

REPORT

**1995 Truck Size and Weight
Performance-Based
Workshop**

**U.S. DOT Comprehensive
Truck Size & Weight Study
Report No. 4**

To

U.S. Department of Transportation

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The primary objectives of the U.S. Department of Transportation's Comprehensive Truck Size and Weight (TS&W) Study are to:

- assess the potential economic, safety, and environmental impacts of changing existing TS&W limits; and
- identify opportunities to increase the efficiency of freight transportation while preserving safety and highway infrastructure.

Reports which have been completed for the TS&W Study, to date, include the following:

- (1) Synthesis of Truck Size and Weight Studies and Issues
- (2) Analysis of the Truck Inventory and Use Survey from the Truck Size and Weight Perspective for Trucks with Five-Axles or More
- (3) Truck Size and Weight Modelling Workshop
- (4) Truck Size and Weight Performance-Based Workshop
- (5) Western U.S.-Canada Crossborder Case Study.

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We want to thank Robert Clarke, Kit Mitchell, and Peter Sweatman for presenting at the workshop and for reviewing this report.

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1.0 Introduction

This is a summary of a workshop on performance-based regulations for truck size and weight (TS&W) organized by the U.S. Department of Transportation's (US DOT) Federal Highway Administration (FHWA). The workshop was held on June 30, 1995, at the Chrysler Center in Ann Arbor, Michigan, on the day after the Fourth International Symposium on Heavy Vehicle Weights & Dimensions.

This is not a verbatim record of the proceedings. Rather, this account follows the discussion as it happened with explanations, definitions, and examples added for clarity.

1.1 Outline

There were three keynote speakers in the morning session as follows:

- Robert Clarke, National Highway Traffic Safety Administration of the US DOT, set the stage by outlining one approach to performance-based regulations. This approach is described in the section entitled **“Implementation of Performance-Based Size and Weight Limits.”**
- Peter Sweatman, Roaduser Research, Australia, discussed vehicle stability and control issues related to performance-based standards. His remarks are summarized in the section entitled, **“Vehicle Stability and Control.”**
- Kit Mitchell, formerly of Transport Research Laboratory, U.K., looked at the interaction of heavy vehicles and pavements and his discussion is summarized in the section entitled **“Vehicle-Pavement Interaction.”**

The afternoon of the workshop consisted of three breakout sessions, each led by a keynote speaker. These are described immediately after the summary of the keynote speeches in the above-mentioned sections. There was insufficient time for the workshop to develop conclusions as such; nevertheless, a summary interpretation of the day's discussion is provided in the last section of this report.

1.2 Purpose and Goals

Chris Winkler, University of Michigan Transportation Research Institute (UMTRI), opened the workshop with two questions:

- What aspects of performance should be regulated?
- What performance can be regulated?

The first question raises the issue of the scope of performance-based regulations. Do they only cover the technical and in-use operational aspects of vehicle performance and vehicle operation; or, do they also attempt to address political, economic, and social considerations? Winkler's second question raises the issue of implementation. "How can performance-based regulations be enforced? How would they fit within the existing structure of state and Federal regulations? And, how do we change from the existing system?" These are all questions which Winkler indicated must be addressed if performance-based standards are to become a reality.

2.0 Implementation of Performance-Based Size and Weight Limits

Robert Clarke proposes a performance-based approach to TS&W regulations as a means of reasonably and responsibly managing pressures for larger trucks while protecting the public's legitimate interests in safety and infrastructure protection. Not all details of this approach have been developed, but the essential elements are outlined below.

2.1 Proposed Approach

Under Clarke's proposal, existing combination trucks of 80,000 lbs or less and straight trucks of 54,000 lbs or less would continue operating under current Federal or state regulations. Over a period of time, trucks heavier than this would be regulated by a new special permit system based on performance standards. States would still have the option of whether or not to allow these heavier vehicles to operate within their borders, but if they chose to do so, they would be required to adopt uniform special permit requirements. Such a system would protect states' rights to choose on this issue, but would also provide a basis for national uniformity, thereby ending "ratcheting" which has occurred in the past. Under this plan, "grandfather rights" vehicles would be phased-out as would the "grandfather rights" themselves, to be replaced by newer vehicles meeting the new performance-based standards. The permits would authorize the operation of trucks known to meet safety performance standards and known to meet the standards required to protect the infrastructure. They might also impose operational restrictions (routes, time-of-day, speed, driver qualifications, etc) on the operator.

2.2 Basis for Proposal

Clarke's proposal is based on his agency's concern for safety. There are two key variables in considering trucks and the part they play in road safety. One consists of factors contributing to the likelihood of a crash—the driver, the operating environment (i.e., road type, weather, traffic density), and the vehicle itself (i.e., the inherent properties of the vehicle plus its condition as affected by maintenance). The other factor is amount of exposure to risk (i.e., miles driven). Crash likelihood times exposure equals the number of crashes. With recent estimates that truck mileage will increase 34 percent¹ between 1993 and 2003, it is clear that unless crash likelihoods are significantly reduced, the number of crashes will increase, regardless of whether the size and weights of trucks changes in that time period.

¹Clarke was referring to a DRI/McGraw Hill study commissioned by the American Trucking Associations

Clarke says that existing size and weight regulations do not take into account the effect they have on vehicle design and, in turn, the role design has on safety performance. He noted that size and weights regulations often unwittingly promote, or at least do not discourage, poorly designed vehicles from a safety and infrastructure-protection viewpoint. He indicated that in the future, size and weights regulations could be proactively used to encourage, if not require, that vehicles perform at least as well as, if not better than, today's "best" vehicles in terms of safety performance.

Clarke acknowledged that, "the politics of allowing larger trucks is explosive," but suggested that if the vehicles were allowed to operate only under a system of performance standards with aggressive pass/fail criteria and rigorous enforcement and accountability, a "win-win" situation could result. Truck annual mileage growth rates would be slowed, thus reducing crash exposure risks, and higher performing vehicles, with reduced inherent crash likelihoods, would eventually replace poorer performing ones.

2.3 Factors Affected When Size and Weight Regulations Change

Clarke noted that it is truck design characteristics and configurations that significantly change when size and weight regulations change and that these changes have measurable effects on safety and infrastructure wear. Several safety performance factors can be directly affected, including: braking, stability while braking, propensity to rollover, and rearward amplification (*the crack-the-whip phenomenon of multiple-trailer combinations that can lead to rollover of the rearmost trailer in a high-speed evasive maneuver*). Second, these vehicle design changes, in turn, affect traffic operational performance, including: low-speed offtracking (*the path of the last axle compared to the path of the tractor's steering axle*), passing-times, the way the truck merges into traffic streams, the time required for a truck to clear an intersection, the maintenance of speed on a hill, acceleration, and slippery road powered traction (*slippery road-powered traction is the minimum level of pavement friction required for a combination vehicle to negotiate a tight turn; that is, the minimum level before the trailer pushes the tractor into a jackknife*). Third, vehicle design differences have the more conventional impacts on pavements and bridges. These are "more conventional" in that they are generally thought to be the controlling influences on existing axle load limits as derived from conventional ideas on pavement performance and on axle loads, axle spacings, and gross weights as derived from the Federal bridge formula (*the formula controls the distribution of a truck's total weight over its axles and the spacing of the axles*).

2.4 Issues to be Addressed and Resolved

Clarke indicated that there are a significant number of detailed points that would have to be worked out before a fully developed performance standards system for larger vehicles could be put in place. First, standardized analytical and testing methodologies would have to be agreed upon. The Federal government, acting in partnership with state governments and the technical community, is probably best suited to assume the leadership role for establishing these methodologies, as well as uniform acceptability criteria.

Next, sufficient numbers of qualified personnel to perform these analyses/tests would have to be made readily accessible to state and carriers/shippers who wished to qualify new vehicle design configurations. A means of certifying these individuals/organizations would have to be established, as well as a means for keeping track of “formula” vehicle designs/configurations that had been successfully qualified, so that they could be universally used.

Finally, an algorithm would have to be developed for assessing, in a uniform and objective/quantitative manner, the suitability of a proposed travel route for these larger vehicles.

Clarke finished with a substantial list of issues that would have to be agreed upon to make this system work. What is the ultimate scope for a performance-based permit system—all trucks or just new heavy trucks? Who will do the testing? How complex and how expensive would it be to design a vehicle to pass the performance criteria? Is it possible to develop a number of generic large trucks (*blueprint* or “*formula*” trucks) that meet the performance criteria and would satisfy most operators’ needs? This would be simpler than having many hundreds of operators developing their own designs. Can the system be properly enforced at the roadside? What are the staffing requirements for the states? Is it possible to develop performance criteria for different road classes to which everyone can agree? Or, are roads and conditions so different in different areas that this is impossible? Is it possible to develop road-user taxes for these permit trucks that can be applied nationally? What if an ESAL-mile of pavement use costs a lot more in some areas than in others? What are the roles for the Federal Government, the state governments and the private sector? Is there room in such a system for special local needs? Is it politically feasible to phase out existing grandfather rights? How can these new regulations be developed in a manner that doesn’t jeopardize other transport modes?

2.5 Breakout Session—Potential Implementation Mechanisms and Procedures

The discussion centered on Bob Clarke’s proposed two-tiered approach. Some people felt that, by taking the two-tiered approach, there is a reasonable chance of breaking the “80,000 lb cap” impasse and implementing a performance-based approach. Others felt that “if performance-based regulations are such a good idea, then they ought to apply to all trucks, not just the bigger ones.” Some thought that there are two questions here and that they should be separated. First, should heavier trucks be allowed (i.e., over 80,000 lbs)? Second, should TS&W regulations incorporate performance standards?

Presuming for the moment that performance-based regulations should be considered for all trucks, the group addressed the question of whether such regulations could practicably be implemented. The obvious first step would be to decide what the acceptability criteria for performance standards would be (*for safety/stability and for infrastructure*). At this point, however, some participants felt that, while it is easy to identify desirable performance levels, it is also critical to understand what impacts achieving these levels entail. “We have known about roll stability for twenty years,” someone said, “but the industry isn’t moving to designs that are optimized in this regard because of the costs that are involved.” As a result, trucks exhibiting better levels of roll stability are not taking over from trucks with poorer levels. Others pointed out that anti-lock brakes are available, and result in better performance, but that they have only reached a five percent penetration rate of the truck fleet.

After determining performance acceptability criteria and the impacts associated with their attainment, a second step needed to implement such a system is to have the technical literature translated into something policy makers can understand. There is a widespread feeling that the people who make laws or regulations have a poor understanding of heavy truck performance.

The third item needed to implement a performance-based approach is to identify all the possible approaches that could be used. These range from, at one end of the scale, a voluntary consensus on what the standards of performance should be and a voluntary adoption of trucks meeting these standards, to direct government intervention with regulations that mandate the use of specific trucks, at the other end of the scale.

3.0 Vehicle Stability and Control

Peter Sweatman described an Australian study on the likely impact of moving to a performance-based system of regulations². He began by suggesting that we tend to forget we already have performance standards in some areas such as braking. (*The concept is in place but principally for single vehicles, not combination vehicles.*) According to Sweatman, there are four key performance attributes relevant to safety: roll stability, rearward amplification, low-speed offtracking and high-speed offtracking.

3.1 Roll Stability

In terms of roll stability³, Sweatman points out that two-axle trucks are the worst performers. For example, a lateral acceleration of about 0.15 g may be sufficient to cause the wheels on some two-axle trucks to lift off. This raises an interesting point about performance-based regulations: should the same measure of performance be applied to all vehicles? In the particular case discussed, two-axle trucks may not perform as well as tractor-semitrailers. For example, a tractor-semitrailer may experience over 0.3 g of lateral acceleration before its wheels lift off. But, Sweatman continues, the driver of a two-axle truck has more feedback than the driver of a tractor-semitrailer. The driver can feel the truck about to tip more directly than the driver of a tractor-semitrailer can feel a trailer about to go over. Sweatman gives no recommendations on this point; he simply raises it as an example of the complexity of moving to a performance-based system.

He also points out how factors such as suspension systems and axle loads improve or degrade roll stability. One measure of performance for all trucks under all circumstances may be simplistic. Another question raised by Sweatman's example is whether the same axle load limits should apply to all configurations. That is, if axle loads affect roll stability and if different trucks exhibit different roll stability characteristics, perhaps the worst performers should be limited to lower axle loads than the best performers.

²Sweatman, P.F. 1993. *Overview of Dynamic Performance of the Australian Heavy Vehicle Fleet*. NRTC Technical Working Paper No. 7.

³This is the same term as the "propensity to rollover" used by Clarke. The measure used by Sweatman for roll stability (or "rollover threshold") is the maximum lateral acceleration required to cause a vehicle to rollover. At the acceleration, all wheels on one side of a vehicle lift off the ground.

In discussing the implementation of roll stability performance standards—and only New Zealand has actually done this across the board—Sweatman notes that one problem is what to do with many current trucks. “A lot of current vehicles fail any reasonable rollover stability standards,” he notes.

3.2 Rearward Amplification

Rearward amplification, according to Sweatman, “doesn’t mean that much by itself.” That is, it affects safety through its influence on the stability of the rear trailer of a combination truck (and this is better expressed in terms of the load transfer ratio). Small differences in rearward amplification do not necessarily degrade the dynamic stability of the rear unit. They do lead to important changes in the amount of road space needed by long configurations in some maneuvers. The main influence on rearward amplification is the type of configuration. Australian road trains and North America longer combination vehicles are the worst performers.

3.3 Offtracking

Australia has standards for low-speed offtracking (*AUSTROADS Swept Path Specification for three road classes*). Sweatman did not explain how these standards are applied, but it seems that most current Australian trucks do not have difficulty meeting them. In terms of high-speed offtracking, Sweatman suggests it is not generally seen as a major problem for most trucks, although truck-trailers may be an exception.

3.4 Implementation

Sweatman suggests that a starting point for implementing performance-based standards would be to use a tiered approach. That is, the new standards would only apply to some part of the truck fleet. To this extent, his suggestion is similar to Clarke’s. However, he differs in his suggestion for the basis for determining the tiers. Sweatman suggests that the initial tier be based on route-specific criteria. (*Clarke’s suggestion was for tiers based on weight groups.*)

Sweatman concluded with thoughts on issues arising in any attempt to implement performance-based standards. He notes that, with the possible exception of New Zealand, no country has really gone very far with this idea. Issues mentioned include: What should the scope of such standards be: all trucks, or classes of trucks? all roads and all regions, or different standards for different roads/regions? Are more performance standards required for combination trucks than for single-unit trucks? What is the complexity or the cost of moving towards a performance-based approach? Or is it possible to develop—as Canada has partially done—a set of blueprint vehicles that would satisfy most truck operator needs?

3.5 Breakout Session—Vehicle Stability and Control

Peter Sweatman summarized the session by noting the following issues that need to be addressed when considering performance-based standards:

- 1) Should standards apply to all vehicles or only heavier, larger trucks?
- 2) What orientation (*a neutral or a positive impact on safety*) should be used?
- 3) What methods can be used to ensure harmonization among the performance-based standards of different countries?
- 4) Should blueprint trucks be developed?
- 5) How can the standards be made practical (*for example, besides specifying performance, will it also be necessary to set absolute limits for length, gross weight, height, and width*)?
- 6) What networks should the standards apply to? (*nationwide, region, specific routes?*)

The breakout session group also felt it would be important to develop an inventory of the current fleet to determine the performance characteristics of trucks already in service. Finally, the group developed a list of performance measures, possible test methods, and a ranking of the difficulty of developing “pass/fail” criteria as summarized in Table 1.

Table 1. Potential Performance Measures

| Performance Measure | Test Method | Difficulty to Develop Specific Criteria (1= easy, 5= difficult) |
|--|---|--|
| Static Rollover Threshold | Test or Simulation, SAE Standards Exist | 5 |
| Load Transfer Ratio | Simulation Needs To Be Drafted | 5 |
| High Speed Off tracking (Steady State, Transient) | Test or Simulation, SAE Standards | 2 |
| Low Speed Off tracking (Manuverability, Swept Path) | Test or Simulation | 1 |
| Braking (Efficiency, Stability) | Test or Simulation, FMVSS Standards | 1 |
| Trailing Fidelity | Needs To Be Developed | 5 |
| Yaw Damping | Test or Simulation | 5 |
| Friction Demand | Test or Simulation | 4 |
| Friction Utilization | Test or Simulation | 4 |
| Rearward Amplification | Test or Simulation | No Specific Criteria Required |
| Handling (Over/understeer) | Needs To Be Developed, But Only As A Primary Filter | 3 |
| Power-to-Weight Ratio ¹ | Test or Simulation | 1 |
| Gradability | Test or Simulation, SAE Standard | 1 |

Source: Performance-Based Workshop breakout session discussion.

¹U.K. has regulation of minimum power-to-weight ratio of 4.4 KW per 1000 Kg.

4.0 Vehicle-Pavement Interaction

Kit Mitchell notes there are three types of standards that can be used for TS&W limits: prescriptive, performance or parametric. Performance standards, for example, are used by the European Union (EU) to control the turning radii of trucks. (*The standard is: Articulated vehicles with an overall length exceeding 15.5M must be able to turn within concentric circles having radii of 5.3M and 12.5M.*) A performance standard controls the particular aspect of the truck directly (*in this case, its turning circle*).

This same, or similar, level of performance can also be accomplished with a prescriptive standard—one that sets limits for semitrailer and, possibly, tractor lengths. A parametric standard, Mitchell explains, is somewhere between a performance and a prescriptive standard. It might, for example, set limits on kingpin setback, overhang, and wheelbase.

4.1 Performance Standards and Pavements

Turning to the specific issue of performance standards and pavements, Mitchell says current regulations (*so much weight per axle*) do not distinguish between tire types, tire pressure or suspension types. Since the object of limiting axle loads is to reduce pavement wear, ignoring tires, pressure and suspensions and the impact these have on pavements means the current prescriptive regulations miss a great deal of the point. From a pavement management perspective, the regulations ought to encourage less damaging tires, tire pressures and suspensions.

But, Mitchell warns, it is not easy translating this idea to a performance-based regulation. “The problem is that there is a lack of scientific knowledge on the causes of pavement damage.” He points out that there are many different types of pavements and it would be quite a task to develop tests of “road friendliness” for all of them.

4.2 The European Union’s Approach To Pavement-Friendly Suspensions

From what we now know, he says, we want suspension systems incorporating twin tires with low contact pressure, soft springs, as little stiction as possible and an appropriate amount of damping—the actual amount varying with the frequency of the suspension. (*Stiction is the tendency of components in contact to slip and stick relative to each other as load varies due to friction between them.*) European Union (EU) directives attempt to encourage these suspensions. Any air suspension is considered road-friendly. Other suspensions are considered road-friendly for a single drive axle if they comply with a maximum bounce frequency and minimum damping (2 Hz and 20% critical, of which no more than half is due to stiction). The directive suggests test methods for measuring frequency and damping (for example, drive the axle slowly off an 80mm step and measure the suspension’s response). For two-axle drive bogies, the only requirement for non-air suspensions is equal weight on each axle. According to Mitchell, while this Directive

works quite well for single axles, it allows as road-friendly some of the worst—that is, pavement unfriendly—two-axle drive bogies (undamped wheel walking beam suspension). It appears that political considerations lie behind the particular standards adopted. Another problem with the EU directives is that they concentrate on the drive axles. According to Mitchell, the evidence in the United Kingdom (UK) is that trailer axles do at least as much damage to pavements as drive axles.

4.3 The Approaches of the European Union and the United Kingdom

Mitchell describes initiatives the UK and the EU have taken. The UK allows an extra 500 kg axle load per axle, but no increase in GVW for tridem bogies with air suspensions. It also, under an EU directive, allows increased GVWs for 3 and 4 axle trucks and tractor-trailer combinations if their drive axles have twin tires and road-friendly suspensions. For a given truck weight, “we think we are getting about 10 percent less pavement wear through these measures,” Mitchell says. But there are problems: “We’re pretty sure air suspension is good for pavements, but we really can’t prove it.” All the evidence is based on laboratory or theoretical research. Also, Mitchell notes, by giving weight bonuses to encourage air suspensions, we may end up with just as much pavement damage per truck (*less damaging axles but higher weights*). This is really only a problem if the resulting trucks carry more freight in total than they did before the new, pavement friendly regulations came into force. Furthermore, even with air suspensions, “we know there are still problems—such as the load distribution of a truck on a hill (*going uphill, weight shifts to the rear axles*), or the load distribution when a truck crosses the short, humped bridge common in the UK (*there is a point when much of the load is on only one axle*).”

Mitchell explains the UK’s concern about axle loads, and its attempt to encourage more pavement friendly suspensions, by noting that a large amount of road maintenance costs are thought to be the result of truck axle loads. So how do you regulate trucks in such a way to limit pavement wear? Well, other than the “bonus” approach being tried in the UK and EU to encourage air suspensions, Mitchell notes that you can use taxes (*in the UK, lower taxes for the six-axle tractor-semitrailer that handles freight—given the GVW limits with fewer ESALs per ton than the five-axle tractor-semitrailer*), outright bans on some suspension systems, speed limit “bonuses” (*again, for some trucks*) or the performance-based approach being considered at this workshop. “Trouble is,” says Mitchell, “the performance-based approach is really difficult.”

4.4 Breakout Session—Vehicle-Pavement Interaction

The group continued the discussion sparked by Kit Mitchell's presentation on the difficulty of developing performance-based regulations meeting pavement management goals. (*The other aspect of infrastructure—bridges—was not discussed.*) Some ideas were:

- There is a need for better pavement designs, that is, designs for longer lives and lower maintenance costs. A performance-based standard for axles loads is intimately related to the issue of pavement design.
- There was a general acceptance of the proposition that lower static axle loads are preferable to higher ones. Whatever else we know about pavement performance, it is generally true that higher static loads cause more wear.
- There is a need for suspension systems that equalize loads within axle groups. In many countries, the current prescriptive regulations simply limit static axle group loads with no requirement for equalization.
- Performance-based regulations should incorporate both tire types and tire pressure. Many current regulations simply specify a limit to the load per width of tire, independent of tire type or pressure.
- There is a difficulty incorporating actual pavement performance into any performance-based regulations. For example, the rate of pavement wear depends on the pavement condition. Once pavements start to fail, they fail quickly. It is not clear how performance-based regulations could take into account this temporal aspect of a particular pavement section.

In wrapping up the discussion, Mitchell notes that, looking at the system as a whole, truck operating costs are much greater than pavement costs, perhaps by a factor of 20 to 30. It is not worth increasing trucking costs to save on pavement maintenance. Indeed, any small increase in truck productivity has large implications for the economy as a whole and may warrant additional expenditures on better pavements. "All the better if we can accomplish this increase in truck productivity while simultaneously developing more pavement-friendly trucks." Perhaps, he notes, this implies we need better designs for pavements on hills and at intersections, places that currently experience more pavement wear.

Mitchell said the breakout group was not sure if performance-based regulations should be developed for the road networks of entire countries or continents, or whether they would be better for regions or even specific routes.

In terms of the implementation of performance-based regulations, the group envisages a role for specialized organizations, using pass/fail criteria, testing various suspension components. The group is not sure how such regulations can be enforced, although some held out the hope that new, emerging technologies—such as means for identifying vehicles electronically—would be

important in this effort. Enforcement is a particular problem where performance-based standards dictate that specific classes of tractors be matched to specific classes of trailers and, even, commodities. Perhaps trucks could be fitted with special plates, or electronic identification devices allowing enforcement officers to determine what axle loads are allowed, given the suspension, tires, etc.

5.0 Summary

There was insufficient time for the workshop to develop conclusions and recommendations. However, the following themes emerged:

- A proposal was made to develop size and weight regulations for large trucks based on a truck's performance rather than the prescriptive rules characterizing current regulations.
- The participants of the workshop spent the day discussing the difficulties associated with implementing such a system of regulations.
- If there was a consensus, it was that performance-based regulations might be possible under some circumstances, but not all aspects of how such a system would be administered and implemented have yet to be worked out.
- Finally, while many of the concerns and much of the day's discussion revolved around technical issues, there was a widely-held feeling that the political and institutional issues were of even more importance. These, as well as the technical issues, must be addressed if anything is ever to come of the proposal to incorporate performance-based standards in truck regulations.

Therefore, there is a need to resolve the remaining technical issues and to provide a more sound basis for addressing the political and institutional issues.