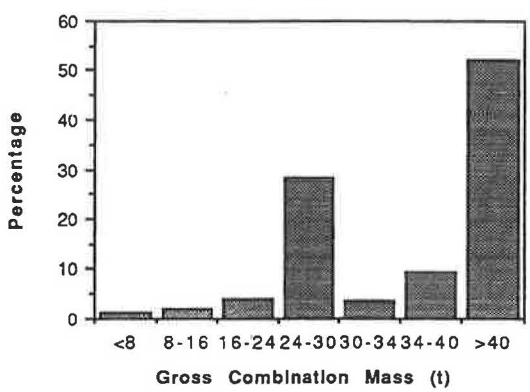

FIGURE 16 Proportion of articulated trucks registered during 1988-1989.

Speeds

Vehicle speeds on Australian rural roads are generally high. The mean speed of cars on rural roads in Victoria was 98 km/hr when the speed limit was 100 km/hr. The 85th-percentile speed was 109 km/hr. On urban roads, the mean speed is less than the statutory speed at the higher legal speeds, but significantly greater than the legal speeds for the lower-speed areas (see Table 15).

The speeds of large combination vehicles are governed to 85 km/hr. In some Australian states, interstate articulated vehicles are governed to 100 km/hr. The mean speeds of singly articulated vehicles were determined to be 89 and 80 km/hr for large combination vehicles on a single-lane bridge. (Traffic in one direction had to give way to traffic approaching from the other direction.) These mean speeds were less than those expected on a two-lane road or bridge. However, the governed speeds would be typical for most heavy vehicles.

Barrier impact speeds can be less than the travel speeds on roads if the verge offers some retardation. Similarly, the impact speeds may be greater than the travel speeds if the verge has an embankment falling down away from the road. It is recommended that the impact speeds should be equal to the traveled speeds.

A design impact speed for urban freeways and for rural roads should be greater than the 85th-percentile speed. Values of 110 or 113 km/hr (70 mph) are suggested.

Accident-Related Data

A recent in-depth study of single-vehicle accidents was conducted in Victoria by Armour, Carter, Cignegrana, and Griffith. A team of investigators collected data from fatal or injury-producing accidents on roads for which the speed limits were greater than 100 km/hr. It was further required that the injuries were severe enough to require hospitalization.

Data were collected concerning the following factors:

- The accident site (road geometry, roadside design, roadside objects, road condition, and delineation);
- The road network that contained the accident site (traffic counts, preceding curve geometry, gradients, and cross sections);
- The vehicle involved in the accident (vehicle defects were noted);
- The drivers involved in the accident (origin-destination information);
- Trip types by other drivers using the road at a similar time and day to those of the accident; and
- The speeds of drivers using the road at a similar time and day to those of the accident.

Using these data, the probable contributing factors were investigated. These factors were those considered to cause the accident and those that increased the severity after the accident process had begun. A further list of possible factors was also identified. The percentage of accidents contributed by a range of factors was listed. Note that there may be more than one probable contributing factor for each accident. Figure 17 shows the percentage of accidents in which the factor was a probable cause and when the factor was a possible cause. Almost two-thirds of the accidents occurred during the day, with only 32 percent at night and 5 percent at dawn or dusk.

TABLE 15 FREE SPEED DATA

		Mean Speed (km/hr)			85 Percentile Speed (km/hr)		
Subgroup	Number of Sample Sites	Cars	Rigid Trucks	Articulated Trucks	Cars	Rigid Trucks	Articulated Trucks
Rural Victoria speed limits: Cars 100 km/hr HCVs 65 km/hr	26	98	78	80	109	88	89
Urban Victoria speed limits: Cars 100 km/hr HCVs 65 km/hr	2	92	73	73	100	82	84
Urban Victoria speed limits: Cars 74 km/hr HCVs 65 km/hr	10	72	59	57	80	68	67
Urban Victoria speed limits: 6 Cars 60 km/hr HCVs 50 km/hr	18	66	59	58	74	66	66
Urban New South Wales speed limits: Cars 100 km/hr HCVs 80 km/hr	4	102	77	80	116	85	92

HCVs = heavy commercial vehicles.

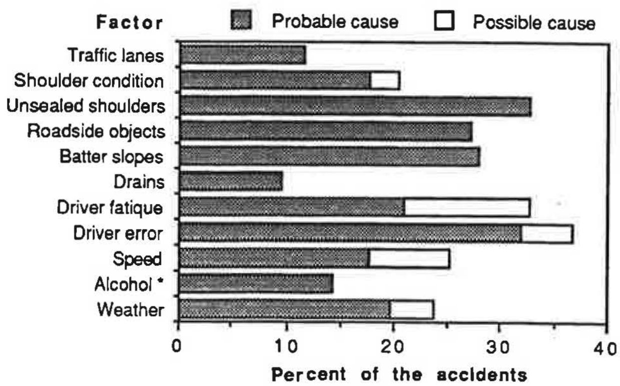

FIGURE 17 Probable and possible contributing factors to high speed vehicle accidents in Victoria, Australia.

It has also been reported that "in 27 percent of cases, roadside objects were considered to have been probable contributing factors to the severity of the accident. Out of 147 accidents, 110 involved a vehicle striking either a fixed roadside object, an embankment, or a cut batter slope. The most common objects struck were trees. In 54 percent of cases, the first object struck was less than 5.0 m from the traffic lane, and 89 percent of objects were less than 10 m from the traffic lane."

These comments reinforce the importance of forgiving roadsides. The high incidence of vehicles colliding with roadside objects is an expected outcome when drivers leave the road, but it indicates that drivers are not regaining control during the incident. The fact that 11 percent of objects were collided with even though they are more than 10 m from the traveled way indicated that clear zones greater than 9 or 10 m are required. There is no evidence of the frequency of other factors that may also contribute to a wider clear zone.

It has also been reported that "the major accident factor related to road design or road conditions was the presence of unsealed shoulders. The most common pattern being that drivers lost control of their vehicles after allowing the vehicle to move onto the left hand shoulder. The poor condition of many shoulders also played a part in many cases. Traffic lane problems played a part in a number of accidents, with the most common problem being a degraded road surface. Low skid resistance was recorded at 35 percent of accident sites."

The overriding factor is the loss of control on either the shoulder or in the traffic lanes. In either case, it can be assumed that many drivers will not be tracking when they hit the object or the barrier. Some accidents have involved the sides of vehicles impacting with guardfence terminals. This aspect of some traffic accidents has been of concern to a number of Australian road authorities.

It is recommended that nontracking, full-scale impacts be used for all types of hardware. These are seen to be more essential for those impacts involving the lighter vehicles.

Road Safety Products and Testing

Most drivers in Australia wear seat belts. It is mandatory that they be used and the observance of the law is high. It is therefore reasonable for the dummies to be restrained by seat belts during full-scale tests.

Australian road authorities have tended to use American safety products in the past. There are some moves now to use techniques from other continents.

The testing of safety devices has typically followed the American standards as in NCHRP Report 230. For example, two series of full-scale tests on lighting standards have been described. In both cases, a 1200-kg vehicle was used, and the impact speeds ranged from 17 to 58 km/hr for frontal impacts and about 35 km/hr for side impacts. Although it was recognized that these were low-energy collisions, the appraisal of the results was examined using the NCHRP Report 230 requirements. Unfortunately, the accelerations were averaged over 50 msec instead of the now-preferred 10-msec period. Nevertheless, the intention has been to conform to the U.S. safety barrier test procedures.

Australia has its own standards for the static testing of light standards. These tests require that both slip-base and impact-absorbent lighting poles must support a lantern with a mass of 20 kg and a projected area of 0.25 m^2. The design wind velocity is 39 m/sec, and the wind drag coefficients are 0.5 for the lanterns and 1.1 for the brackets. Further, the "deflection at the top of the pole when subject to a test load equal to 50 percent of the design load (dead load and wind load) . . . shall not exceed 5.5 percent of the nominal pole height." Refer to the standard specifications developed by Roads Corporation, Victoria.

Some designs that have performed satisfactorily when impact tested have failed these static test standards. It is important to develop suitable loadings for these standards and to apply appropriate dead loads to the lighting pole before dynamic testing. It is obviously not necessary to apply the wind loads when the standard or the pole is subjected to full-scale testing.

Future Requirements

In a discussion of the update of NCHRP, Ross and Michie commented:

"Another changing need is to develop roadside features with a range of performance capabilities and associated test procedures to evaluate the features." This range of performance levels allows the user to evaluate the use of the barrier in a particular location after deciding whether the features of the barrier will meet the requirements of the user and the authority. The multiple performance levels can be used in a benefit-cost analysis. In Australia, a cost-benefit analysis is not detailed for each installation, but rather included in the warrants for a barrier. (The warrants do not indicate when a barrier would offer improved post-impact conditions for a single driver, but rather when it would be cost-effective to install a barrier given the number of road users.) Nevertheless, it would be useful for Australian road authorities to have an indication of suitable substitute configurations.

More effort is required to develop barriers for the lower service level roadways. This effort certainly will be of benefit to Australian road authorities. Australia is a big country with many areas having a very low road density. Low-cost barriers would be of considerable value.

It has been suggested that "state-of-the-possible" criteria "could allow use of structures that vastly improve the safety of the traveling public while not meeting all the requirements of the NCHRP Report 230 or *Transportation Research Circular 191*." This would seem to be very useful and could be further developed using a set of qualitative statements that describes the full-scale test outcome and performance. There is at times a desire to use only quantitative measures. However, these should be augmented using qualitative measures. Tests that just fail could be so documented. Hardware that had a very poor performance should also be identified.

Australian authorities would favor the use of surrogate test vehicles. These have the potential of reducing testing costs at least for initial tests. The FHWA Federal Outdoor Impact Laboratory (FOIL) in McLean, Virginia, looks most promising. A standard and readily constructed generic car, pendulum, or bogie would be the most acceptable. This choice should allow testing from a large number of locations to be combined. Along with a standardized surrogate testing facility, some thought should be given to minimizing the specialized equipment and test facilities required for these tests. Australian authorities do not see that it is necessary to retest hardware used on Australian roads if well-documented tests have been undertaken in the United States, the United Kingdom, or Europe. However, it would be desirable if some standard preliminary testing could be undertaken on a new Australian innovation, if necessary.

There is a growing perceived need for a flexible barrier that would offer greater occupant protection through decreased decelerations. A cable barrier is considered appropriate as it offers the flexibility and is less visually obtrusive. There is concern about the possible excessive loading of cables on the A pillar of a car. There is also a greater possibility of vehicles overturning. Of the collisions with the median barrier of cable type, 3.9 percent were some 60 percent greater in the same year. The median cable barrier is no longer used on new construction. Nevertheless, it would be suitable to use a more flexible barrier with greater deflections on some freeways with moderate-to-light traffic volumes and wide medians.

The Australian passenger car fleet closely resembles the European fleet although our heavy commercial vehicle fleet can be very large. In the northwestern region of Australia, large combination vehicles operate and can impose considerable load on the barriers. Fortunately, these vehicles operate on roads where safety barriers would not normally be required.

On motorway sections of the road system, many Australian authorities are constructing extra lanes in the brake-down lanes. This process can often mean that accidents on the motorway can cause considerable and long-lasting congestion. Authorities are now constructing gates in the median barriers to allow vehicles to bypass an accident site. These gates remain untested. At other sites, relocatable barriers are used in the median. These offer the advantage that emergency openings can be quickly constructed. The Tric-Bloc barrier is an example that has been used in these circumstances.

Conclusion

Australia is a large country with long road lengths per head of population and for each registered vehicle. The protection of all errant vehicles under these conditions is costly. The long distances also affect travel speeds. The 85th-percentile speed on important highways on the eastern seaboard is around 110 km/hr. On other roads in the northwestern areas, speeds can be much higher. There has not been a significant downsizing of the passenger car vehicle fleet; the 85th-percentile mass is currently about 1.4 tonnes. A subcompact vehicle type is considered to be suitable for Australian conditions. The gross combination masses of commercial vehicles are varied. Some vehicles have a gross combination mass of 120 tonnes, whereas the median mass is less than 4 tonnes.

The structural requirements for Australian safety appurtenances have generally been based on the standards set out in NCHRP Report 230. This is historical because the Australian road authorities have based safety barrier requirements on the American practice. There have been few full-scale tests on safety barriers in Australia and those that have been done have generally been of a preliminary nature. Nevertheless, the NCHRP Report 230 testing requirements have been used in, or have been the basis of, the Australian tests.

It is recommended that an update of NCHRP Report 230 include

- Use of multiple performance levels;
- Provision for tests on safety barriers for low-volume roads;
- Use of standardized qualitative and quantitative test standards; and
- Use of surrogate test vehicles, pendulum testing, and bogies, including generic cars or test vehicles.