

# Applicability Of Performance-Based Standards To Truck Size And Weight Regulation In The United States

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## ABSTRACT

This study investigates the applicability of performance-based standards for truck size and weight regulation in the United States. The study examines truck size and weight regulations in industrialized countries to determine the extent and nature of the criteria employed by those countries to control the interaction between vehicles and the highway infrastructure and the traffic safety environment. Pavement design philosophies and vehicle configurations of studied countries are then examined to determine similarities between the study countries and the United States. Scheduled for completion in November 1995, the study will note performance-based standards that, if integrated into the truck size and weight regulation framework of the United States, may result in greater vehicle productivity with equal or less infrastructure wear and with equal or greater traffic safety.

## INTRODUCTION

The Iowa Transportation Center is conducting a research project under contract with the American Trucking Associations' Trucking Research Institute to examine the development and use of performance-based standards for commercial vehicle size and weight regulation in other industrialized countries and to identify areas where performance-based standards could be integrated into United States size and weight regulations. The goal of the research is to identify how performance-based standards could be integrated into the current United States truck size and weight regulatory framework resulting in greater vehicle productivity while improving, or at least not worsening, highway safety and pavement wear.

First this paper provides an overview of the concept of performance-based standards for truck size and weight regulation. Second, a brief summary of the evolution in truck size and weight regulation in the United States is presented to provide an understanding of the current regulatory framework. Third, this paper presents summary

results of a review of the truck size and weight regulations of approximately 30 countries, including those in the European Community, to identify performance attributes incorporated into each country's size and weight regulation framework. Fourth, the identified performance attributes are classified into two broad categories: those designed to control pavement wear or protect the highway infrastructures, and those designed to protect traffic safety and the highway safety environment. Fifth, the paper discusses pavement design standards for many industrialized countries and examines how axle and gross vehicle weights are taken into account in pavement design standards. Finally, for those countries using performance criteria designed to control or protect the traffic and highway safety environment, the allowable vehicle configurations are reviewed to identify similarities/differences with the vehicle configurations used in the United States.

## PERFORMANCE-BASED STANDARDS FOR TRUCK SIZE AND WEIGHT REGULATION

Fundamentally, the objective of performance-based truck size and weight regulation is to govern vehicle dimensions based on safety and pavement wear performance of the vehicle. For example, two trucks with the same axle loads and gross weights but different suspension systems may impose different amounts of wear to pavements. Under a performance-based size and weight regulation regime, the vehicle with the suspension that is less harmful to the pavement should be allowed to have higher axle or gross weights. By regulating size and weight based on the vehicle's impact on the road or impact on traffic safety, performance-based regulations provide an incentive for operating vehicles with superior performance.

## EVOLUTION OF TRUCK SIZE AND WEIGHT REGULATION IN THE UNITED STATES

Current size and weight limits for interstate commercial vehicle operations on the Interstate System and National Network in the United States were derived from an

amalgamation of state-generated size and weight standards. Between 1913 and 1933 every state generated its own size and weight standards. Sometimes the standards were consistent from one state to the next, but often each state developed its own size and weight standards without considering uniformity among states. The legacy of independently developed size and weight standards has become the base upon which national standards were enacted. As a result, national standards were achieved through compromise among a number of non-uniform historical standards.

In 1932, the American Association of State Highway Officials (AASHO), which later became the American Association of State Highway and Transportation Officials (AASHTO), recommended a 16,000-pound (7.25 metric tons) axle load limit. AASHO later revised its policy in 1946 and recommended a single-axle load limit of 18,000 pounds (8.15 metric tons) and a tandem-axle limit of 32,000 pounds (14.5 metric tons). (1) To limit the stress on bridges, the AASHO policy recommended a maximum weight limit of 73,280 pounds (33.25 metric tons) for vehicles with extreme axles at least 57 feet (17.4 meters) apart. The maximum weight limits were based on the Bridge Formula, which determines gross weight based on the distance between axle extremes in any set of an axle group.

The Federal-Aid Highway Act of 1956 applied the AASHO standards to the Interstate Highway system. The act also allowed states to continue to use weight and size limits greater than those recommended in the AASHO policy, thus grandfathering higher weight and size limits in place.

In 1974, Congress adopted increased axle limits of 20,000 pounds (9.05 metric tons) per single-axle and 34,000 pounds (15.4 metric tons) per tandem-axle. It also adopted a revised bridge formula to allow gross vehicle weight to increase to 80,000 pounds (36.3 metric tons). The new axle and gross weight limits were caps for states that did not already have higher limits. Other states that already had higher limits were allowed to grandfather the higher pre-existing limits. States that did not want to increase their weight limits to the higher limits on the Interstate Highway System could stay at prior gross weight and axle load levels. The 1974 legislation (as well as the 1956 legislation) included provisions for states that already issued permits for oversized and/or overweight trucks to continue to exercise that authority (e.g., longer combination vehicles (LCVs)). (2)

The Surface Transportation Assistance Act (STAA) of 1982 removed the option of states to have lower than the uniform standard for weight limits on the National Highway Network, thus promoting uniformity. With few exceptions, states could no longer impose limits on weights, widths, lengths, or combinations that were more restrictive than the federal limits. The STAA introduced an increased federal role in vehicle size and weight regulation by preempting the

states' right to limit overall length of singles or doubles and requiring "reasonable access between the National Highway Network and terminals and facilities for food, fuel, repairs, and rest." (3) The STAA also grandfathered state limits that exceeded federal limits and continued to allow states to authorize the operation of larger trucks under special permits. Since the enactment of the STAA in 1982, truck size and weight regulations have remained constant. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 even froze current limits on the use of oversized and/or overweight trucks operating under divisible load permits to highways where states permitted their operation as of June 1, 1991. (4)

The current standards for size and weight regulation were based on political compromise and historical reasons rather than on standards that could strike an efficient balance between vehicle safety, wear imposed on the highway, and freight transportation productivity. The current prescriptive size and weight standards provide no incentives to purchase vehicles with dimensions and components that allow the vehicle to handle more safely or cause less pavement wear. One of the objectives of performance-based size and weight specifications is to provide incentives for the development and procurement of trucks with superior performance. Performance-based standards have also been proposed as a method for improving the productivity of freight vehicles, while promoting motor carrier industry innovation. (5) Further, performance-based standards create a completely new structure for size and weight regulation, thus allowing states to evolve to a new and more rational size and weight regulation system.

#### EXAMINATION OF TRUCK SIZE AND WEIGHT REGULATIONS FOR INDUSTRIALIZED COUNTRIES

The size and weight limits for commercial vehicles have been tabulated for approximately 30 industrialized countries. In examining the tabulated size and weight regulations among the study countries, the following differences have been noted:

- Near uniformity exists in width limits, with maximum widths ranging from 8.20 feet (2.5 meters) to 8.53 feet (2.6 meters).
- Single-axle weight limits are generally consistent and range from 18,000 pounds (8.2 metric tons) in South Africa to 22,000 pounds (10 metric tons) in the majority of the European Community countries, except for some countries such as Australia, Canada, Greece, Israel, and New Zealand, which further restrict single-tire steering-axle weights.
- Tandem-axle weights are generally consistent and range from 34,000 pounds (15.4 metric tons) in the United States to 44,000 pounds (20 metric tons) in many European Countries.

- Wide disparities exist in allowable gross weights. For example, maximum allowable gross weights for five-axle tractor/semitrailer combinations (3S-2) range from 61,700 pounds (28 metric tons) in Switzerland to 110,200 pounds (50 metric tons) in Norway.

Most countries in the study use performance criteria to regulate vehicles at or near maximum vehicle dimension limits for both size and weight. These performance criteria specify vehicle parameters such as axle spacing; turning abilities, including off-tracking or area swept by the rearmost portion of the trailer; and power rating of the towing unit. Examples of noted performance criteria among countries studied thus far are listed below:

- In New Zealand, "B" Train vehicle configurations may operate at 97,000 pounds (44 metric tons) gross weight provided that they meet target performance values of 1) 0.35g static roll threshold, 2) 0.8 meters high-speed transient off-tracking, and 3) 60 percent dynamic load transfer ratio.
- In Canada, certain vehicle configurations (eight axle "B" Trains) may operate at 137,800 pounds (62.5 metric tons) gross weight, provided that 1) steer axle weight limits do not exceed 12,000 pounds (5.5 metric tons), 2) tire load limits do not exceed 560 pounds per inch of tread width, and 3) axles share loads equally within each axle group.
- In Great Britain, six-axle tractor/semitrailer vehicle configurations in "Combined Transport" (intermodal) operations may operate at 97,000 pounds (44 metric tons) gross weight provided that 1) the tractors are equipped with "road friendly suspensions," 2) all axles (except steering axles) are equipped with twin tires, 3) inter-axle and kingpin spacing conform with complex dimension requirements, and 4) the vehicle meets the European Community turning circle requirements.
- In Sweden, six-axle tractor/semitrailer vehicle configurations may operate at 123,500 pounds (56 metric tons) gross weight provided that they comply with complex axle spacing requirements.
- In Finland, seven-axle road trains may operate at 123,500 pounds (56 metric tons) provided that the towing vehicle has at least 5.90 horsepower for each 2,200 pounds (metric ton) of gross weight. For example, a 123,500 pound vehicle requires a minimum tractor horsepower of 330.

Performance criteria have been designed to control both the interaction between the vehicle and the highway infrastructure and the interaction between the vehicle and the traffic safety environment. For example, the performance criteria used in Great Britain control highway infrastructure interactions by specifying "road friendly" suspensions and axle spacing dimensions and control traffic safety interactions by specifying turning circle requirements and kingpin dimensions.

## CLASSIFICATION OF PERFORMANCE CRITERIA

To facilitate an international comparison of truck size and weight regulations, the size and weight standards for approximately 30 industrialized countries were analyzed. Eighteen countries were found to have performance-based attributes in their size and weight regulations. The countries with performance-based attributes in the size and weight standards are further subdivided into three groups. The first group includes those countries with regulations that predominantly control the interaction between the vehicle and the pavement and/or bridge infrastructure. They specify axle spacing dimensions within each axle group, axle spacing dimensions between axle groups, the maximum allowable weight limits on single-tire steer axles or additional weight tolerances with "road friendly" suspensions. The second group of countries has regulations that predominantly control the interaction between the vehicle and the traffic safety environment. They specify off-tracking measures, static roll thresholds, dynamic load transfer ratios, and/or minimum power requirements. The third group involves countries that have regulations with performance-based attributes emphasizing controlling the vehicle interactions with both the highway infrastructure and the traffic safety environment. The first group of countries includes Canada, Greece, and South Africa. The second group of countries includes Australia, New Zealand, and Luxembourg. The third group of countries includes Belgium, Denmark, Finland, France, Germany, Great Britain, Italy, Mexico, the Netherlands, Norway, Spain, and Sweden. Because this paper is a discussion of research in progress, the review of national standards has not covered all countries and there may be others not yet researched which include performance-based criteria in their size and weight regulations.

## PAVEMENT DESIGN PHILOSOPHIES OF STUDY COUNTRIES

There is a myriad of methods for designing pavements, ranging from designs based on experience to mechanistic methods based on the mechanics of materials. However, the predominant pavement design methodologies used in most industrial countries tend to fall into two categories. One type involves collecting a number of design inputs, such as the soil supporting strength, current and projected traffic by volume and by vehicle classification distribution, and other design inputs, and then working through a number of charts and nomographs to reach a design. The AASHTO pavement design guide is an example of such a methodology, and the design guide provides a number of charts and nomographs the designer uses to determine the design. (6) The other type involves the use of design catalogues where fixed solutions are provided for design factors. An example of a design catalogue is the French-Catalogue. (7)

All methods are based on empirical relationships between the wear imposed on the pavement and the traffic loadings. Underlying all methods is a relationship between

pavement wear and the static axle loads imposed on the pavements as a result of traffic and pavement life. For example, in the AASHTO's design guide, the relationship is accounted for explicitly by the designer who starts by calculating the number of axle loads a pavement will receive over its life and the weight distribution of those loadings. Then, each axle load is equated to equivalent standard axle loads (18,000 pounds is used as a standard axle load). For example, a 10,000-pound axle load is a fraction of one standard axle load, and 20,000 is more than one standard axle load. The relationship between imposed wear and static axle weight is non-linear and, in a fairly general sense, every time axle weight doubles, wear is increased roughly sixteen-fold. (8) The designer totals the number of equivalent standard axle loads the pavement will receive over its life and determines the thickness of the pavement layers to withstand the estimated number of loads. Within the British pavement design guides, the calculation to develop a factor for the accumulative wear over a pavement's life is made indirectly. The British design guides assume a standard axle load distribution and traffic growth rate. (9) Assuming that truck volumes and/or traffic growth is within a normal range, the only traffic related design input necessary is the current traffic volume. The load equivalence factors are embedded within the methodology and are transparent to the user.

Regardless of the country, however, current design methods do not take into account the dynamic (as opposed to static) interaction between the pavements and vehicle axle loadings. Current design methods are based on the correlation between vehicle static weights and pavement wear. The intention of performance-based criteria is to relax weight restrictions on vehicles that are designed to reduce the dynamic loads imposed on the pavement as the vehicle passes over. Given the current state of the art of pavement design techniques, these techniques are currently insensitive to vehicle modifications to reduce dynamic loads. To provide insight into the benefits of vehicles designed to reduce dynamic loadings, computer simulation models have been developed to model the dynamic interactions between truck and pavements. (10) The Dynamic Interaction Vehicle Infrastructure Experiment (The DIVINE project), which is currently being conducted through a consortium of 17 member countries, is intended to provide empirical data on the dynamic interactions of vehicles and the highway infrastructure. (11)

## VEHICLE CONFIGURATIONS OF STUDY COUNTRIES

The predominant vehicle configurations of study countries are similar to those used in the United States. For example, all countries specify separate size and weight limits for rigid or unarticulated vehicles ("straight trucks") and articulated vehicles ("tractor/semitrailer" combinations). Generally, gross weights for all vehicle configurations are determined by the number of axles and axle spacing. Some countries, such as New Zealand and Australia, allow larger vehicle configurations, including multiple trailer road trains.

However, these countries often specify additional performance criteria for these configurations and emphasize controls between the vehicle and the traffic safety environment.

New Zealand, for example, allows three types of twin trailer configurations shown in Figure I. Truck and full trailer configuration may not exceed 86,000 pounds (39 metric tons) gross weight and 62 feet (19 meters) in length. "A Train" configurations may not exceed 86,000 pounds (39 metric tons) gross weight and 66 feet (20 meters) in length. (12) The gross weight limits of these configurations do not exceed the gross weight limits specified for common tractor/semitrailer configurations. "B-Train" configurations may operate at up to 97,000 pounds (44 metric tons) and 66 feet (20 meters) in length, provided that they meet the following performance criteria:

- Static Roll Threshold (maximum steady turning lateral acceleration without rollover) = 0.38g.
- High Speed Transient Off-tracking (lateral offset between trajectory of lead and trailing units in same maneuver) = 31 inches (0.8 meters).
- Dynamic Load Transfer Ratio (indication of nearness to rollover in a highway-speed evasive steering maneuver) = 0.6 (60 percent).

Australia allows the routine use of 26 types of vehicle configurations, which range from two-axle rigid vehicles ("straight-trucks") to sixteen-axle, three-trailer "B-Trains." (13) The latter of these are permitted to operate legally at 255,000 pounds (115.5 metric tons) gross weight and 174 feet (53 meters) total length on specified routes. Currently, these road train configurations must comply with the following performance criteria: (14)

- Maximum road speed capability of the power unit must not exceed 56 miles per hour (90 kilometers per hour).
- Brake application pressure must reach 425 kpa (62 psi) within 1.5 seconds at the brake chamber farthest from the brake treadle valve.

Additional performance criteria are currently being developed by the Australian Road Research Board Ltd. These performance criteria will specify maximum permissible low-speed off-tracking, static roll threshold, and dynamic load transfer ratios.

Sweden also allows seven axle vehicle configurations at gross weights not exceeding 123,500 pounds (56 metric tons) and lengths not exceeding 75 feet (23 meters). As of this writing, no additional performance criteria except for the number of axles and the axle spacing have been noted for these vehicle configurations. However, since the existence of such criteria is presumed, further research in this area is currently being conducted. (15)

An additional control between the vehicle and the traffic safety environment, often specified and required by

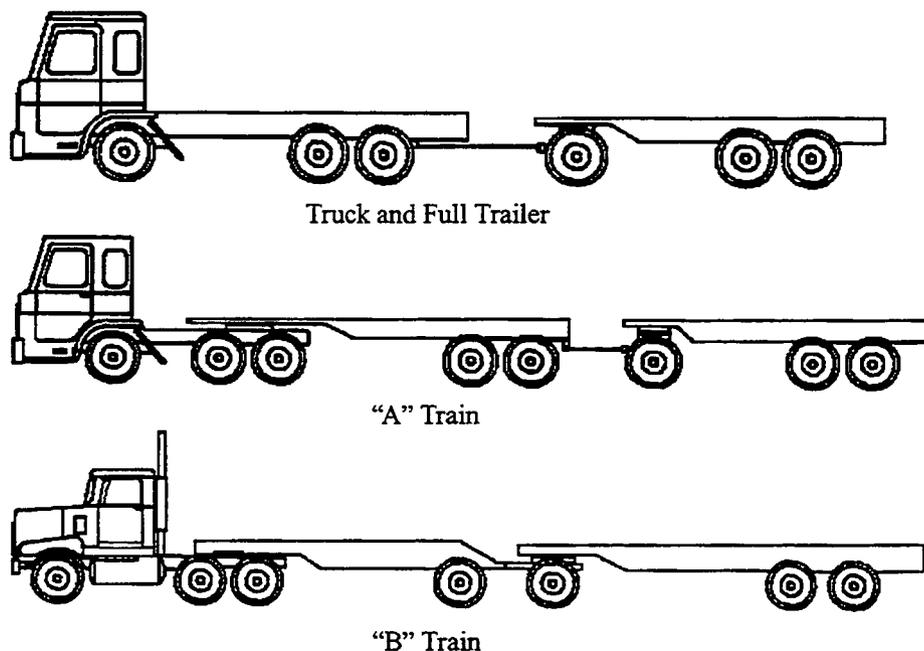


Figure I: New Zealand vehicle configurations

the European Community, is a turning circle specification. This specification is a surrogate for total vehicle length because it specifies the maximum area consumed by any vehicle in a tight turn. This specification requires that all vehicle configurations must negotiate a 360-degree turn with the steering axle negotiating a circle such that no portion of the front of the vehicle protrudes beyond the radius of a 41-foot (12.5 meter) circle and that no portion of the rear of the vehicle protrudes beyond the radius of a 17-foot (5.3 meter) radius circle. The intent of this performance criterion is to assure that vehicles can make tight turns in crowded areas without striking any buildings or other infrastructure elements.

#### SUMMARY

The research thus far has revealed many types of performance criteria used to control the interaction between the vehicle and the highway infrastructure and traffic safety environments. Each country has its own unique transportation needs and issues, and the performance criteria selected reflect those needs. For example, Australia and Zealand primarily specify performance criteria to control

the safety of the interaction between the vehicle and other traffic. These are both countries where a diverse mix of goods are moved over long distances on rural highways. The freight hauling environment in Australia and New Zealand is conducive to multiple-trailer combinations, and in both countries extremely long multiple-trailer combinations are operated. The principal concern, however, with the operation of long combinations is safety. Therefore, performance-based regulations in Australia and New Zealand focus on reinforcing safety.

Current pavement design methodologies are insensitive to vehicle dynamics and, therefore, existing design methods can not identify the impact of performance-based size and weight standards on pavement wear. Although dynamic simulation models have been constructed to estimate the interaction between pavements and vehicle designs, empirical data validating the simulations are not available. The empirical work to better understand the pavement life implications of vehicle components designed to reduce dynamic pavement impacts, however, is currently being conducted.

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