Geometric Design for Large Trucks—An Overview of the Issues from the Perspective of the American Trucking Associations, Inc.

RICHARD A. LILL

ABSTRACT

Size and weight regulations represent compromises between conflicting needs. There is a need to accommodate diverse kinds of highway transportation demands and a need to fit trucking into the capabilities of the highway system. A consistent pattern of size and weight regulation, characterized as the "spread-the-load" strategy, has evolved and does a good job of meeting most of these needs. Under this strategy, increased productivity in trucking has come about largely through changes in vehicle type and gross weight, not through increases in the maximum allowable axle loads. For instance, there have been only two general axle weight limit increases in the United States since weight regulation became of central concern. One came during World War II and the second in 1974. The spread-the-load weight regulation strategy strongly influences vehicle design and thus also influences geometric highway design. The Federal-Aid Highway Amendments of 1974 formalized this weight regulation strategy, and the Surface Transportation Assistance Act (STAA) of 1982 accelerated the use of vehicles dictated by it. How the industry is adapting to the 1982 STAA criteria and why there is minimal overall impact on the highway network are described. Also presented are some specific examples of how size and weight regulations "design" the trucks used by the industry and a brief discussion of how future developments may be reasonably accommodated.

Issues that relate to geometric highway design and truck size in the broad context of the overall strategy that has governed the development of vehicle size and weight limits in the United States are addressed. This is necessary to obtain a balanced view of the subject.

Fundamentally, all size and weight regulations represent a series of compromises between conflicting needs. There is the need in the trucking industry to provide for the safe and efficient movement of commodities of widely different densities and characteristics. There is the need in the highway design community to provide for the safe and efficient movement of a motor vehicle population of significantly different sizes, weights, and operating characteristics.

If there is one thing that can be said about highway transportation, it is that it is dynamic. In a period of 75 years or so, highway transportation has moved from a nonexistent status to being the dominant form of transportation in the United States. The development of trucking has paralleled that of highway transportation in general.

An indication of the present significance of truck transportation for economic development and growth is contained in a series of surveys sponsored by Business Week magazine. The intent of these surveys was to find out what factors industry management considers most important when selecting a new plant site (1).

Table 1 gives selected excerpts of those factors company executives consider most important when they are siting new plant facilities. The data reflect responses in the survey years of 1976, 1980, and 1984.

TABLE 1 New Plant Location Survey—Selected Responses by Category and Ranking Within Survey

	1984		1980		1976	
	Percentage	Rank	Percentage	Rank	Percentage	Rank
Cost of property	84	1st	79	1st[a]	69	2nd
Trucking	75	2nd	79	1st[a]	76	1st
Reasonable taxes	73	3rd[a]	71	3rd	61	4th[a]
Construction cost	73	3rd[a]	69	2nd[a]	58	6th
Near airport	36	24th	31	28th	26	20th[a]
Rail freight access	25	29th	27	29th	31	17th

[a]Tied.

Overall, there were 49 categories of questions posed in the surveys. This table gives the categories of generally highest significance plus responses that related to other prominent transportation modes.

The survey indicates the significance of the costs of building and owning a new facility and the availability of truck transportation. The direct cost factors have become dominant, but truck transportation has remained a priority item. Nearness to an airport has gained, but availability of rail freight transportation has declined.

Highways and truck transportation are presently a major and integral part of the economic fabric of the United States. They have created a revolution in the way the nation does its business. It is a revo-

Department of Highway Policy, American Trucking Associations, Inc., 2200 Mill Road, Alexandria, Va. 22314.

lution that reflects the superior transportation service they provide for a wide range of activities. Moreover, the prediction is that the vehicle miles of combination truck travel will grow on the order of 2 to 4 percent annually through 1995, indicating that trucking will continue to be a dynamic industry.

From this point on, some of the factors that have shaped the trucking industry and that are expected to shape it in the future will be discussed. Simply put, the trucking industry exists in its present form because of the strategy that has governed developments in vehicle size and weight limits. In other words, trucks are "designed" to obtain the most effective use of what the size and weight laws permit.

Some observers may not be aware of this strong connection between the size and weight laws and vehicle design or recognize that a fairly consistent "strategy" of regulation has guided the changes in limits over the years. However, such is the case. The strategy can be termed the "spread-the-load" concept, and it has been in effect for the major part of the trucking industry from the earliest days of regulation.

For instance, there have been only two general axle weight limit increases in the United States since axle weight regulation became of central concern. One came during World War II, when maximum single axle limits were increased from 16,000 to 18,000 lb as a war emergency measure. Tandem axle limits were not increased at that time. The second general axle weight limit increase came in the Federal-Aid Highway Amendments of 1974, which permitted a 2,000-lb increase in both single and tandem axle limits up to the 20,000-lb single and 34,000-lb tandem level. It should be noted that these changes affected only some of the states of the nation because many states had always allowed limits that exceeded the values included in the 1974 action.

The 1974 amendments also added another important feature to the federal regulation of vehicle sizes and weights. This was the inclusion of a "bridge" or gross weight formula applicable to vehicles that took advantage of the new gross limit of 80,000 lb. This action formalized the spread-the-load strategy at the federal level for the first time, but the principle has been present in state regulations much longer.

For instance, the 80,000-lb maximum gross weight is permitted only if the overall axle spacing is 51 ft if a vehicle has five axles, or 57 ft if a vehicle has only four single axles. It is seen that options exist under the formula, but length limits, vehicle design considerations, and commodity type will determine how the industry will use it.

The present gross vehicle weight (GVW) formula has two major characteristics. One is that the maximum axle load limits cannot be legally obtained on all the load axles unless they have adequate distances between them. The other is that an increase in the number of axles within a given spacing may permit an increase in the maximum allowable GVW. In practice, however, the total permissible load will not usually be equal to the sum of the maximum allowable axle load limits.

The strategy has proven effective by increasing productivity in the trucking industry while reducing the demand on highway pavements from the transport of a given tonnage of freight. Figure 1 shows the equivalent single axle loads generated in the movement of a given amount of freight for a few different vehicle types. Because of the gross weight formula, the longer combination vehicles, on the average, exert less demand on pavements per ton carried than do shorter vehicles, even though they transport more freight per trip. These data for 1979 are based on the average loaded weights reported in the 1975-1979 National Truck Characteristic Report (2).

Truck transportation is not only flexible, it is also a "tailored" transportation mode. It is tailored to fit the commodity involved, it is tailored to fit the demands of shippers, and it is tailored to fit the size and weight regulations.

Thus the industry must always adjust its equipment to account for differences in density and characteristics of freight, operational requirements, and use of equipment. The spread-the-load strategy adversely affects the carriers of some commodities by causing the vehicle dead weight to be increased out of proportion to changes in total permissible weight. Nevertheless, the trucking industry generally accepts the viability of the concept.

Within the highway community there is the need to compromise among pavement costs, bridge costs, and geometric costs. To a limited extent, the bridge and

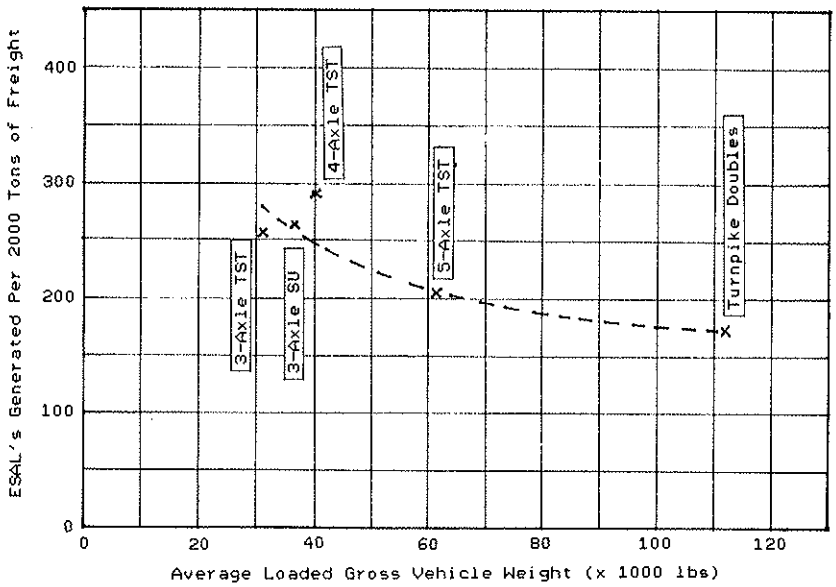

FIGURE 1 Generation of ESALs by vehicle type and average gross weight in moving 2,000 lb of freight—1979 national truck weight data computed for PCC pavement.

pavement costs have dominated while the geometric costs have received lesser concern. This may be because modern geometric features are desirable for all types of highway traffic.

Everyone, of course, has a strong interest in the safety of operations. There is no trucking company that will survive if it operates equipment that has inherent safety problems. The industry is sensitive to these issues and works hard, as a group, to have a good safety record. Because insurance rates are increasing rapidly, it is likely that safety of operations will become more and more significant in the future.

The remainder of this paper is a discussion of a few specific vehicles that demonstrate directly how trucking has been fitted into the regulatory environment. Presented here are only a few examples that show the broad relationship; hundreds of different adaptions could be shown.

Figure 2 is a picture of an old single-unit truck. The very first stages of axle weight regulation were applied to this vehicle. The regulation took the form of restricting the weight allowed per inch of hard rubber tire width. This type of regulation remains on the books of some states and is applied to pneumatic tires. The maximum axle loads permitted on these vehicles were on the same order as are allowed today.

FIGURE 2 Old single-unit truck.

Figure 3 is an early version of the three-axle tractor-semitrailer combination. Tandem axles were available in the early days of trucking, but most gross weight limits precluded their widespread use on combination vehicles.

The four-axle tractor-semitrailer vehicle shown in Figure 4 became the workhorse of trucking during the 1940s and 1950s, particularly on the East Coast where the heaviest axle loads are allowed. The passage of the 1956 Federal-Aid Highway Act led to increases in GVW limits up to 73,280 lb. This led in turn to the use of the five-axle tractor-semitrailer in most of the United States, although the four-axle semitrailer remained in substantial use in the East because of the heavier axle limits.

Figure 5 shows the vehicle that was designed to fit the 1946 AASHO bridge formula. Also, the present federal formula was slightly altered to permit a significant population of existing equipment to obtain the productivity gains envisioned by the 1974 Federal-Aid Highway Amendments. Even so, the restrictions of the formula have prevented some carriers, notably bulk commodity carriers on the East

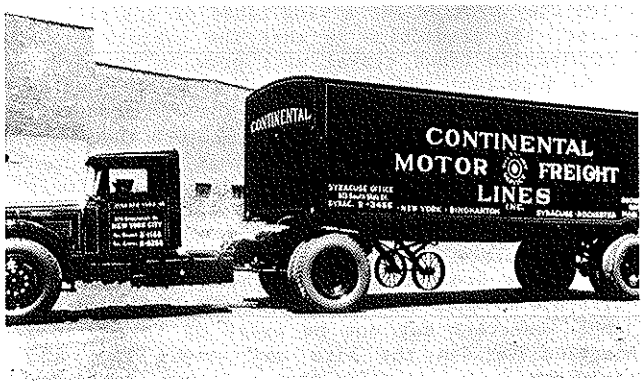

FIGURE 3 Early version of three-axle tractor-semitrailer combination.

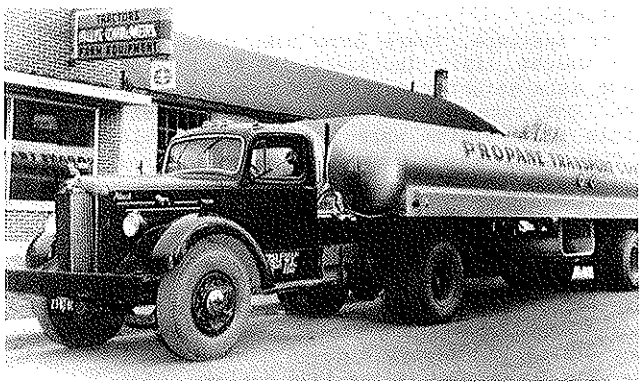

FIGURE 4 Workhorse of trucking in the 1940s and 1950s.

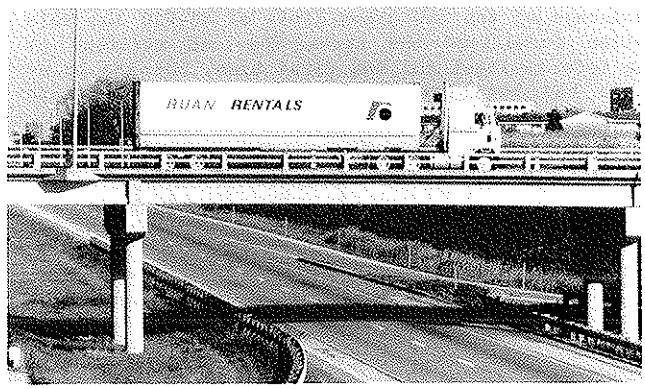

FIGURE 5 Vehicle designed to fit the 1946 AASHO bridge formula.

Coast, from converting to the five-axle unit because their existing trailers do not fit the formula.

This figure also shows the way in which many carriers with five-axle semis are using the 48-ft trailers. Because their existing equipment already meets the spacing requirements of the formula, most are adding 3 ft in back of the rear tandem. Doing this does not affect vehicle offtracking.

Figure 6 is an example of a vehicle that has been designed from the ground up to fit the current GVW formula. The multiple load axles are common but the "twin-steering" axles are not. This vehicle fits the formula well and keeps dead load to a minimum. It is desirable for certain types of dense commodities.

FIGURE 6 Vehicle designed to fit the current GVW formula.

The same twin-steer concept is applied to the truck-full trailer combination shown in Figure 7. Conventional five-axle semitrailer combinations have difficulty in reaching the 80,000-lb limit because of problems in shifting enough weight to the steering axle. This vehicle is designed for about 22,000 lb on the twin-steer assembly. It thus can be fully loaded and also give some flexibility in loading the regular load axles. Because of advanced design concepts, this vehicle comes in at about 5,000 lb less dead weight than many five-axle tractor-semitrailers.

Figure 8 shows another vehicle that fits the GVW formula very well. It is a five-axle twin-trailer combination that was built to haul a specific bulk commodity. Its dead weight is also about 21,000 lb, and it is easily adaptable to different regulations.

FIGURE 7 Truck-full trailer combination.

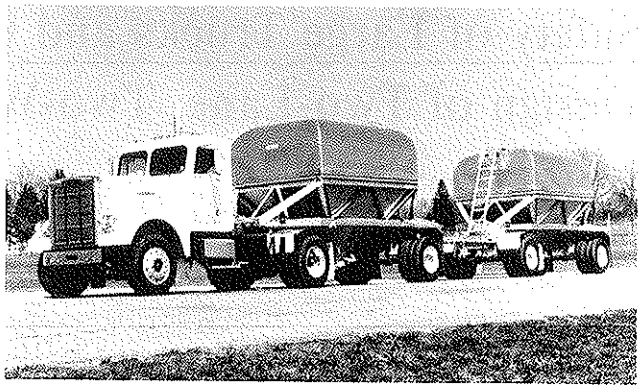

FIGURE 8 A second vehicle designed to fit the GVW formula.

In summary, the trucking industry adapts its vehicles to the regulations that govern their use. Productivity is the key word, and it is the primary factor in determining how the industry will make use of changes in regulations.

The spread-the-load size and weight regulation strategy is sound and there is little likelihood that it will be significantly altered. The strategy thus potentially affects geometric design in the areas of turning and offtracking of longer combination vehicles because these are the vehicles the strategy produces. It should be recognized, however, that modest adjustments in the implementation of the strategy may be in order and that there will be a continuing need for special-case exceptions.

The 1982 STAA introduced the concept of "designated highway systems" for the operation of more productive vehicles on the national level. Such designations provide a viable means of recognizing the greater capabilities of modern highways for meeting the crucial transportation demands of the nation. The need for balancing bridge, pavement, geometric, and safety concerns will remain, but problems will be worked out as they have been in the past. Goods transportation is too important for this not to be the case.

REFERENCES

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