12. D.L. Ivey, C.E. Buth, M.L. Love, and W.L. Campise. The Response of Atypical Vehicles During Collisions with Concrete Median Barriers. Texas Transportation Institute, Texas A&M University, College Station, Jan. 1985.
13. T.J. Hirsch and E.R. Post. Truck Tests on Texas Concrete Median Barrier. Research Report 146-7. Texas Transportation Institute, Texas A&M University, College Station, Dec. 1972.
14. T.J. Hirsch, W.L. Fairbanks, and C.E. Buth. Concrete Safety Shape with Metal Rail on Top to Redirect 80,000 lb Trucks. Research Report 416-1F. Texas Transportation Institute, Texas A&M University, College Station, Dec. 1984.
15. T.J. Hirsch and A. Arnold. Bridge Rail to Restrain and Redirect 80,000 lb Trucks. Research Report 230-4F. Texas Transportation Institute, Texas A&M University, College Station, Nov. 1981.
16. T.J. Hirsch and W.L. Fairbanks. Bridge Rail to Restrain and Redirect 80,000 lb Tank Trucks. Research Report 911-1F. Texas Transportation Institute, Texas A&M University, College Station, Feb. 1984.
17. T.J. Hirsch. Analytical Evaluation of Texas Bridge Rails to Contain Buses and Trucks. Research Report 230-2. Texas Transportation Institute, Texas A&M University, College Station, Aug. 1978.
18. T.J. Hirsch, J.J. Panak, and C.E. Buth. Tubular W-Beam Bridge Rail. Research Report 230-1. Texas Transportation Institute, Texas A&M University, College Station, Oct. 1978.
19. A. Arnold and T.J. Hirsch. Bridge Deck Designs for Railing Impacts. Research Report 295-1F. Texas Transportation Institute, Texas A&M University, College Station, Nov. 1983.
20. E.O. Wiles, C.E. Kimball, and M.E. Bronstad. Evaluation of Concrete Safety Shapes by Crash Tests with Heavy Vehicles. In Transportation Research Record 631, TRB, National Research Council, Washington, D.C., 1977, pp. 87-91.
21. J.A. Bloom, T.J. Rudd, and J.J. Labra. Establishment of Interim Guidelines for Bridge Rails Required to Contain Heavy Vehicles. Reports FHWA-RD-75-45, FHWA-RD-75-46, and FHWA-RD-75-47. FHWA, U.S. Department of Transportation, Vols. 1-3, Nov. 1974.
22. R.M. Olson, E.R. Post, and W.F. McFarland. Tentative Service Requirements for Bridge Rail Systems. NCHRP Report 86. HRB, National Research Council, Washington, D.C., 1970.

Traffic Control Device Problems Associated with Large Trucks

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ABSTRACT

The changing pattern of traffic and increased truck volumes and sizes are resulting in blockage of road signs. The inability of drivers to see advisory and warning signs will result in an increasing number of accidents leading to a growing number of law suits with the states as defendants. There are some guidelines that engineers can use, but a general solution is not available at this time.

How often do you find that your view of the road ahead is suddenly obliterated by a truck pulling into the lane in front of you? Then you look in your rear view mirror to find yourself sandwiched between two units with a third passing to your left, and, in the congestion and confusion, you miss an important directional or advisory sign. How many people realize that when they pull out to pass a truck, they may also be cutting off their view of all signs for the next 1/4 mi? And who of us can read a sign more than 1/4 mi away?

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There are potential accident situations developing as a result of the presence of more trucks on the road. Think of drivers misreading, misinterpreting, or missing a sign altogether because of total or partial blockage and then overreacting or overcompensating, or both, in an effort to recover from the situation in which they find themselves. They miss a ramp, pass the intersection at which they should have turned, are in the wrong lane for through traffic, do not see a stop sign, or are confronted with a sudden traffic pattern change. The legal ramifications for the political entity that is responsible for the roadway could be devastating.

Ours is a society that believes that if there is a problem, the solution is to sue. For a plaintiff to get a case into court, he need only show that the defendant--state, city, or borough--knew that conditions existed that might potentially result in an accident. This places the question of actual negligence in the hands of the jury. Unfortunately, the question is all too often decided by emotions, how much sympathy the attorney can generate for the injured party, not on the factual merits of the case. The bottom line is that the cost to the governing body could be astronomical.

What can be done to correct the problem and stay the inevitable onslaught of law suits and who should do it are the current critical issues. But first, engineers must recognize the problem. Trucks driving in convoy, whether by design or coincidence, clustering as they follow and pass each other are becoming an ever more common sight on highways. Trucks involved in interstate and intercity transport frequently dominate the sight lines on expressways and major roadways. On rural roads traffic movement is often restricted and limited by truck movements, and urban traffic is even more frequently dominated by truck movements and loading and unloading patterns.

The problems that these trucks and other large vehicles create for the effectiveness of current road signs and signals are at best difficult to correct. In reality there are an almost infinite number of problems, most without any complete solution (1-6). The solution could be as simple as removing all trucks from streets and highways. On the other hand, the solution could be as complicated as having to treat each and every sign and signal as a separate engineering problem. Each sign and signal and its location would be given individualized attention, and the final recommendation as to location, height, size, and color would depend only on the ability of the driver to see the sign; there would be no other applicable standards. There may not be a topic for which the advice that is given to the engineer in the standards, to use good engineering judgment, is more significant.

The complexity of the problems is the focus of this paper. An effort is made to alert the reader to some of the many factors of which the engineer needs to be aware and to some of the effects each factor may have on others. No effort is made to recommend a general solution to the problems for, indeed, there may not be one. The factors that affect visibility and comprehension of road signs and signals are many and what is of even more concern is that they are ever changing. Even the most obvious conditions that affect sight lines, such as truck size (height and length) and driver's eye height, have become variables.

There are at least six major categories that must be considered in each evaluation of visibility:

1. Trucks,
2. Automobiles (or other vehicles conveying passengers),
3. Roads,
4. Atmosphere,
5. Human factors, and
6. Signs.

Each of these is a variable with numerous subfactors that require understanding and evaluation (Table 1).

It is doubtful that there is any engineer, researcher, or psychologist with experience in this field who could not add to this list or propose a reasonable and meaningful further breakdown of subfactors, or both. It also becomes obvious that there is no way that the engineer concerned with the problem will be able to account for each and every factor let alone the infinite combination with which the designer will be confronted.

TABLE 1 Visibility Evaluation Factors

Major Factor	Subfactor
Trucks	Size, length, height, width
	Number of units using the road
	Frequency of use
	Speed
	Position
	Following distance (number in a row)
	Passing
	Performance characteristics
Other vehicles	Type
	Driver's eye height
	Vehicle visibility
	Windshield size and angle
	Side windows
	Driver's position
	Visibility angle through windows
	Position of units relative to the truck
	Following
	Passing
	Performance characteristics
Road	Type
	Expressway or other high-speed multilane
	Rural: two lane, three lane, one way, two way, sidewalk
	Urban: parking lanes, sidewalks, buildings, setbacks, overhead wires, crossovers
	Geometry
	Curve: left, right, degree of
	Grade: up, down, percentage, crest, valley, on a curve, and at what point
	Number of lanes--width
	Median strip
	Width
	Type
	Roadside conditions
	Shoulder type and width
	Other recovery areas, if any
	Blockage
	Fixed objects and their location
	Seasonal (trees)
	Lighting (if any)
	Type, location, intensity
	Shadows (fixed objects and others)
	Shadows (seasonal, trees)
	Construction and maintenance zones
Atmosphere	Day- or nighttime
	Weather
	Rain
	Snow
	Fog
	Background color (sky, clouds, etc. affected by geometry and weather)
Human factors (driver)	Performance
	Behavior
	Physical condition
	Eye range (full and effective)
	Peripheral vision
Signs	Location
	Side
	Overhead
	Size
	Color
	Height (sign and post)
	Distance of setback
	Illumination
	Type
	Shape

If any attempt is to be made to analyze the problem, the engineer should consider the road system as composed of at least three categories of road:

1. Expressways and other multilane high-speed highways,
2. Rural roads, and
3. Urban streets.

The special conditions created by construction and maintenance zones should be considered as a separate problem.

The factors listed in Table 2 indicate that the situation generated on expressways is the least com-

TABLE 2 Road Evaluation Factors

Category	Problem	Factor
Open roads (expressways and other multilane high-speed highways)	Passing	Position of trucks
		No. of trucks
		Roadside signs
		Overhead signs (see Figure 3)
	Following	Distance
		Height of truck
		Driver's eye height
		Roadside signs
		Overhead signs
Rural roads	Problems of open road	
	Other conditions	Limited sign locations
		Sharper grades and curves
		Cross traffic
		Pedestrian traffic
		Greater need for signs
		Increased roadside activity
Urban streets	Problems of rural roads	
	Intensification of conditions	Limited sign location
		Sharper grades and curves
		Cross traffic
		Pedestrian traffic
		Greater need for signs
		Increased roadside activity
	Additional conditions	Need for new type of signs
		Small informational signs (street names, no-parking, etc.)
		Higher traffic volumes
		Congestion
		Parking
		Loading and unloading activity
		Traffic control devices
Construction and maintenance zones	Problems of road where zone exists	
	Additional conditions	Limitations caused by the activity
		Change in traffic pattern
		Need to advise
		Limitations of placing temporary advisory signs, channeling devices, traffic control devices
		Constant change

plex. This is due in part to the wider right-of-ways, limited access, and minimal activity allowed on these roads. There are also other advantages: at least two lanes in each direction, built-in periodic overhead sign supports (bridges) that can be used when needed, and two shoulders and off-road recovery areas on which signs can be erected. If all variations in unit size are disregarded, driver's eye height and limitations on sight range due to physical limits of the vehicle design (windshield size and shape, etc.) and human factors, the study can be reduced to its simplest form.

PASSING

Consider a full-sized passenger vehicle passing a 50-ft tractor-trailer. Place the automobile so that the front is adjacent to the rear of the trailer (Figure 1). This condition only limits the passing driver's view of roadside signs for a distance of about 150 ft. Because off-road signs would be visible for quite some distance to the same driver in his following position (before he pulled out to pass), it is unlikely that an observant driver would miss seeing any approaching signs. However, if the first truck is following a second truck (same size) and is within 63 ft of that unit, the obliterated sight distance is increased more than threefold to more than 455 ft. What causes the real problem is a potential third unit ahead of the second truck. If the spacing between the second and third units is 192 ft or less, the obstructed sight distance is extended and can be as much as 0.2 mi. This number and spacing of tractor trailers on roadways is already common. (Observations and an attempt to photograph were made on the Pennsylvania Turnpike, US-81 between the Pennsylvania Turnpike and Hagerstown, and PA-132.) Any roadside signs in that area become totally useless to the passing driver. The effect can be further exacerbated if there are other trucks in the sequence or if the units are longer than 50 ft (i.e., 55-ft or double trailers, both of which are common on expressways today). In such situations, there appear to be five obvious solutions:

1. Use overhead signs in the passing lane,
2. Repeat the signing,
3. Require greater spacing between trucks,
4. Restrict passing, and
5. Place signs high enough to be seen over the top of a trailer.

Only Solutions 1 and 4 can provide reasonable assurance that a sign will be seen in adequate time for a driver to properly react to its message and Solution 4 is impractical and unrealistic on a multilane highway. Placing an additional sign is not a guarantee because it too can be missed in another passing maneuver although the probability of seeing the second sign is greatly increased. With regard to spacing, maintaining a safe distance appears to be the most sensible approach, but this is something over which the traffic engineer has no control. It is a matter of law enforcement, and restrictions are not likely to be effective. Elevating the signing so that it can be observed over the top of the trailers is shown in Figure 2. For eye height of a driver in a full-sized automobile (3 ft 9 in.) and a trailer height of 12 ft, the required sign height is dependent on the angle of observation over the top left edge of the trailer. The heights shown are also a function of the position of the sign relative to the edge of the road. The elevations shown are for the bottom of any sign. If a sign were placed just off the shoulder or 10 ft from the outside edge of the right lane, it would have to be 34 ft above the roadway to be completely readable. It is interesting to note that, in this situation, adjustment for truck height or driver's eye height is not as critical as might be expected. A 3-in. adjustment only changes the sign height requirement by 1 ft.

FOLLOWING

Following a truck presents no significant difficulty in seeing off-road signs on an expressway but does place a limitation on seeing overhead signs (and signals on other roadways). If, for illustration, a speed of 50 mph is assumed and the following vehicle is dropped back five car lengths (95 ft), an overhead sign with a 16-ft clearance cannot be fully seen until the trailing car is within 141 ft or 1.92 sec of the sign (Figure 3). On the surface, this does not look like too bad a situation, but two factors make it significant. First, it involves the uncontrollable situation of spacing or following distance. Second, should the following take place in the passing lane under the passing conditions explained previously, it eliminates overhead signing as an effective way of providing information to drivers of vehicles in the passing mode.

The information in Table 2 makes it obvious that no matter how complex any solution may be for an expressway, rural roads, urban streets, and construc-

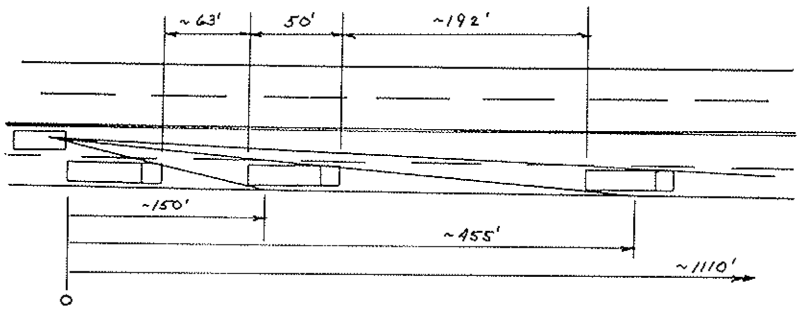

FIGURE 1 Horizontal sight line—passing mode.

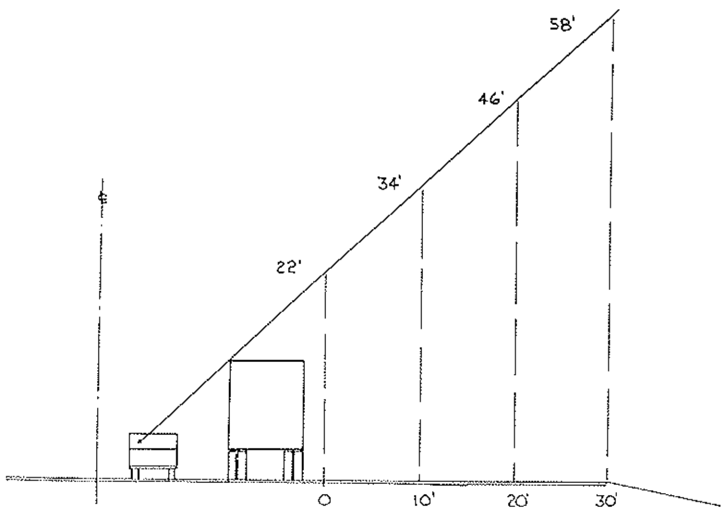

FIGURE 2 Vertical sight line—passing mode.

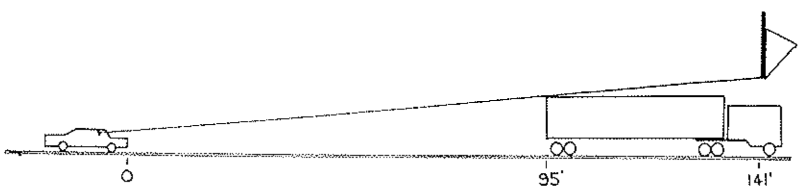

FIGURE 3 Vertical sight line—following mode.

tion zones present an even greater number of limitations and hence reduce the probability of finding a general solution to almost zero. Add to this the effect of the atmosphere and nighttime driving and engineers are faced with an almost impossible task of establishing an effective set of general standards to satisfy all conditions.

There is no way that the situation can correct itself. Eye heights are dropping because of the reduced size of automobiles. Trucks are getting longer and to a limited extent taller and wider by virtue of carrying oversized loads. The number of trucks is growing and clustering is increasing. Engineering logic says to do the best that can be done, that nothing is ever 100 percent sure. But as William A. Silver once said, "Engineering is logical but the law is the law and law is not logical." The present condition is sure to result in an increase in the number of highway accidents and, with the elimination of sovereign immunity to protect the states, an increase in law suits that name states as primary defendants.

Lawyers will quote from the engineering standards that say that signs should be placed and be of a proper size and color to be readable at a great enough distance to allow a driver ample time and distance to interpret and react to the message. They will say that the signs were placed to advise or warn drivers and that by placing them in a position that allowed a truck to obstruct the view of the automobile operator (hence depriving him of the advice and warning he had the right to expect) the state placed the driver in danger. Hence, the state knew of a potential hazard, or it would not have placed the sign there in the first place, and then left the driver vulnerable by allowing the sign to be blocked by a truck. With the image of the state as the bad guy and the members of the jury placing themselves in the position of the confused driver who suddenly found himself in an accident because he missed a warning sign, a good plaintiff's attorney will get the jury to render a verdict based on emotion, not on engineering logic and the dictates of prudent driving.

The lawyer would further argue that, by virtue of the developed standard practice of placing signs, the driver has the right to expect to be advised of and warned about hazardous situations and changes in traffic patterns. Hence the state is negligent in not having placed signs properly, which resulted in violation of the driver expectations and an accident.

What can the engineer do to better protect the public, the state, and the engineer? There may not be an answer, and, if there is one, this author does not yet know of it. Several guidelines, however, are worth noting:

1. Repeat signs whenever practical and if possible use them in combination, roadside and overhead.
2. Educate the driving public placing emphasis on the need to maintain a suitable spacing not just for stopping, which is where the big push has been, but also for observing and reacting to signing.
3. Increased effort to enforce good driving with legal criteria, not just a recommendation, for vehicle spacing.
4. Document all design and sign placement with a permanent record to show that a study was conducted and the installed system was the best possible.
5. Do a site inspection and check for any unusual condition that did not show up on paper (e.g., need for added height for a traffic signal to be seen when installed just beyond the crest of a grade or moving a sign so it precedes a driveway that is used by trucks that would block it while waiting to enter the traffic stream).

The cost of repeating, educating, enforcing, documenting, and inspecting for a year may indeed be less than the cost of legal defense of a single law suit or being found liable, or both.

REFERENCES

1. P. Abramson. Blockage of Signs by Trucks. Traffic Engineering, April 1971.
2. G.F. King, P. Abramson, and C. Duerk. Truck Blockage of Signals. In Transportation Research Record 597, TRB, National Research Council, Washington, D.C., 1976, pp. 1-9.
3. Traffic Control Device Handbook. FHWA, U.S. Department of Transportation, 1983.
4. A Policy on Design of Urban Highways and Arterial Streets. AASHTO, Washington, D.C., 1973.
5. A Policy on Geometric Design of Rural Highways. AASHO, Washington, D.C., 1965.
6. Manual on Uniform Traffic Control Devices. FHWA, U.S. Department of Transportation, 1983.