Review of U.S. Department of Transportation Truck Size and Weight Study - Second Report: Review of USDOT Technical Reports

DETAILS

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Second Report: Review of USDOT Technical Reports

Contents:

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SUMMARY

The U.S. Department of Transportation (USDOT) asked the Transportation Research Board to convene a committee to review the study of truck size and weight limits that the 2012 surface transportation authorization act requires USDOT to carry out. The first report of the committee (TRB 2014) reviewed preliminary products of the study. This final report is the committee's review of the USDOT study's technical reports, which present estimates of five categories of impacts of changes in federal truck size and weight limits: effects on bridges, pavements, shares of total freight traffic carried by trucks and other freight modes, safety, and enforcement of truck regulations. In its review, the committee considered how the USDOT study addresses the questions identified by Congress and the appropriateness of the methods and data used to produce the estimates. The committee's recommendations propose actions suggested by the experience of the USDOT study to increase the value of any future truck size and weight studies.

Responsiveness to the Questions Identified by Congress

The USDOT report specifies how the study attempted to address the requirements of the legislative charge and acknowledges gaps in its ability to estimate impacts of alternative configurations. However, a more comprehensive and useful response would have been possible within the resources of the study. Areas in which the study fell short of the requirements are described below.

Lack of a Summary Evaluation

The USDOT report lacks a consistent and complete quantitative summary of the evaluations of the alternative configuration scenarios. Important categories of costs are not estimated, measures of the various impacts are incommensurate, and assessments of the uncertainty of estimates are missing or inaccurate. Consequently, the information presented does not enable the reader to form a coherent picture of the likely impacts of allowing alternative configurations or of the degree of confidence to place in the predictions of impacts.

At the least, the report could have provided a framework for understanding all the costs and benefits. A comprehensive list of the categories of costs and benefits, the features of the hypothesized regulatory change that influence each category, the direction of change, and the categories that are likely to be critical to the evaluation all can be identified from results of the present and past studies.

Costs that were not estimated in the USDOT study include the following major categories, as well as others of probably smaller magnitude:

- Infrastructure costs on roads not part of the Interstate system or National Network,
- Expected or likely bridge structural costs,
- User costs of bridge replacements and retrofits and of bridge weight restrictions, and
- Aggregate crash and casualty frequency and associated costs.

Units of measure in which the impacts estimates are presented are inconsistent; therefore, the report cannot support the process of weighing costs, benefits, and trade-offs of alternative courses of action that regulatory decisions require. Changes in logistics, congestion, and enforcement costs are reported in annual dollars; bridge costs are reported as an initial capital expenditure; pavement costs are reported as the percentage change in present value of all future costs; and energy and pollution impacts are expressed in physical units.

Evaluation of Consequences of Grandfather Exemptions

The legislative study charge appears to call for USDOT to assess the costs and benefits of impacts of the grandfather and other exemptions in federal size and weight regulations on infrastructure, safety, and state finances in each state where the exemptions are in effect. The study does not provide such an overall assessment.

Methods and Data

Chapters 3 through 7 present conclusions with regard to the methods and data used in the estimates of each category of impact in the USDOT study. Highlights of those conclusions include the following:

- The procedure for selecting the sample of bridges used in the bridge analysis may have introduced bias. The sample was selected judgmentally from among bridges for which the necessary input data were already available. The method of defining the representative pavements analyzed also gives rise to concern about possible bias.
- In the alternative configuration scenarios, the estimates of diversion of freight from rail to truck and of the redistribution of freight among truck configurations use a synthetic database of shipments in which shipment size and other characteristics are assumed. The effect of the assumptions on the accuracy of the mode share projections is unknown.
- The estimated logistics cost savings per vehicle mile of truck traffic reduction are much larger than in earlier studies for the alternative configuration scenarios involving heavier tractor-semitrailers. Confidence in the estimates could have been strengthened by accounting for such differences.
- The estimates of actual vehicle miles of travel by each truck configuration (which affect the estimates of infrastructure and safety impacts of alternative configurations) are derived from data collected by the states from weigh-in-motion (WIM) devices. Interpretation of WIM data is difficult. The USDOT report does not indicate whether any tests of the estimates' accuracy were carried out.
- The comparisons of alternative configuration and control vehicle crash rates do not consider some factors that influence safety performance, including driver characteristics, company management

practices, and the temporal distribution of travel. The populations of the alternative configurations are likely to differ from the control vehicles in some of these factors.

- In the vehicle stability simulations, the rearward amplification of triple-trailer configurations in the avoidance maneuver was found to be no different from that of doubles. Earlier studies found the rearward amplification of triples to be substantially more severe than that of doubles. Examination of the source of differences with past results would have enhanced the credibility of the USDOT study.

Recommendations

USDOT should promote improvement of state information systems aimed at monitoring the impact of existing truck traffic on highway performance. Improvements in information systems would support highway agencies' efforts to manage impacts and would have the secondary benefit of allowing more credible projections of the effects of changes in truck regulations. The most critical needs are for better understanding of how truck traffic affects crash risks and of how it affects bridge-related costs.

USDOT and state analyses of truck size and weight policy should aim at evaluating the full range of methods for mitigating costs of truck traffic—not only size and weight limits but also changes in vehicle design; changes in bridge design, monitoring, and inspection practices; enforcement of regulations; and design of permit and fee systems. The goal should be development of comprehensive strategies for reducing the public costs and increasing the benefits of highway freight transportation.

Chapters 3 through 7 present recommendations for improving estimates in each of the impact categories in any future truck size and weight study. The following are highlights of the recommendations:

- Bridge cost estimates in any future study should be based on explicit assumptions about state highway agency responses to changes in truck traffic. Projections of probable state responses and determination of economically optimal responses both would be useful.

- The analysis of pavement and bridge impacts in any future USDOT truck size and weight study should include estimates of costs derived from evaluations of scientifically designed samples of actual pavements and actual bridges selected from the entire U.S. road system.
- USDOT should undertake research to improve understanding of the behavioral factors that influence freight demand, analytical techniques to depict freight markets as they are affected by public policy, and data required for freight market analysis. Research should develop and test three methods of predicting mode choice: disaggregate models, aggregate econometric models, and expert opinion.
- USDOT should continue to support three potentially valuable areas of research and data development begun in the present study:
  - Development of data systems in cooperation with the states to monitor the safety performance of truck configurations. Refinement and validation of WIM-derived vehicle distributions would improve exposure data for estimating crash rates.
  - Research to understand the relationship of crash frequency on a road to the traffic volume and mix of vehicle types on the road.
  - Analysis of the relationship between weight enforcement effort and frequency of violations. Knowledge of this relationship could lead to improvement in the cost-effectiveness of enforcement.

Reference

Abbreviation
TRB Transportation Research Board

TRB. 2014. Review of U.S. Department of Transportation Truck Size and Weight Study: First Report: Review of Desk Scans. March 31. http://onlinepubs.trb.org/onlinepubs/sr/TS&WDeskScans.pdf.

1. INTRODUCTION

Section 32801 of the 2012 surface transportation authorization act, Moving Ahead for Progress in the 21st Century (MAP-21), called for the U.S. Department of Transportation (USDOT) to conduct a comprehensive truck size and weight limits study. The law required the study to examine the effects of operation of large trucks in terms of impacts on bridges, pavements, safety, fuel efficiency, the environment, enforcement of truck regulations, and shares of freight traffic carried by trucks and other freight modes. The MAP-21 study charge to USDOT is included as Appendix A of this report.

USDOT asked the Transportation Research Board (TRB) to provide a peer review of the study it carried out in response to this provision of the statute. To conduct the review, TRB convened a committee that includes members with expertise in highway safety, freight transportation economics, bridge engineering, pavement engineering, and highway safety enforcement. Members' biographies appear at the end of this report.

The committee has delivered its review in two reports. The first report (TRB 2014) reviewed desk scans (literature reviews) prepared by USDOT in each of the technical areas of the USDOT study with respect to their thoroughness in identifying past research, assessing models and data for conducting the comprehensive study, and synthesizing the preceding body of work. This final report is the committee's review of the USDOT technical reports (USDOT 2015a, 2015b, 2015c, 2015d, 2015e, 2015f), which present estimates of five categories of impacts of changes in federal truck size and weight limits: effects on bridges, pavements, shares of total freight traffic carried by trucks and other freight modes, safety, and enforcement of truck regulations. The report on shares of traffic by freight mode also addresses environmental impacts, energy efficiency, and effects on shipper costs. USDOT describes the content and purpose of the technical reports as follows (*Summary*, ES-1):[1]

[1] In this report, for ease of reference, the volumes of the technical report are cited as follows: *Bridge* = USDOT 2015a, *Compliance* = USDOT 2015b, *Safety* = USDOT 2015c, *Modal Shift* = USDOT 2015d, *Pavement* = USDOT 2015e, and *Summary* = USDOT 2015f.

> FHWA [the Federal Highway Administration] did not intend to develop or support a position on changes to current Federal truck size and weight limits in this study; rather, the agency intended to assess the impacts that any such changes might have in the various areas included in the study to better understand the impacts that trucks operating above current Federal truck size and weight limits have today. The study was set up to provide the results of the assessments that were completed and to provide a summary of this analysis to Congress.

The committee's task statement (Appendix B of this report) requires the committee to comment on the extent to which the technical analysis and findings address the issues identified by Congress.

At a public meeting of the committee on July 14, 2015, USDOT staff presented summaries of the technical reports and responded to questions from the committee. The meeting included an opportunity for members of the public to comment to the committee on its task. Appendix C acknowledges public comments that the committee received. This report was subject to an independent review according to the procedures of the National Academies of Sciences, Engineering, and Medicine, as described in Appendix D.

The committee understands that the USDOT report's primary intended audience is Congress and that the report's purpose is to provide Congress with information about the consequences of any changes that it may enact in federal truck size and weight regulations. USDOT also recognizes other audiences for its report, as indicated by its outreach to state government, industry, and the public during the study. The states need information to guide their decisions about size and weight regulations, and members of the public wish to understand the possible effects of proposed changes in regulations. The committee assessed the USDOT study with respect to these intended audiences and purposes. Its review of each of the technical reports sought to answer a series of questions: Do the technical analysis and findings address the issues identified by Congress, is the methodology theoretically credible, and are the data adequate for carrying out the estimates according to the chosen method?

The scope of the committee's review was limited. The committee's conclusions concentrate on the principles of the methodologies used, the credibility of major results, the format of the presentation of results, and the overall structure of the USDOT study. With few exceptions, the committee did not attempt to verify data or computations described in the technical reports. Also, as the reviews of the technical reports below note, in some instances the reports do not give full details on methods and assumptions. The committee understands that additional documentation may be published later or will be available from USDOT, but it was unable to pursue documentation beyond the already published reports.

The committee understands that USDOT does not plan substantial revisions to the technical reports. The committee's recommendations propose improvements that are suggested by the experience of the USDOT study and that could be adopted if USDOT, the states, or others undertake studies in the future. The recommended improvements would increase the usefulness of future studies to governments and the public as sources of information on the consequences of truck size and weight regulation.

The next chapter of this report presents conclusions and recommendations concerning the USDOT study as a whole. The five subsequent chapters present conclusions and recommendations concerning the analyses in each of the technical reports: bridges, pavement, modal shift, safety, and enforcement.

References

Abbreviations

TRB	Transportation Research Board
USDOT	U.S. Department of Transportation

TRB. 2014. Review of U.S. Department of Transportation Truck Size and Weight Study: First Report: Review of Desk Scans. March 31. http://onlinepubs.trb.org/onlinepubs/sr/TS&WDeskScans.pdf.

USDOT. 2015a. *Comprehensive Truck Size and Weight Limits Study: Bridge Structure Comparative Analysis Technical Report*. June.

USDOT. 2015b. *Comprehensive Truck Size and Weight Limits Study: Compliance Comparative Analysis Technical Report*. June.

USDOT. 2015c. *Comprehensive Truck Size and Weight Limits Study: Highway Safety and Truck Crash Comparative Analysis Technical Report*. June.

USDOT. 2015d. *Comprehensive Truck Size and Weight Limits Study: Modal Shift Comparative Analysis Technical Report*. June.

USDOT. 2015e. *Comprehensive Truck Size and Weight Limits Study: Pavement Comparative Analysis Technical Report*. June.

USDOT. 2015f. *Comprehensive Truck Size and Weight Limits Study: Volume 1: Technical Reports Summary*. June.

2. GENERAL OBSERVATIONS

The conclusions below concern the extent to which the technical reports as a whole address the issues identified by Congress and the appropriateness of methods and data that affect all parts of the USDOT study. The recommendations concern information needs and the structure of future truck size and weight policy studies.

Responsiveness to the Questions Identified by Congress

The USDOT report carefully specifies how the study attempted to address each of the requirements of the congressional study charge (*Summary*, 15–18) and acknowledges gaps in its ability to estimate impacts of alternative configurations. However, the experience of past truck size and weight studies suggests that the present study could have been more responsive to the needs of Congress and its other audiences. Limitations of the USDOT study that could have been at least partially overcome are identified below.

Lack of a Summary Evaluation

The USDOT report lacks a consistent and complete quantitative summary of the evaluations of the alternative configuration scenarios. In the absence of such a summary, the report is not fully responsive to the congressional charge to assess the impacts of alternative and exempt vehicles. Moreover, the lack of a summary diminishes the report's value to its intended audiences.

The 1981 USDOT truck size and weight study and past TRB studies contained summaries of all impacts considered of specified changes in size and weight regulations, with most impacts expressed in terms of nationwide dollar-denominated annual costs and benefits (USDOT 1981, V-6; TRB 1990a, 13–15; TRB 1990b, 180–181). The 2000 USDOT study included a summary table of the percent changes in each cost and benefit, excluding safety, for each regulatory scenario (USDOT 2000, 38) and presented estimates of nationwide dollar impacts in the body of the report. The tabular summary in the 2015 USDOT report (*Summary*, ES-11–ES-12) presents findings for some, but not all, costs considered, and with such disparity in definitions and metrics that comparison among the scenarios is impractical.

Omission of a summary evaluation was a decision of the 2015 USDOT study's authors. USDOT concluded that "data limitations are so profound that results cannot accurately be extrapolated to predict national impacts."[2] However, projections of the kind contained in the 2015 and earlier studies cannot be characterized simply as accurate or inaccurate. Each estimate possesses some degree of uncertainty, which must be described. None of the past studies used models or data that were more accurate than those of the 2015 USDOT study. The reports of some of those studies included adequate discussion of critical uncertainties and of the role of judgment in estimating impacts, while others did not.

The 2002 TRB committee that reviewed all major past truck size and weight studies concluded that, because of the complexity of the highway freight transportation system, "it is not possible to predict the outcomes of regulatory changes with high confidence" (TRB 2002, 3). If highly confident forecasts of impacts were the standard, no regulation would ever be enacted or changed. Changes at the federal and state levels are being considered or enacted today, and government transportation professionals need to provide the best estimates available at any time to aid these deliberations.

Notwithstanding the USDOT study's conclusion that some costs of the regulatory alternatives are impossible to estimate confidently, the report could have provided a framework for understanding all the costs and benefits that would help users to put the costs that are estimated in perspective. A comprehensive list of the categories of costs and benefits, the features of the regulatory change that influence each category (e.g., pavement wear is affected by axle weight limits, bridge costs by gross weight), the expected direction of change, and the cost categories that are likely to be critical to the evaluation all can be identified on the basis of the results of the 2015 USDOT study and past size and weight studies.

A useful summary would correct three shortcomings in the USDOT report's analysis and

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[2] Letter of Peter M. Rogoff to Hon. Bill Shuster, June 5, 2015.

presentation: missing estimates of categories of costs and benefits, inconsistent units of measure of impacts, and inconsistent and sometimes misleading assessments of the uncertainty of estimates. These limitations are examined in the sections below.

Missing Costs

Categories of costs that were considered in past studies or that are likely to be affected by changes in size and weight regulations but were not estimated in the USDOT study include the following:

- Infrastructure costs on roads not part of the Interstate system or National Network;
- Bridge deck maintenance and rehabilitation costs;
- Expected or likely bridge structural costs [the cost estimates reported are described as an "extreme upper bound," and the USDOT study concludes that "neither the actual costs nor the lower bound costs are determinate" (*Bridge*, 58)];
- User costs of bridge replacements and retrofits and of bridge weight restrictions;
- Aggregate crash and casualty frequency and associated costs;
- Crash risk in highway work zones; and
- Costs in future years, when freight traffic and total highway traffic will be greater (costs and benefits are unlikely to grow proportionally with traffic volume).

In some cases (e.g., crash frequency, bridge decks, local roads), the USDOT report acknowledges that a cost would occur, although it does not estimate the cost. Other important costs are not mentioned in the body of the technical analysis, although estimates of past studies may be cited in the desk scans.

The committee recognizes that producing definitive estimates of all of these costs would not have been practical within the constraints of time and resources available for the USDOT study. The critical uncertainties in evaluations of changes in size and weight limits, according to the 2002 TRB committee review of the problem (TRB 2002, 3-4), are safety consequences and bridge costs. Differences in crash rates that depend on vehicle weight or configuration will remain difficult to measure until improvements are made in the systems for regular monitoring of traffic volumes and for recording characteristics of vehicles involved in crashes. An appropriate bridge cost estimate (as described in Chapter 3 below) would require development of new methods and might not have been feasible within the study's resources.

Nevertheless, the USDOT study could have produced order-of-magnitude estimates of the important costs, with confidence intervals derived from the range of estimates produced in the 2015 study as well as past studies and from sensitivity analysis. Moreover, the study could have presented its estimates in a comprehensive, consistent framework defining national costs and benefits. Such a presentation would be useful to Congress and the public in considering proposed changes to regulations. It would show the overall magnitude of potential benefits and costs at stake in regulatory decisions; indicate how impacts would be distributed among shippers, carriers, highway agencies, highway users, and the public; and possibly reveal some actions that promised benefits at low risk. Such a comprehensive summary evaluation also is necessary for identifying priorities for research on measuring impacts and on mitigating the costs of truck transportation.

Inconsistent Metrics

Inconsistency in the units of measure in which the impacts estimates are presented makes it impossible for the reader to weigh the trade-offs that are inherent to any regulatory decision:

- Changes in logistics costs, congestion costs, and enforcement costs are reported in annual dollars, in the analysis base year of 2011 (i.e., 2011 freight volume, highway traffic, and prices are assumed).
- Changes in fuel consumption and pollutant emissions are reported in physical units (gallons of fuel and pounds of emission) on an annual basis.

- Costs of accommodating bridge structures to heavier gross weights are reported as an upper bound of the one-time capital expenditure required for replacement or retrofit of bridges.
- Pavement wear costs are presented as a percentage change in life-cycle cost (i.e., the percentage change in the present value of highway agency costs for construction and rehabilitation of pavement in all future years).
- Safety impacts are described in a bullet-point list of various qualitative and quantitative observations about crash rates and stability properties of alternative configurations.

Use of a single unit of measure, at least for the costs most readily expressed in dollar terms, would have enhanced the usefulness of the USDOT study. The most comprehensive measure would be the present value of future changes in each cost category. Alternatively, impact estimates could be presented in annualized dollars in the analysis year (2011) and in one or more future years to illustrate the effect of traffic growth on costs and benefits.

Inconsistent Assessments of Uncertainty

The USDOT report provides insufficient quantitative indication of the degree of uncertainty of its impact estimates. Users of the report need indications of the degree of confidence to be placed in each impact estimate. No simple way of defining or expressing uncertainty in such a complex study exists; however, past truck size and weight studies have used several techniques effectively:

- Comparison and synthesis of evidence from all available sources, including comparison with estimates from past studies. For example, the TRB committee that evaluated twin trailer trucks based its estimates of crash rates on a critical review and synthesis of 16 past studies. None of the 16 studies individually was conclusive, but the TRB committee concluded that collectively their results narrowed the range of uncertainty about safety impacts (TRB 1986, 320–324). The desk scans prepared for the USDOT study summarize results of past studies, but the USDOT report makes little use of these results, either to supplement the study's own estimates or as a check on the credibility of the new estimates.

- Comparison of estimates derived by alternative independent methods. If two independent methods yield similar estimates, confidence is improved. For example, this approach could have been used to help assess the validity of the sample of bridges used in the bridge structural cost estimates in the USDOT study.
- Estimates of statistical uncertainty (e.g., the uncertainty of an estimate derived from information on a sample of the population of interest or based on errors of measurement in the inputs to an impact).
- Highlighting of uncertainties that are most important for decision making. The tolerable magnitude of uncertainty of an impact estimate depends on the relative magnitude of the impact. For example, past studies have established that, for changes in regulations involving changes in gross weight limits but no change in axle weight limits, costs of pavement impacts are much smaller than costs of bridge impacts. Therefore, devoting more study resources to improving estimates of pavement impacts would not contribute greatly to the accuracy of the overall assessment of infrastructure impacts of such a regulatory change. An estimate of an upper bound on a cost (as the USDOT study estimated for bridge structural costs) is sufficient if the cost is known to be small compared with other costs. However, for major costs (including bridge structural costs of increases in gross weight limits), an estimate of expected cost with a confidence interval is needed.
- Sensitivity analysis. For example, the TRB committee that authored the report on the Turner proposal used sensitivity analyses to show how bridge costs would be affected by alternative assumptions about responses of highway agencies to introduction of heavier trucks and to show how alternative projections of market penetration of new truck configurations would affect highway agency costs (TRB 1990b, 191–194, Tables 7-2 and 7-3), and the TRB *Truck Weight Limits* committee used

sensitivity analysis to show how alternative assumptions about the relationship of truck weight to crash rate would affect the estimates of safety costs of changes in limits (TRB 1990a, 252–253). The USDOT report does not make systematic use of sensitivity analysis.

The past USDOT and TRB studies used these techniques to support incisive conclusions about the probable range of effects of changes in size and weight limits, in spite of the gaps in knowledge that have confronted all such studies.

Definition of Regulatory Alternative Scenarios

The USDOT study estimates costs and benefits for six scenarios. Each scenario is defined in terms of a single vehicle not allowed under present federal law that federal law would allow to operate on the Interstate system and the federal designated National Network (or on a more restricted network in the triple-trailer scenarios). In contrast, the earlier USDOT and TRB studies defined scenarios in terms of changes in regulations (e.g., a change in the gross weight limit). Analyzing vehicles one at a time is insufficient for estimating the effects of regulatory changes that would lead to increased use of more than one configuration type because the impacts of introducing two of the alternative configurations would not equal the sum of the impacts of introducing each one individually.

The alternative configuration scenario definitions reflect the point of view expressed in USDOT's presentation to the committee on the technical reports, which defined the "fundamental truck size and weight policy question" as follows: "Do the estimated 'positive' impacts of a particular TSW [truck size and weight] change outweigh the estimated 'negative' impacts?"[3] The TRB committee that authored *Regulation of Weights, Lengths, and Widths of Commercial Motor Vehicles* (TRB 2002) argued that this definition of the size and weight policy problem is insufficient and that, instead, a truck size and weight policy study should begin by defining the objectives of size and weight regulations [which the 2002 TRB

[3] FHWA presentation to the committee, July 14, 2015.

committee defined as "balancing the potential public costs of truck travel against the benefits of lower shipper and carrier costs for freight transportation" (TRB 2002, 41)] and then should search for changes in the regulations and other government policies that would better meet the objectives (TRB 2002, 41–42). For example, if evaluations indicated that a change in limits would allow reductions in shipper costs but that bridge-related costs and uncertainty about safety were obstacles, the size and weight study should next consider whether means of overcoming these obstacles may exist (e.g., by identifying vehicle design requirements to improve safety, cost-effective strategies for mitigating bridge impacts, or fee schemes to fund necessary improvements).

The legislative study charge requires USDOT to evaluate "alternative configurations," but nothing in the charge precludes the approach recommended by the 2002 TRB committee. The charge does not specify the form of the change in federal law (e.g., a change in the federal dimensional limits or an exemption from the limits for a specified configuration) that would lead to introduction of the alternative configurations. In defining the alternative configuration scenarios of its study, USDOT found it necessary to specify various aspects of the regulatory provisions that would govern the alternative configurations, including road networks and axle weight limits.

Evaluation of Consequences of Grandfather Exemptions

Congress charged USDOT to "evaluate the impacts to the infrastructure in each State that allows a vehicle to operate with size and weight limits that are in excess of the Federal law and regulations, or to operate under a Federal exemption or grandfather right, in comparison to vehicles that do not operate in excess of Federal law and regulations . . ., including—(A) the cost and benefits of the impacts in dollars; (B) the percentage of trucks operating in excess of the Federal size and weight limits; and (C) the ability of each State to recover the cost for the impacts, or the benefits incurred. . . ." [MAP-21, Section 32801(a)(2)]. USDOT was also to "provide data on accident frequency and evaluate factors related to accident risk of vehicles that operate with size and weight limits that are in excess of the Federal law and regulations in each State that allows vehicles to operate with size and weight limits that are in excess of the Federal law and regulations. . . .” [MAP-21, Section 32801(a)(1)]. These directions appear to call, at least, for USDOT to provide an overall assessment of the consequences for infrastructure, safety, and state finances of the grandfather and other exemptions in federal size and weight regulations in the states where the exemptions are in effect. The 1981 and 2000 USDOT truck size and weight studies directly addressed the question of the consequences of the grandfather exemptions by assessing regulatory scenarios in which the exemptions were eliminated (USDOT 1981, II-2; USDOT 2000, II-11). Estimates of costs and benefits in these scenarios in the earlier studies were presented for the nation, rather than at the state level, although the 1981 study discussed state-level industry economic impacts.

The 2015 USDOT study does not provide an overall assessment of the consequences of the grandfather exemptions in the states where they apply. It therefore falls short of responding to this part of the congressional charge.

Methods and Data

The observations in this section concern study methods that affect multiple impact areas. Chapters 3 through 7 below present the committee’s conclusions concerning methods and data used in the USDOT study’s estimates of each of the five impact categories.

Limitations of Advanced Models

The USDOT study cites its use of improved models and data sets as an advance over the previous USDOT studies (*Summary*, 31–32). The most current methods are used in the pavement, bridge, and safety analyses. The modal shift and truck travel estimates used traffic information from FHWA’s Freight Analysis Framework, which did not exist at the time of the previous studies. Certainly, it was appropriate for the study to examine whether these new resources could provide new insights into the size and weight problem. However, the data requirements and other features of the new models imposed restrictions on the study. The bridge analysis examined a sample of 490 bridges, whereas the 2000 study analyzed more than one-fourth of all U.S. bridges with a simpler method. In the pavement analysis, the model cannot represent all pavement deterioration mechanisms or load impacts on pavement overlays. The USDOT study might have been able to complete or confirm some of the impact estimates in the report by using older models alongside the new ones.[4] Comparison of results of new and old models also would have been valuable as a test of the benefits of the new models.

Many states have more reliable, detailed, and comprehensive data today about infrastructure condition and truck weights and traffic volumes than were available for the 1981 and 2000 USDOT truck size and weight studies, as a result of progress in infrastructure management programs. Taking advantage of improved data, rather than enhanced models, might have been the greatest opportunity for advancing analysis of size and weight policy over the earlier studies.

Inaccurate Descriptions of Uncertainties

Estimates in several of the impact categories that involve statistical calculations or that include confidence intervals inappropriately characterize uncertainty:

- The tests of significance of differences in crash rates between pairs of vehicle types (*Safety*, Tables 8–10) are incorrect. The test applied assumes that the values of the denominators in the ratios compared are known with certainty, but in this computation, the values of the denominators [vehicle miles of travel (VMT) for each vehicle type] are uncertain to an unknown degree.
- In the presentation of the results of the model relating crash frequency to traffic volume (*Safety*, 29–30, Figures 2 and 3), the extrapolation of the relationship derived by regression far beyond the range

[4] The bridge analysis used an alternative method of structural evaluation for bridge types that the preferred method could not represent (*Bridge*, 13–14).

of the observations is unjustifiable because the extrapolated crash frequencies have extremely large uncertainties.

- The table presenting estimates of the change in life-cycle pavement costs (*Pavement*, 28, Table 12; *Summary*, 58–59, Table 9) shows ranges of values, as if indicating the uncertainty of the estimates. However (as the text explains), the high and low values shown are simply the estimates for two assumed values for the discount rate in the life-cycle analysis. The report does not analyze the effect of any other source of uncertainty.
- In the bridge analysis, the report explains that the sample size of 490 bridges selected for structural analysis was determined according to a calculation of the sample size required to achieve a desired confidence level in estimates derived from the sample (*Bridge*, 16). However, because the sample was not randomly selected, this calculation is inapplicable.

Truck Travel Estimates from Weigh-in-Motion Data

The baseline estimates of annual VMT by each truck configuration used throughout the study (for estimates of bridge and pavement costs and alternative configuration crash rates) are derived from data collected by the states from weigh-in-motion (WIM) devices. The committee's 2014 report noted the difficulties encountered by others in using WIM data for research purposes (TRB 2014, 9). The USDOT report outlines the complex series of computations and assumptions leading to the baseline estimates of VMT by truck category (*Modal Shift*, 236–241). However, no tests of the estimates' validity or accuracy are reported.

Recommendations

The research and data collection programs that would make the greatest contribution to future evaluations of truck size and weight regulations would be aimed at monitoring the impact of existing truck traffic (and changes in traffic) on highway performance and at supporting state and local highway agencies' efforts to manage the impacts. USDOT should promote and support development and improvement of these information systems. Improvements in information systems would have the secondary benefits of supporting more credible estimates of the effects of proposed changes in truck regulations. To improve regulations, the most critical information needs are for better understanding of how truck traffic characteristics (and changes in truck traffic over time) affect (*a*) bridge condition and highway agency costs related to bridges and (*b*) highway crash and casualty risks. To project infrastructure and safety impacts of regulatory changes, information on the determinants of vehicle and mode choice is necessary.

USDOT and state research on truck regulatory policy should aim at evaluating the full range of methods for mitigating costs of truck traffic—not only size and weight limits but also changes in vehicle design; changes in bridge design, condition monitoring, and inspection practices; enforcement of dimensional and safety regulations; and design and management of truck permit and fee systems. The goal of research should be development of comprehensive strategies for improving the performance of highway freight transportation. Size and weight limits alone provide only weak leverage for improving performance. Future truck size and weight studies should be organized as evaluations of comprehensive policy options rather than evaluations of alternative truck configurations.

Research aimed primarily at improved methods for predicting the impact of proposed changes in limits may have value for guiding policy. However, confidence that regulations are effective can come only from the ability to observe the impact of existing rules and the actual consequences of changes.

References

Abbreviations

TRB	Transportation Research Board
USDOT	U.S. Department of Transportation

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Research Council, Washington, D.C.

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3. BRIDGES

The MAP-21 Section 32801 study charge requires the USDOT study to evaluate the impacts on the infrastructure (including bridges) of vehicles that operate under federal exemptions or grandfather rights (i.e., vehicles that federal law exempts from the normal federal weight or dimensional limits that apply on the Interstate or National Network systems) and the infrastructure impacts of allowing operation of alternative configurations, compared with configurations now allowed nationally under federal law.

The USDOT report considers three kinds of effects of changes in size and weight limits: the change in numbers of bridges that would require posting for restricted truck traffic, strengthening, or replacement because their structural load-bearing capacity would be exceeded after the change in limits; change in the cost of load-induced fatigue in steel bridges; and change in the costs of bridge deck deterioration. Deck deterioration costs were not estimated because the study could not identify a suitable method. The fatigue analysis compared effects of alternative configurations and control vehicles for selected details on four actual steel bridges but did not scale the estimates to nationwide impacts or relate the effects to bridge costs. The cost of the change in the number of bridges with insufficient structural capacity was estimated as the cost of strengthening or replacing all such bridges. This strengthening or replacement cost is described as "the extreme upper bound of possible costs" (*Bridge*, 58) because states would choose to restrict truck traffic on some deficient structures rather than to retrofit or replace them.

The structural analysis simulated the response of 490 actual bridges to changes in loads in each of the alternative configuration scenarios according to the AASHTOWare Bridge Rating software package, which is used by 36 states for rating the structural capacity of bridges. Sample bridges were selected in each of 22 categories: 11 structural types on the Interstates and the non-Interstate National Highway System (*Bridge*, 13). The number of sample bridges found structurally substandard (according to a specified criterion that is a function of bridge structure and loads imposed) was scaled to a national estimate on the basis of the systemwide total number of bridges in each of the 22 categories.

Responsiveness to the Questions Identified by Congress

The response of the bridge analysis to the legislative charge is incomplete on account of the following omissions:

- Missing costs (as identified in the following section);
- Lack of a comprehensive framework that would allow the reader to put the USDOT study's impact estimates in perspective with respect to total bridge-related costs and the factors that determine costs; and
- Lack of estimates of bridge impacts of grandfather and other exemptions from federal limits in the states where the exemptions apply, and lack of evaluation of the ability of each state in which exempt trucks operate to recover the costs of the trucks' bridge impacts.

Methods and Data

The conclusions below concern aspects of the bridge analysis that affect the credibility and usefulness of the estimates.

Missing Costs

The USDOT study does not include estimates of potentially important bridge-related costs:

- Costs of changes in truck traffic on bridges on local roads: Local bridges tend to have shorter span lengths than the bridges on the major roads included in the study analysis. The alternative configurations are more likely to cause distress in short-span bridges than longer-span bridges.

- Bridge deck costs: The USDOT report states: "It was not possible to draw national conclusions or present findings concerning the effect on overall bridge service life. While it is highly likely that bridge deck deterioration will accelerate with additional or heavier axle loads, the complex relationship of parameters that determine that performance is not well-defined."[5]
- User costs of delay at bridge construction projects or for detours around posted bridges: Even bridges that states selected for eventual strengthening or replacement would be posted for some time, until funds became available for construction.
- Cost of fatigue: The USDOT study considers one fatigue-prone detail, cover-plate end welds in steel girder bridges. Other fatigue-prone details and distortion-induced fatigue, especially in gusset plates, are omitted. Fatigue cost in future years will depend on the rate of growth of truck traffic, an effect that the USDOT study does not take into account.
- Expected or likely bridge structural costs: The cost estimates reported are described as an "extreme upper bound," and the USDOT study concludes that "neither the actual costs nor the lower bound costs are determinate due to the range of program and policy decisions available to the States" (*Bridge*, 58). That is, actual highway agency and user costs will depend on decisions and management practices of state highway agencies, which the USDOT study does not consider. It is not clear that the cost estimated in the study is an upper bound, since the report does not explain the assumption in the calculation about whether bridges with insufficient capacity are strengthened rather than replaced.
- Cost of building stronger bridges in the future: If changes in truck size and weight limits increase bridge capacity requirements, the cost of building bridges may be increased. Some states today build bridges to carry permit loads that are heavier than normal legal maximums; this practice may reduce the need to upgrade designs of future bridges if the federal limits are changed.
- Costs of structurally deficient bent caps, columns, or foundations.

[5] For comparison, the 2000 USDOT report concludes: "If total truck VMT decreases and axle loads do not increase as the result of TS&W [truck size and weight] limit changes, bridge deck deterioration may be reduced somewhat. No direct relationships currently exist between truck traffic, axle loads, and bridge deck deterioration, but research currently is underway to develop such relationships" (USDOT 2000, Vol. III, VI-4).

Because of these omissions, the USDOT study provides little information to policy makers about bridge costs, which the past USDOT and TRB truck size and weight studies have concluded would be the major infrastructure impact of changes in truck size and weight limits. Credible estimates of the order of magnitude of the missing costs would have been possible, based on methods used in past studies and reasonable assumptions, and sensitivity analyses could have been used to illustrate the degree of uncertainty in the costs. The following are examples:

- An order-of-magnitude estimate of bridge deck costs could have been made on the assumption that the percent change in deck costs would be similar in magnitude to the percent change in pavement cost in a scenario, because both costs increase with frequency of axle loadings and increase nonlinearly with axle weights. Total annual baseline bridge deck costs could be estimated on the basis of deck sufficiency ratings, deck area, and current average deck repair costs in states that have these data. The baseline cost multiplied by the expected percent change in the cost in each scenario would be an estimate of the change in nationwide deck costs in the scenario. Such an estimate would be highly approximate; sensitivity analysis could provide an indication of whether the cost is likely to be important in comparison with other infrastructure costs.
- States concerned about bridge cost impacts of accommodating specialized hauling vehicles (short, heavy trucks such as dump trucks and refuse trucks, typically with four to seven axles) are carrying out studies that could have provided a lower bound for bridge costs in some of the USDOT study scenarios. Cost impacts include needs for posting additional bridges, thereby limiting goods movement, or strengthening or replacing bridges. The concern is motivated in part by a new federal requirement that states rate bridges for these vehicles.
- The 2000 USDOT study estimated the cost to road users of delay and rerouting caused by bridge construction. It concluded that this cost would be greater than highway agency costs for the construction (USDOT 2000, VI-11). Posting bridges that are not replaced also imposes costs on users.

- The TRB *Truck Weight Limits* (TRB 1990a, 102–104) and Turner proposal (TRB 1990b, 152) studies estimated the average annual cost of building future bridges to the higher design standards that would be adopted to accommodate heavier trucks. This cost was estimated to be 10 to 25 percent of total bridge-related costs of various regulatory scenarios.
- Two alternative kinds of estimates of structural costs would be relevant for policy decisions: an estimate based on assumptions about likely state responses to changes in truck traffic, determined by observing state practices; and an estimate based on the assumption that states make optimum decisions with regard to bridge maintenance, inspection, posting, weight limit enforcement, and retrofit and replacement, with all agency and user costs of their decision taken into account (TRB 2002, 73). The Turner proposal study described the effect on estimated cost of alternative assumptions about state decisions concerning posting or replacing bridges and presented a sensitivity analysis showing how the timing of bridge expenditures would affect highway agency costs (TRB 1990b, 153–156, 191–194). The TRB *Commercial Motor Vehicles* study compared the results of the bridge cost estimates in the 2000 USDOT study with actual state practices for selected bridges in one state (TRB 2002, 64–66) and outlined a method for estimating bridge costs if states followed optimal bridge management practices (TRB 2002, 69–75).
- Costs of changes in truck traffic on bridges on local roads were estimated in all the past USDOT and TRB size and weight studies (e.g., USDOT 2000, VI-9; TRB 1990a, 99–100).

The bridge structure cost estimated in the USDOT study is the cost of strengthening or replacing the increment, caused by introduction of each alternative configuration, in the backlog of structurally substandard bridges on the Interstates and the National Network. The USDOT report could have provided perspective on this incremental cost by noting the cost of eliminating the existing backlog. The 2000 USDOT study presented bridge costs in this way (USDOT 2000, VI-12, Table VI-2).

Bridge Sample

The report contains only a general description of how the sample of 490 bridges was selected. USDOT explained to the committee that the bridges were sought and selected to make the sample appear representative with respect to age, span length, and other features. Moreover, the sample was limited to bridges from states that use the AASHTOWare Bridge Rating software applied in the USDOT study and to bridges for which these states had coded the data that the software package requires. (Two bridge types, truss and girder-floor-beam bridges, which the software cannot analyze, were assessed by a different method.)

The procedure for selecting the 490-bridge sample creates the possibility that it is biased. The states that use the AASHTOWare package may not be representative of all states in their bridge management and maintenance procedures. Also, the bridges for which a state has data available in the model format may not be representative of all bridges of their structural type in the state (e.g., they might be bridges for which the required data were most easily obtained).

The report explains that the sample size of 490 was selected according to a calculation of the sample size required to achieve a desired confidence level in estimates derived from the sample (*Bridge*, 16). However, because the sample was not randomly selected, this calculation is inapplicable and gives no information about the confidence level of the bridge cost estimates.

An approach to checking the validity of the bridge sample would have been to repeat the 2000 USDOT bridge analysis method (which used a simpler criterion requiring fewer data items for determining which bridges would be overstressed by alternative configurations) for a random sample of bridges from the National Bridge Inventory and for the 490-bridge sample of the 2015 study. Similar failure rates for bridges of the same type in the two samples would be evidence in support of the validity of the 490-bridge sample. Another check on the validity of the sample would have been to compare the distribution of square feet of bridge deck by bridge type in the sample with the distribution for the U.S. population of bridges.

Unit Costs

The bridge replacement and strengthening cost estimates in the USDOT study assume an average cost of $235 per square foot, derived from records of federal-aid project costs. The report does not describe the derivation of this cost, the variability in costs from project to project, or the mix of strengthening projects and replacement projects in the data from which it was derived. Although the committee did not attempt any estimate of its own, the reaction of some committee members was that the value appears very low.

Truck Weight Assumptions

The structural analysis compares the number of bridges that fail the rating criterion when exposed to the control vehicle loaded to 80,000 pounds (for the tractor-semitrailer control vehicle) or 71,700 pounds (for the double-trailer control vehicle) with the number that would fail when exposed to the alternative configuration loaded to the maximum weight defined in each scenario. The increase in the number of bridges failing is attributed to the change in limits, and the cost of replacing or retrofitting them is considered a cost of the change in limits. However, virtually all of the sample bridges are exposed today, with some regularity, to loads heavier than the assumed loads of the control vehicles, from trucks operating under special permits or from grandfathered trucks (not considering illegal overloads). The bridge structural cost of the alternative configuration scenarios, estimated according to the procedure of the USDOT study, will vary greatly depending on whether the base case is defined as existing legal nonpermit loads, existing legal permit loads, or existing illegal overloads. In other words, the bridge cost estimates in the USDOT study are highly sensitive to arbitrary assumptions.

The assumption in the bridge impact estimates (and in the vehicle handling and stability simulations) that all vehicles are loaded to their maximum legal weight except the control double vehicle, for which the assumed weight is 71,700 pounds rather than the legal maximum 80,000 pounds, may be appropriate for the purpose of the study. However, the report does not adequately explain the inconsistency in the weight assumptions. A more transparent procedure would have been to conduct the analyses at two assumed weights of the control double (71,700 and 80,000 pounds) to show the consequences of the assumption.

Recommendations

The final report of the USDOT study should provide a framework to explain the significance of its bridge cost estimates to the nonspecialist reader. The framework should identify all relevant categories of costs and present estimates of each category from past studies as well as the present study in consistent units.

Any future USDOT truck size and weight study should define such a framework. Bridge cost estimates should include the effect of changes in truck traffic on all bridge components and all forms of impact that affect bridge performance. The addendum to this chapter outlines practical approaches for filling the major gaps in the present study to allow comprehensive estimates. FHWA is ideally situated to champion research on the infrastructure investment needed to increase highway transport efficiency.

Bridge cost estimates in any future study should be based on explicit assumptions about state highway agency responses to changes in truck traffic. These assumptions could be projections of likely state responses based on interviews with states and review of historical state bridge policies and actions. Analysis of the optimal highway agency response according to engineering economic principles also would be valuable in a future study.

The bridge analysis in any future study should include cost estimates derived from evaluation of a scientifically designed sample of all U.S. bridges.

Addendum to Chapter 3

Ideas are offered below on an approach for a practical but comprehensive study of bridge costs of changes in size and weight limits. The largest costs will arise from three impacts:

- Deck degradation leading to deck repair or replacement,
- Loads exceeding the strength of main load-carrying members, and
- Increased cost of future bridges.

Deck cost projections are essential for alternative configuration scenarios that involve higher maximum or average axle weights or that include a triple axle configuration. It is reasonable to expect that the need for deck replacement will be accelerated by heavier axle loads (i.e., that increased loads will bring some bridge decks to the threshold of needing immediate action). The National Bridge Inventory database provides deck sufficiency ratings and contains all bridge lengths and average widths. States have data on their cost per square foot for deck replacement. With this information and an assumption on a cutoff sufficiency rating, an order-of-magnitude estimate of deck costs can be made and added to that for strengthening bridges.

Cost impacts of weak girders can be determined without a model of each bridge. The shear and bending moment demands due to each of the scenario vehicles need to be calculated for all practical span lengths. These values can be compared with those for current legal loads. Each state has cost data on bridge strengthenings and replacements. Replacement costs should be used for bridge types such as precast prestressed girder bridges, trusses, and slab bridges that cannot be strengthened. Steel girder bridges can be strengthened in most cases.

Finally, projects are not completed instantaneously. Costs must be projected over 5 to 10 years and delay costs added for the time a bridge is posted.

Future bridges may need deeper cross sections to carry an alternative configuration. A modified table of depth-to-span ratios for each structure type would need to be developed for each of the scenario vehicles. Construction cost averages in each state for each bridge type could then be used to project a percent increase in new bridge cost.

References

Abbreviations

TRB	Transportation Research Board
USDOT	U.S. Department of Transportation

TRB. 1990a. *Special Report 225: Truck Weight Limits: Issues and Options.* National Research Council, Washington, D.C.

TRB. 1990b. *Special Report 227: New Trucks for Greater Productivity and Less Road Wear: An Evaluation of the Turner Proposal.* National Research Council, Washington, D.C.

TRB. 2002. *Special Report 267: Regulation of Weights, Lengths, and Widths of Commercial Motor Vehicles*. National Academies, Washington, D.C.

USDOT. 2000. *The U.S. Department of Transportation's Comprehensive Truck Size and Weight Study: Volume III: Scenario Analysis*. Aug.

4. PAVEMENT

The MAP-21 requirements concerning pavement analysis parallel the bridge analysis requirements: the USDOT study is to evaluate the impacts on the infrastructure of vehicles that now operate with grandfather or other exemptions to federal size or weight limits and the infrastructure impacts of allowing operation of alternative configurations, compared with configurations now allowed nationally under federal law.

The pavement analysis in the USDOT study uses a model of pavement wear as a function of traffic (the AASHTO Mechanistic–Empirical Pavement Design software package) to estimate the change in life-cycle pavement costs (i.e., the present value of the cost to the highway agency of all future pavement rehabilitations in a 50-year period necessary to maintain a specified average pavement condition) caused by replacing existing (baseline) traffic with the predicted traffic in each alternative configuration scenario. The estimates are based on analysis of a set of hypothetical representative pavement sections (*Pavemen*t, 28).

Responsiveness to the Questions Identified by Congress

Congress specifically required that the study "evaluate the impacts to the infrastructure in each State that allows a vehicle to operate with axle and weight limits that are in excess of the Federal law and regulations . . . in comparison to vehicles that do not operate in excess" and "the cost and benefits of the impacts in dollars. . . ." [Section 32801(a)]. The pavement analysis in the USDOT study does not adequately address this part of the charge. The study included an analysis comparing the time until the first required rehabilitation for selected pavement sections subjected to baseline traffic with the time to rehabilitation for the baseline traffic with all overweight axles removed (*Pavement*, 32). This analysis did not estimate impacts in the individual states that allow vehicles to operate with weights in excess of federal limits and did not take into account the pavement designs actually used in the states where heavier axle loads are allowed. The report does not state whether the total quantity of truck cargo was held constant in the analysis. (If axle weights were reduced, a greater number of truck trips would be required to transport the same quantity of cargo.)

Results of the pavement analysis are presented as a percent change in life-cycle cost for each scenario with respect to cost with the baseline traffic. Consequently, estimated changes in pavement costs cannot be compared with changes in bridge costs or in logistics costs, which are estimated in dollars and as annual costs (logistics) or as one-time costs for upgrading (bridges).

Methods and Data

The basic methodology for assessing the pavement impact of the various truck traffic configuration scenarios is appropriate. The USDOT study report acknowledges certain limitations of the analysis (*Pavement*, ES-5, 2): only the distresses and pavement types that the pavement model is capable of representing are considered, overlay pavement impacts could not be evaluated with the model, and local road impacts could not be estimated for lack of pavement and traffic data. The traffic analysis also appears not to have considered the possibility of changes in the existing overweight vehicle population due to increased legal limits in the alternative configuration scenarios. Vehicles currently operating over the legal load limits have a major effect on anticipated pavement life.[6]

The report does not provide a complete description of the basis for selecting the pavement sections analyzed. Pavements typically are designed for a life of 20 to 30 years. Most of the pavement sections analyzed have a design life (with baseline traffic) outside the typical range. Four sections show a design life of less than 10 years, and three sections have a design life of more than 50 years (*Pavement*, 94–97). The method of computing the weighted averages of the results of the analyses of the selected pavement sections is not fully explained.

[6] Appendix D, Pavement Effects of Illegally Overweight Trucks, of the 1990 TRB committee study of truck size and weight limits (TRB 1990, 254–255) provides an illustrative estimate of the likely range of the share of highway agency pavement costs attributable to illegal overloads.

The ranges shown for life-cycle cost estimates (*Pavement*, 28, Table 12) are simply the results using two values of the discount rate in the calculation of present value of future expenditures. This presentation appears likely to be misunderstood as an estimate of the overall uncertainty of the results, although it is not related to pavement analysis uncertainty.

In general, the report does not adequately describe the uncertainties inherent in the estimates. The cost estimates are subject to uncertainty from two sources: uncertainties in the input data on pavement structure and truck traffic and uncertainties from the limitations of the modeling method used (in particular, the exclusion of some pavement types and distress mechanisms in the estimates). To interpret the importance of the pavement cost estimates, users of the report need information about the estimates' reliability and about the magnitude of likely pavement costs (measured in dollars) compared with other categories of dollar-denominated costs and benefits.

Recommendations

In any future USDOT truck size and weight study, estimates of pavement impacts of changes in truck size and weight regulations should begin by defining a conceptual model of the effect of a change in truck traffic on actual pavements, identifying all mechanisms of impact for all important pavement structures. The absence of such a framework in the report of the USDOT study makes interpretation of the results of the partial analysis that the study conducted difficult.

Future analyses should estimate the impacts of changes in truck traffic on local roads, on the basis of available data and necessary assumptions about pavements and traffic, and should systematically examine the sensitivity of costs on all roads to assumptions and data uncertainties. Finally, any future study should include an estimate of pavement costs derived by evaluation of a scientifically designed sample of actual existing pavements.

Reference

Abbreviation
TRB Transportation Research Board

TRB. 1990. *Special Report 225: Truck Weight Limits: Issues and Options*. National Research Council, Washington, D.C.

5. MODAL SHIFT

MAP-21 requires the USDOT study to estimate the following [Section 32801(a)(6)]:

> (A) the extent to which freight would likely be diverted from other surface transportation modes to principal arterial routes and National Highway System intermodal connectors if alternative truck configuration is allowed to operate and the effect that any such diversion would have on other modes of transportation;
> (B) the effect that any such diversion would have on public safety, infrastructure, cost responsibilities, fuel efficiency, freight transportation costs, and the environment;
> (C) the effect on the transportation network of the United States that allowing alternative truck configuration to operate would have; and
> (D) whether allowing alternative truck configuration to operate would result in an increase or decrease in the total number of trucks operating on principal arterial routes and National Highway System intermodal connectors.

The modal shift technical report describes the estimates, for each alternative configuration scenario, of diversion of freight from railroads to trucks and the change in annual truck VMT by configuration, highway system, and operating weight that would occur as a consequence of the alternative trucks' greater capacities. The estimates are of VMT in a single year, with respect to a base case defined as 2011 actual traffic volumes, and assume that freight patterns have reached equilibrium at some time after introduction of the alternative configurations. The report also presents single-year estimates of changes in shippers' transportation and nontransportation logistics costs, railroad revenue, traffic congestion costs, pollutant emissions, and energy consumption (*Modal Shift*, ES-9–ES-11, 43).

Responsiveness to the Questions Identified by Congress

The USDOT report presents estimates of the quantities required in the congressional charge: diversion of freight from other modes and effects on the other modes (i.e., revenue loss) caused by allowing the alternative trucks, and effects of allowing the alternative trucks on freight transportation costs, truck traffic volume, fuel efficiency, and the environment. However, the method used to estimate the diversion of freight from rail to truck and from preexisting to alternative configuration types is of questionable validity. Shortcomings in the mode choice analysis have important implications, because the estimates of changes in truck travel by configuration and weight determine the magnitudes of the infrastructure, safety, and enforcement cost estimates in the USDOT study. The estimates of effects of changes in truck travel on fuel efficiency and the environment are produced by simple but practical methods that are appropriate for the study, although the results will be inaccurate if the mode choice estimates are inaccurate.

Methods and Data

Application of the Intermodal Transportation and Inventory Cost Model

Freight mode choice models can be classified into two families: disaggregate (including discrete choice models and supply chain–based mode choice models) and aggregate (including market share models, elasticity-based models, and economic cost models). Disaggregate models estimate the preferred mode for each shipment of each establishment, while aggregate models directly estimate the market share for each mode.

Disaggregate models can realistically represent the underlying decision-making behavior of shippers. If aggregate estimates of market shares are needed, as in the USDOT truck size and weight study, the estimates produced by these models must be aggregated into market shares. This aggregation requires data on shipment characteristics from a suitable sample of establishments. The quality of the market shares estimates depends on both the ability of the model to represent each shipper's mode choice decisions and the quality of the disaggregate shipment characteristics data available.

The USDOT study used the Intermodal Transportation and Inventory Cost (ITIC) model (*Modal Shift*, ES-6–ES-8), a typical example of supply chain–based mode choice models. ITIC is a disaggregate single-shipper model that computes the optimal (lowest total logistics cost) combination of shipment size and freight mode (choosing between rail and truck and among truck configurations). The model replicates the decisions made by shippers and receivers. ITIC needs data at the establishment level relevant to logistics costs, including inventory costs, amount of cargo to be transported from the shipper to each receiving location, and transportation cost. These shipper and shipment characteristics vary greatly with industry sector, geographic location, company size, and other factors. As a result, it is not possible to select "typical" values as input to ITIC that will provide meaningful market share projections.

Among the required inputs to ITIC are data on shipper-to-receiver flows of freight. The only readily available database containing records of shipments by origin, destination, and shipment size is the Carload Waybill Sample, submitted by the railroad industry to USDOT, which contains data only on rail shipments. The Commodity Flow Survey, conducted by the Bureau of the Census, collects shipment size data for all modes, but this information is confidential. The survey does not record truck configuration and body type used for carrying specific commodities, information needed to project market penetration of alternative configurations.

In the absence of a comprehensive database of establishment-level freight shipments by origin, destination, and shipment size, application of ITIC requires estimating the flows by means of a model or by assumption. The USDOT study generated the required freight flows by first estimating annual county-to-county flows by commodity and mode. These were disaggregated into shipments by assuming that shipment size equals the maximum payload of the vehicle carrying the freight and that all shipment origins and destinations are county centroids (*Modal Shift*, 9, 16). This procedure is equivalent to assuming that all shippers of a commodity in a county cooperate in consolidating their shipments and that all have identical preferences for level of service. The effect of these strong and arbitrary assumptions on the accuracy of the ITIC mode share projections is unknown, and consequently the USDOT study is not a correct application of the model.[7, 8]

The USDOT study assumes that total ton-miles of freight traffic are unchanged from the base case in the alternative configuration scenarios. In reality, a reduction in the cost of freight is likely to induce additional traffic. (For example, a producer may take advantage of lower transportation costs by consolidating production at fewer locations or by choosing a more distant source for a raw material, or a firm trading internationally may change the ports it uses for shipping its goods.) The desk scan cited research that concluded that the effect is difficult to estimate (*Modal Shift*, 91–94). However, because the effect of changing size and weight limits on truck traffic volume drives all other impacts, the USDOT study should have included an estimate, presented as a range of possible induced freight volumes, reflecting the range of estimates in the literature.

As the USDOT report explains (*Modal Shift*, 171–172), in predicting shippers' choices between two modes, the ITIC model assigns all freight to the mode that the model predicts to have the lower cost, regardless of the magnitude of the cost difference, whereas models based on observations of shipper behavior have found that, when costs appear close, both modes may retain a substantial share of traffic (presumably on account of cost-related factors not included in the models). A sensitivity analysis might reveal whether this simplifying assumption is likely to greatly affect the aggregate mode share projections of ITIC.

Logistics Cost Estimates

The estimated cost savings per vehicle mile of truck traffic reduction (*Modal Shift*, ES-10 and Table ES-3) are strikingly large in Scenarios 1, 2, and 3 ($6.68, $4.71, and $4.58 per vehicle mile in Scenarios 1, 2,

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[7] For an example of correct use of a logistics cost model, see Leachman et al. (2005) and Leachman (2008).

[8] The modal shift desk scan (*Modal Shift*, 94) cites a Government Accountability Office report using ITIC that expressed a similar concern about the uncertain effect of missing input data on the reliability of the estimates produced by the model (GAO 2011, 60).

and 3, respectively). The ratios for Scenarios 4, 5, and 6 ($0.79, $1.00, and $1.01, respectively) are consistent with past studies' results. In the USDOT study analysis, shifts from rail to truck are small and no new freight is generated when limits are relaxed, so cost savings on the order of the reduction in truck VMT times the average operating cost per truck mile (roughly $2.00 for truckload general freight carriers) would be expected. ITIC estimates inventory and other logistics costs in addition to vehicle operating costs. As an example of a nontransportation cost savings, allowing heavier tractor-semitrailers might enable a shipper to avoid transferring cargo into trailers from arriving marine containers that are too heavy to carry on the highway under present weight limits. However, savings in nontransportation costs of the magnitude that the study's total logistics cost estimates imply in the alternative configuration scenarios would be remarkable and should be explained in the report.

Environmental Impacts

The emissions impact analysis assumes that changes in emissions of carbon dioxide and oxides of nitrogen are proportional to changes in gallons of fuel consumed (*Modal Shift*, 52). As the USDOT report notes, this is a simplification for oxides of nitrogen emissions, which vary with the vehicle drive cycle. Apparently, no estimate of changes in emissions from trains was made. The lack of an estimate of changes in particulate matter emissions is a significant omission. The report projects reductions in traffic congestion in all the alternative configuration scenarios but does not estimate the effect of this reduction on fuel consumption and emissions of all motor vehicles.

Treatment of Uncertainty

The USDOT report presents point estimates for the modal shift analysis results. The concerns raised above about the accuracy of the ITIC projections in the study could have been alleviated through sensitivity analysis. In a sensitivity analysis, the model would be run repeatedly, with assumptions about input values varied over plausible ranges (e.g., with alternative assumed shipment size distributions). The range of the resulting model estimates would provide an indication of the uncertainty of the estimates and reveal which input assumptions were most critical in view of the intended policy application of the estimates.

Recommendations

USDOT should undertake a significant effort to improve understanding of the behavioral factors that influence freight demand and freight mode choice, the analytical techniques used to depict freight markets as they are affected by public policy, and the data required for analysis and modeling of freight markets. Research should be performed to develop and test the three methods of predicting mode choice described in the desk scan (*Modal Shift*, 96–99): disaggregate models, aggregate econometric models, and expert opinion. The Commodity Flow Survey, in its current form, will not be able to provide the data needed to estimate mode choice in a future truck size and weight study because it does not collect data about vehicle choice.

USDOT, together with the Bureau of the Census, should resume the conduct of the Vehicle Inventory and Use Survey, which was discontinued in 2002. The survey was the only source of systematic data on truck shipment sizes, truck cargo capacities, and the truck configurations and body types suitable for carrying specific commodities. Data on these truck transportation characteristics are needed for credible projections of truck travel. In addition, qualitative surveys that capture shipper, carrier, and receiver behaviors and decision-making processes are much needed to improve projections.

References

Abbreviation	
GAO	Government Accountability Office

GAO. 2011. *Intercity Passenger and Freight Rail: Better Data and Communication of Uncertainties Can Help Decision Makers Understand Benefits and Trade-Offs of Programs and Policies*. GAO-11-290, Feb.

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6. SAFETY

The MAP-21 study charge calls for two analyses of truck safety: a comparison of accident frequency and accident risk of vehicles operating under grandfather or other exemptions from federal size and weight limits [Section 32801(a)(1)] and analysis of the safety impacts of allowing six-axle tractor-semitrailers and other alternative configurations [Section 32801(a)(5)], including the safety effect of any diversion of freight to highways that allowing operation of alternative configurations would induce [Section 32801(a)(6)(B)].

The three components of the USDOT study's safety analysis were a comparison of crash rates of the alternative and control vehicles in states where vehicles similar to the alternative configurations now operate, comparison by simulation models of the stability of the alternative and control vehicles, and comparison of results of vehicle safety inspection conducted by enforcement officers. These are necessary components of the safety analysis and have been included in most past truck size and weight studies. The crash rate and enforcement analyses explore methods that may advance knowledge over the methods of past studies.

Responsiveness to the Questions Identified by Congress

The study does not respond to the legislative charge to evaluate the safety impacts of changing regulations to allow alternative configurations. Such an evaluation would require considering how the combined effects of changes in traffic volume and changes in crash rates resulting from the introduction of alternative configurations would affect the total systemwide frequency of crashes and casualties.

The USDOT study explored the possibility of estimating the change in the annual number of crashes nationwide that would occur in each of its alternative configuration scenarios (*Safety*, 91–93). However, the study concluded that "it is not possible to draw national conclusions or present findings concerning national crash rates due to a lack of relevant crash data" (*Summary*, ES-6). Past truck size and weight studies (e.g., USDOT 1981, II-22; TRB 1990a, 15; TRB 1990b, 129–130) included such quantitative comparisons of systemwide safety impacts of alternatives based on syntheses of information from analyses of crash data, results of research of others on crash rates, and vehicle stability simulation and testing.

Methods and Data

The comments below concern features of the alternative and control vehicle crash involvement rate estimates in the USDOT study that affect the credibility of the estimates, the interpretation of the results of the model of the relationship of truck crash frequency to truck traffic volume, and comparison of the vehicle stability results of the USDOT study with those of past studies.

Crash Involvement Rate Analysis

Systematic Uncertainty in Truck VMT Estimates

The uncertainty in the estimates of VMT by truck configuration [the denominators in the crash involvement rate estimates (*Safety*, 26–27)] is unknown and potentially large, especially for uncommon vehicles. The distributions of VMT by vehicle configuration, road system, and state are derived from WIM data. The calculation of these distributions entailed a series of assumptions and approximations (*Modal Shift*, 236–241). The report does not describe any attempt to validate the estimated distributions (e.g., by comparing the estimates with observed distributions).[9] The study estimated distributions of VMT by configuration for 2 years, 2008 and 2011, but used only the 2011 VMT distribution estimates in estimating crash rates. The report (*Safety*, 17–18) explains that the 2008 VMT estimates were discarded

[9] The committee understands that USDOT plans to publish additional documentation on data methods in a volume titled *Data Acquisition and Technical Analysis Plan.*

because "the method used to estimate configuration-specific VMT in the 2008 data differed from the 2011 data to the extent that the 2008 data were not usable as a second data point." This observation exposes the shortcoming of the WIM-derived VMT distribution estimates: the configuration distributions are sensitive to assumptions made in processing the WIM data.

As one example of difficulties in interpreting WIM data, it was pointed out to the committee[10] that one axle on some Michigan six-axle tractor-semitrailers is a lift axle that is raised from the pavement when the truck is not loaded. WIM data would record such vehicles as having five axles, while crash data would record them as six-axle vehicles. The documentation of the derivation of the vehicle class distributions does not indicate that this problem was taken into account.

The tests of significance of differences in crash rates between pairs of vehicle types shown in Tables 8, 9, and 10 (*Safety*, 26–27) are incorrect. The test applied assumes that the values of the denominators in the ratios compared are known with certainty. In this case, the values of the denominators (VMT) are uncertain to an unknown degree.

Citing consistent results in all three states for which data were obtained for the comparison of six-axle with five-axle tractor-semitrailer crash involvement rates, the USDOT report concludes: "This consistency across states lends validity to this finding" (*Safety*, 46). This argument would be sound if the estimates in the three states were independent. However, the crash rate estimates all depend on VMT estimates derived by the same procedure. If that procedure introduces systematic error in the VMT estimates, the consistency across states could be the result of the error.

Risk Factors Not Considered

The safety performance of a population of trucks depends on the characteristics of drivers, management practices of the companies that operate the vehicles, the physical condition and traffic characteristics of

[10] Letter of Kirk T. Steudle, Director, Michigan Department of Transportation, to the committee, July 27, 2015. The letter states that data of the Michigan Department of Transportation suggest that the ratio of six-axle to five-axle VMT is higher than reported in the USDOT study. The committee did not examine the state data.

the roads the vehicles use, and the distribution of the trucks' travel by time of day and season of the year. Therefore, in many circumstances, factors other than size and weight are likely to dominate safety comparisons among populations of vehicles. The crash rate estimates control for some of these factors by limiting the comparison to Interstate routes in individual states and by separately comparing urban and rural rates. However, the other factors influencing crash rates are not considered in the analysis. The populations of the alternative configurations and the control vehicles likely differ in some of these factors. In the states where they are in use today, the alternative configurations typically serve specialized, niche markets (e.g., an extractive industry operating entirely within the state boundaries), whereas the control vehicles are widely used in a broad variety of markets. Failure to consider differences in factors influencing crash rates may have biased the estimates of crash rate differences between the alternative and control vehicles. If the alternative configurations now used primarily in intrastate niche markets became legal for general nationwide use, the characteristics of their drivers, carriers, routes, and other features of use would resemble those of the present-day control vehicles rather than those of the present-day alternative configurations.

Descriptions of Alternative Configurations in Operation

The committee received information from the state of Michigan that descriptions of Michigan Interstate truck size and weight limits in the USDOT report are inaccurate. In Table 1 of the safety volume (*Safety*, 3), the maximum gross vehicle weight for a tractor-semitrailer in Michigan is shown as 104,000 pounds. This would be the maximum in the state for a six-axle tractor-semitrailer with the steering axle loaded to 18,000 pounds; however, tractor-semitrailers with more than six axles and weights up to 154,000 pounds operate on Michigan Interstates. Later the report states that the maximum gross vehicle weight for a six-axle tractor-semitrailer is 105,500 pounds (*Safety*, 13); the state informed the committee that the correct limit is 104,000 pounds. The state's communication also notes that six-axle tractor-semitrailers in

Michigan typically operate with the rearmost three axles widely spread, rather than in the tridem configuration illustrated in the report and assumed in the stability analysis (*Safety*, ES-3, 56).[11]

The description of triple-trailer use in Iowa (which does not enter into the report's safety analysis) also requires clarification. Triples operate in Iowa, as Table 2 in the summary volume (*Summary*, 9) indicates, but the committee understands that they are allowed only in the Sioux City metropolitan area in the extreme northwest corner of the state.

Presentation of Crash Rate Estimates in the USDOT Report

The USDOT report acknowledges that the state estimates are not nationally representative, but USDOT repeatedly and prominently cites them: in the *Summary* volume (p. ES-6), the transmittal letter to Congress,[12] and the *Safety* volume summary (p. ES-6). The statements acknowledging unrepresentativeness of the state-level crash rate estimates are not accurately worded. The *Summary* volume (p. ES-6) states: "Crash rates for the six-axle alternative truck configuration in Washington State are significantly higher than the five-axle control truck rates. However, it is not possible to draw national conclusions or present findings concerning national crash rates due to a lack of comparable crash data in other States." As explained above, the USDOT study does not show that the estimated rate differences are significantly different in the statistical sense. Therefore, the limitation is not simply lack of comparable data in other states, but unknown validity of the estimates in the states where data were obtained.

Lack of Consideration of Crash Severity and Traffic Volume in the Safety Analysis

The USDOT study reports evidence that the average severity of crashes of some alternative configurations appears to be less than that of control vehicle crashes (*Safety*, 94). This finding does not

[11] Letter of Kirk T. Steudle, Director, Michigan Department of Transportation, to the committee, July 27, 2015.
[12] Peter M. Rogoff to Hon. Bill Shuster, June 5, 2015: "FHWA was able to identify significantly higher crash rates in six-axle trucks compared to five-axle trucks in the State of Washington. . . ."

show a causal relationship; it may reflect differences in operating environments not considered in the analysis (e.g., a larger share of the alternative configuration's VMT may occur on congested roads, which tend to have higher crash rates but lower average crash severity than uncongested roads). Nevertheless, consideration of changes in severity along with changes in rates is necessary in assessing the safety of alternative configurations. Computing crash rates by severity (e.g., for casualty crashes and property-damage-only crashes) and by type of crash (e.g., for single-vehicle and multivehicle crashes or for rollover and run-off-road crashes), where data are sufficient, might have aided interpretation of the rates.

The most meaningful measure of the safety effects of changing federal regulations is the change in the total costs of road crashes, including changes in the frequency of fatalities and nonfatal injuries, in property damage costs, and in congestion costs of crashes. The change in total costs depends on changes in crash rates, crash severities, and truck traffic volumes. Past studies have concluded that the change in truck traffic volume is likely to be the critical determinant of safety impact of the changes in regulations most commonly proposed (TRB 2002, 110). The federal study does not include an estimate of changes in crash costs.

Analysis of the Relationship of Crash Involvement Rate to Traffic Volume

The committee's first report (TRB 2014, 33) commended the federal study's plan to explore an approach to modeling truck crash risk that takes into account truck volume and total traffic volume rather than assuming that the crash involvement rate for a particular truck configuration is a constant on all roads of a particular road class. The results of the model estimation (*Safety*, 28) appear reasonable, indicating that truck involvement rates decline as truck volume on a road increases. However, the model has weaknesses. Segment-level annual average daily traffic (AADT) by vehicle type data were not available and had to be estimated on the basis of the strong assumption that the distribution of VMT by vehicle type is the same on all roads of the same functional class (*Safety*, 22). Also, the analysis did not consider factors other than

AADT that may affect the risk comparisons. For example, any differences between truck types in patterns of use by time of day or in frequency of use of Interstate exits would likely influence relative crash rates.

Figures 2 and 3 (*Safety*, 29–30), illustrating the results of the crashes-versus-AADT model, are misleading. Figure 2 shows an extrapolation of the six-axle tractor-semitrailer crash frequency to traffic volumes that are 50 times greater than any observed. At the high-volume end of the curve, the confidence intervals on the extrapolated values (which the report does not indicate) are extremely large. Because the analysis did not use actual segment-level AADT by vehicle type, important risk-related factors were not considered in the analysis, and extrapolation far beyond the range of the observations is not statistically justifiable, the plots of predicted alternative configuration crashes at high traffic volume are not meaningful. The figures would be more instructive if the data points used to estimate the relationships were shown.

The committee attempted to replicate points on the graphs of Figures 2 and 3 by using the estimated equation parameters and AADT data in the report but could not. Part of the difficulty is that the report does not define all the variables appearing in the model specifications. The graphs should be carefully checked before the report is put in final form.

Vehicle Stability Analysis

The vehicle stability analysis estimated metrics of vehicle performance during five vehicle maneuvers for each control and alternative configurations (*Safety*, 53), using a standard truck dynamics simulation model. The report also summarizes the results of braking tests with actual vehicles. Several of the results appear inconsistent with results of past analyses. Most notably, the rearward amplification of seven-axle and nine-axle triples in the avoidance maneuver was found to be no different from that of 28-foot and 33-foot doubles (*Safety*, 71). In contrast, the 2000 USDOT truck size and weight study (USDOT 2000, VIII-12) found the rearward amplification of seven-axle A-train triples at 132,000 pounds to be substantially more severe than that of the five-axle 28-foot double at 80,000 pounds. A 1990 FHWA simulation study of truck stability similarly reported much worse rearward amplification for seven-axle triples than for five-axle doubles (Fancher and Mathew 1990, 127). As the USDOT study notes (*Safety*, 53), greater rearward amplification is believed to be associated with greater risk of rollover during an avoidance maneuver. The study would have been strengthened if it had included examination of the sources of differences with results of past studies.

In describing the performance of the four multitrailer combinations in the avoidance maneuver simulation, the USDOT report states that "all would be in danger of rolling over" and that, for the triple trailers, "the load on one end of the axle on the third trailer was completely removed for periods of less than one second." This adverse finding does not appear in the summaries of the stability analysis in the safety report (*Safety*, 73–75) or in the summary volume (*Summary*, 50–51).

The USDOT report notes that highway work zone hazards may increase in the alternative vehicle scenarios (*Modal Shift*, 62) but does not estimate the change in crash risk. Larger trucks may perform more poorly in construction zones than existing trucks, and introducing certain of the larger trucks would require an increase in highway construction for some period. The report's interpretation of the results of the simulations of path deviation and high-speed off-tracking of double-trailer and triple-trailer combinations does not consider the consequences of narrower lanes in construction zones.

As the USDOT report acknowledges (*Safety*, 58), the stability analysis does not consider the consequences of the new National Highway Traffic Safety Administration (NHTSA) regulation requiring electronic stability control on all new truck-tractors in 2017. NHTSA expects that the rule will greatly reduce the frequency of truck rollover and loss-of-control crashes [80 *Federal Register* 36050 (June 23, 2015)].

Inspection and Violation Analysis

The USDOT study compared the alternative configurations with the control vehicles with respect to rates of violation of safety rules found in roadside safety inspections conducted routinely by state enforcement officials.

The analysis found that "tractor semitrailer configuration was not a significant predictor of the likelihood of a violation. That is, no significant difference was observed between the alternative tractor semitrailer configurations and the 80,000-lb. semitrailers with respect to violations, when controlling for other factors. . . ." (*Summary*, 53). The other factors controlled for were driver age, vehicle age, and carrier out-of-service (OOS) violation rate. This finding is important for the entire safety analysis, because it suggests that differences in operator characteristics may be the major source of safety-related differences in comparisons of groups of vehicles. As noted above, operator characteristics were not taken into account in the USDOT study's crash rate comparisons.

The report's interpretation of the finding that operator characteristics predict violation rates is a non sequitur: "These findings have direct implications for the use of heavier combination vehicles. If carriers that enter the market using the heavier 3-S3 vehicles also have higher OOS and older equipment, this model suggests they may have higher violation rates as well" (*Safety*, 84). Operators with high OOS rates and old equipment that switched to the alternative configurations would have violation rates the same as those they had with their previous equipment, according to the USDOT study's analysis. Moreover, there are no grounds for expecting that carriers with higher OOS rates or older equipment would be more likely to convert to the alternative configurations than carriers with lower rates. Any differences today between alternative and control vehicle operators in OOS rate or equipment age most probably reflect the specialized niche markets where the alternative configurations in operation today are concentrated. If the alternative configurations became the standard nationwide, their operators would have the same characteristics as present-day operators of nationally standard vehicles.

Recommendations

The USDOT study's effort to identify states with crash data and traffic data adequate to support estimates of crash rates for specific truck configurations was worthwhile. USDOT should continue to work with the states to develop data systems that can be used to monitor the safety performance of tractor-semitrailers operating within the federal weight limit, heavier tractor-semitrailers, and multitrailer combinations. Development and analyses of exposure data that would help to improve crash rate estimates derived by the USDOT study's method include the following:

- Validation of the WIM-derived vehicle type distributions by comparison with independent data sources (e.g., visual counts).
- Sensitivity analysis to show the effect of assumptions and approximations in the derivation of the vehicle type distributions [e.g., comparison of distributions from the 2008 WIM analysis method with those using the 2011 method described in the report (*Safety*, 17–18)].
- Comparison of crash rates derived by the study method with other credible, independent estimates.
- Inclusion of more states in the estimates. Selection of the states included in the USDOT report crash rate estimates appears to have been based, in part, on availability of data required for the regression model of crash rate versus traffic volume. Whether these were the only states for which unadjusted crash rates could have been computed for various truck configurations is not clear.
- Improvements in WIM data collection and analysis to allow extension of the method to non-Interstate roads and to allow computation of crash rates by time of day and traffic volume.

Understanding the safety effect of changes in truck traffic volume and characteristics requires a model of the relationship of total crash frequency on a road to the traffic volume and mix of vehicle types on the road. The traditional model, in which each vehicle type is assigned a fixed crash involvement rate for each road functional class, is unrealistic (TRB 1996, 69–72). USDOT should support research aimed at understanding this relationship. The models of crash frequency versus traffic volume explored in the USDOT study are a contribution to this development.

References

Abbreviations

TRB	Transportation Research Board
USDOT	U.S. Department of Transportation

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7. ENFORCEMENT AND COMPLIANCE

MAP-21 requires the USDOT study to "evaluate the frequency of violations in excess of the Federal size and weight law and regulations, the cost of the enforcement of the law and regulations, and the effectiveness of the enforcement methods" [Section 32801(a)(3)]. The USDOT study responds to this part of the charge with three assessments: a summary of U.S. trends in truck size and weight enforcement spending, frequencies of weighings and citations, and measures of enforcement effectiveness; a comparison of enforcement costs in states where vehicles exempt from federal weight limits operate with costs in states where the federal limits apply; and an estimate of the effects on enforcement costs of allowing the alternative configurations to operate nationwide based on estimates of costs of weighing specific vehicle types.

Responsiveness to the Questions Identified by Congress

The USDOT study's interpretation of the enforcement evaluation charge is as follows: "The purpose of this study is to assess the cost and effectiveness of enforcing TSW limits for trucks operating at or below current Federal truck weight limits as compared with enforcement costs and effectiveness for alternative truck configurations in six scenarios" (*Compliance*, 2). The legislative language does not explicitly call for an evaluation of the effect of allowing alternative configurations on enforcement; however, USDOT's examination of how enforcement costs would be affected by the alternative configurations is relevant to the study charge to evaluate safety and infrastructure impacts of the alternative configurations.

The report provides a thorough summary of available data on trends in enforcement expenditures and unit costs, numbers of weigh scales in operation, and frequencies of weighings and citations (*Compliance*, 45–79), addressing the legislative charge to evaluate the frequency of violations and the cost of enforcement.

The effectiveness measures used in the study are defined as follows: "Three pertinent relationships are established, namely: the weighing cost-efficiency ([non-WIM] weighings per personnel cost), the weight violation citation rate (citations per weighing), and the relationship between citation rate and enforcement intensity (measured as the number of weighings per truck vehicle-miles of travel (VMT))" (*Compliance*, 3). The last measure, the impact of enforcement on violations, appears closest to answering the enforcement question that would be most relevant to Congress: Is the level of enforcement sufficient to reduce violations to a tolerable level? (The tolerable level would depend on the safety and infrastructure costs of violations and the cost of enforcement.)

The conclusion of the USDOT study that directly addresses the legislative charge to evaluate enforcement effectiveness is the following: "The relationship between citation rate and enforcement intensity revealed that the citation rate decreases as enforcement intensity increases (i.e., more weighings per million truck VMT), but reaches a point of diminishing return. Moreover, those States that conduct a higher proportion of portable and semi-portable weighings generally have a lower overall enforcement intensity and a higher citation rate" (*Compliance*, ES-6–ES-7). The USDOT report makes a worthwhile beginning at understanding the relationship between enforcement effort and outcomes (*Compliance*, 79–83) but stops short of establishing the relationship. It concludes that "measuring enforcement effectiveness in terms of a citation rate is complex because both relatively low and relatively high citation rates could be interpreted as a reflection of an effective enforcement program" (*Compliance*, ES-7). Therefore, the report does not fully address the charge to evaluate the effectiveness of truck weight enforcement.

Methods and Data

Measures of Enforcement Effectiveness

The indicator of effectiveness used in the USDOT study, the relationship between weight violation citation rate and enforcement intensity, uses the frequency of citations as a proxy for frequency of violations. However, as the report points out, citations can be a misleading measure of violations. A relatively high rate of citations in a state may indicate a relatively high frequency of violations or it may indicate that the state's enforcement program is highly efficient at catching violators. To establish the relationship between enforcement and violations, a direct measure of violations is necessary.

WIM data, if installations were appropriately sited and operated, would be an ideal source of information on the frequency of overweight vehicles. (To determine violations, corrections would be needed to account for legally permitted overweight vehicles. The measurement errors in WIM readings that prevent their use as evidence for legal citations are not an obstacle to the use of the data to monitor enforcement effectiveness.) The report does not exploit WIM data to assess the overall frequency of weight violations (although WIM data are used to compare frequency of violations of the control and alternative configurations). The authors may have concluded that limitations of presently available WIM data make the data unsuitable for this purpose.

Enforcement Cost Estimates

The report's description of the method of computing the change in enforcement costs in the alternative configuration scenarios (*Compliance*, 13–14, 57–58) is not detailed enough to allow the calculations to be reconstructed. The alternative scenario enforcement costs appear to depend on estimates of (*a*) the average enforcement personnel cost per truck weighed today, (*b*) the ratio of the personnel time required to weigh an alternative configuration to the time required to weigh a five-axle tractor-semitrailer, and (*c*) the change in the volume of trucks by configuration in the scenarios. The report states (*Compliance*, 8) that no attempt was made to allocate state enforcement expenditure data between weighing and safety inspection (both of which occur at the same roadside stops). Therefore, the estimates appear to be based on an average cost that includes the personnel cost of safety inspections but takes into account only time changes due to weighing.

A complete estimate would have included the cost of any changes in average safety inspection time in the alternative scenarios. The results of the inspection and violation analysis in the safety technical report (*Safety*, 76) suggest that inspection times may differ, although, as explained in the review of the safety technical report above, any observed differences in violation rates in that analysis may be the result of differences in operator characteristics rather than in vehicle configuration. Inspection of more complex vehicles (triples replacing double-trailer configurations or six-axle tractor-semitrailers replacing five-axle tractor-semitrailers) might be expected to require more personnel time per vehicle.[13]

Recommendations

Knowledge of the relationship between weight enforcement effort and frequency of weight violations would be of great value in planning and budgeting enforcement programs. USDOT should continue the analysis of this relationship begun in the truck size and weight study. The analysis should determine the relationship between enforcement effort and frequency of violations as observed in WIM or other nonenforcement weighing data, as well as the relationship between enforcement effort and frequency of citations. The analysis must be deepened to distinguish relative effectiveness of alternative methods and strategies of enforcement.

In any future truck size and weight study, estimates of enforcement costs should explicitly account for costs of safety inspections as well as costs of weighings.

[13] The change in total enforcement time is the difference between the time per inspection multiplied by the frequency of inspections in the alternative configuration scenario and time per inspection multiplied by the frequency of inspections in the base case. If truck traffic volume declines in the alternative configuration scenario because the alternative configuration has greater capacity than the control vehicle, then the frequency of inspections, for a constant enforcement intensity, will decline.

Appendix A
MAP-21 Section 32801. Comprehensive Truck Size and Weight Study

[112th Congress Public Law 141]
[From the U.S. Government Printing Office]

[[Page 126 STAT. 405]]

Public Law 112-141
112th Congress

An Act

To authorize funds for Federal-aid highways, highway safety programs, and transit programs, and for other purposes. <<NOTE: July 6, 2012 - [H.R. 4348]>>

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, <<NOTE: Moving Ahead for Progress in the 21st Century Act. State and local governments.>>
SECTION 1. SHORT TITLE; ORGANIZATION OF ACT INTO DIVISIONS; TABLE OF CONTENTS.

(a) <<NOTE: 23 USC 101 note.>> Short Title.—This Act may be cited as the “Moving Ahead for Progress in the 21st Century Act” or the “MAP-21”.

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SEC. 32801. COMPREHENSIVE TRUCK SIZE AND WEIGHT LIMITS STUDY.

(a) <<NOTE: Deadline.>> Truck Size and Weight Limits Study.—Not later than 45 days after the date of enactment of this Act, the Secretary, in consultation with each relevant State and other applicable Federal agencies, shall commence a comprehensive truck size and weight limits study. The study shall—

(1) provide data on accident frequency and evaluate factors related to accident risk of vehicles that operate with size and weight limits that are in excess of the Federal law and regulations in each State that allows vehicles to operate with size and weight limits that are in excess of the Federal law and regulations, or to operate under a Federal exemption or grandfather right, in comparison to vehicles that do not operate in excess of Federal law and regulations (other than vehicles with exemptions or grandfather rights);

(2) evaluate the impacts to the infrastructure in each State that allows a vehicle to operate with size and weight limits that are in excess of the Federal law and regulations, or to operate under a Federal exemption or grandfather right, in comparison to vehicles that do not operate in excess of Federal law and regulations (other than vehicles with exemptions or grandfather rights), including—

(A) the cost and benefits of the impacts in dollars;

(B) the percentage of trucks operating in excess of the Federal size and weight limits; and

(C) the ability of each State to recover the cost for the impacts, or the benefits incurred;

(3) evaluate the frequency of violations in excess of the Federal size and weight law and regulations, the cost of the enforcement of the law and regulations, and the effectiveness of the enforcement methods;

(4) assess the impacts that vehicles that operate with size and weight limits in excess of the Federal law and regulations, or that operate under a Federal exemption or grandfather right, in comparison to vehicles that do not operate in excess of Federal law and regulations (other than vehicles with exemptions or grandfather rights), have on bridges, including the impacts resulting from the number of bridge loadings;

(5) compare and contrast the potential safety and infrastructure impacts of the current Federal law and regulations regarding truck size and weight limits in relation to—

(A) six-axle and other alternative configurations of tractor-trailers; and

(B) where available, safety records of foreign nations with truck size and weight limits and tractor-trailer configurations that differ from the Federal law and regulations; and

(6) estimate—

(A) the extent to which freight would likely be diverted from other surface transportation modes to principal arterial routes and National Highway System intermodal connectors if alternative truck configuration is allowed to operate and the effect that any such diversion would have on other modes of transportation;

(B) the effect that any such diversion would have on public safety, infrastructure, cost responsibilities, fuel efficiency, freight transportation costs, and the environment;

(C) the effect on the transportation network of the United States that allowing alternative truck configuration to operate would have; and

(D) whether allowing alternative truck configuration to operate would result in an increase or decrease in the total number of trucks operating on principal arterial routes and National Highway System intermodal connectors; and

(7) identify all Federal rules and regulations impacted by changes in truck size and weight limits.

(b) Report.—Not later than 2 years after the date that the study is commenced under subsection (a), the Secretary shall submit a final report on the study, including all findings and recommendations, to the Committee on Commerce, Science, and Transportation and the Committee on Environment and Public Works of the Senate and the Committee on Transportation and Infrastructure of the House of Representatives.

Appendix B
Committee for Review of USDOT Truck Size and Weight Study
Statement of Task

An ad hoc committee will provide a peer review of a comprehensive truck size and weight study that Congress required the U.S. Department of Transportation (USDOT) to conduct. The review will include two letter reports. The first will review "desk scan reports" (literature reviews) prepared by the Federal Highway Administration (FHWA) based on their thoroughness in reviewing the existing literature, analysis of existing models and data for conducting the comprehensive study, and overall synthesis of the preceding body of work as it applies to the study that is to follow. The desk scans are expected to be available for committee review in August–September 2013. Once FHWA has completed the technical analysis for the study in March 2014, the committee will prepare and issue its second and final report, commenting on the extent to which the technical analysis and findings address the issues identified by Congress. The committee's second letter report will be due by May 1, 2014.

Appendix C
Parties Submitting Comments to the Committee

The following persons submitted comments on the committee's task in writing or in remarks at the December 5, 2013, or July 14, 2015, public meetings:

Steve Carter, Board of County Commissioners, Sequoyah County, Oklahoma
Rob Effinger, American Association of State Highway and Transportation Officials
James and Marge Freeman
Steve Howard, Terex Advance Mixer, Charleston, South Carolina
Henry Jasny, Advocates for Highway and Auto Safety, Washington, D.C.
Donald J. Kaleta, Rome, Ohio
Shaun Kildare, Advocates for Highway and Auto Safety, Washington, D.C.
John Lannen, Truck Safety Coalition, Arlington, Virginia
John Runyan, Coalition for Transportation Productivity, Washington, D.C.
Ed Slattery, Parents Against Tired Truckers, Arlington, Virginia
Curtis Sloan, GoRail, Alexandria, Virginia
Kirk T. Steudle, Michigan Department of Transportation
Tami Friedrich Trakh, Citizens for Reliable and Safe Highways, Arlington, Virginia
Peter J. Vanderzee, LifeSpan Technologies, Alpharetta, Georgia
John Woodrooffe, University of Michigan Transportation Research Institute

Appendix D
Review of the Document

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC's) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that assist the authors and NRC in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The contents of the review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. The following individuals participated in the review of this report: R. Stephen Berry, University of Chicago; Judith Corley-Lay, North Carolina Department of Transportation; Norman Dofflemyer, Maryland Department of State Police; Gongkang Fu, Illinois Institute of Technology; Lidia Kostyniuk, University of Michigan; Gerard McCullough, University of Minnesota; Bernard Robertson, BIR1, LLC; and C. Michael Walton, University of Texas at Austin. Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the committee's conclusions or recommendations, nor did they see the final draft of the report before its release.

The review of this report was overseen by National Academy of Sciences member Susan Hanson, Clark University (emerita), and National Academy of Engineering member Maxine Savitz, Honeywell, Inc. (retired). Appointed by NRC, they were responsible for making certain that an independent examination of the report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

STUDY COMMITTEE BIOGRAPHICAL INFORMATION

James Winebrake (*Chair*) is Professor and Dean of the College of Liberal Arts at Rochester Institute of Technology (RIT) and Co-Director of the RIT Laboratory for Environmental Computing and Decision Making. Previously, he was chair of the Department of Science, Technology, and Society/Public Policy, directing a BS program in public policy and an MS program in science, technology, and public policy. Dr. Winebrake has published on a wide variety of transportation, energy, and environmental topics. Over the past decade, he has been involved in evaluating the environmental impacts of freight transportation, with emphasis on air quality, health, climate change, and regulations. He has served or is serving on a number of professional committees related to freight transportation, including the U.S. Department of Energy Transportation Energy Futures Steering Committee, the National Academies Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles, and the National Academies Committee for a Study of Potential Energy Savings and Greenhouse Gas Reductions from Transportation. Before joining RIT, Dr. Winebrake served as an associate professor of integrated science and technology at James Madison University. He received a BS in physics from Lafayette College, an MS in technology and policy from Massachusetts Institute of Technology (MIT), and a PhD in energy management and policy from the University of Pennsylvania.

Imad L. Al-Qadi is the Founder Professor of Engineering, Director of the Advanced Transportation Research and Engineering Laboratory, and founding Director of the Illinois Center for Transportation at the University of Illinois at Urbana–Champaign. Before that, he was the Charles E. Via, Jr., Professor at Virginia Tech. His work has resulted in the development of new pavement modeling methods, techniques, and testing standards. He is the President of the American Society of Civil Engineers (ASCE) Transportation and Development Institute Board of Governors and the editor-in-chief of the *International Journal of Pavement Engineering*. Professor Al-Qadi has received the National Science Foundation’s Young Investigator Award, the quadrennial International Geosynthetics Society Award, the ASCE James Laurel Prize, the American Road and Transportation Builders Association Steinberg Award, the ASCE Turner Award, and the French Limoges Medal. In 2010 he was elected as an ASCE Distinguished Member. He is a registered professional engineer. Dr. Al-Qadi holds a BS from Yarmouk University and an MEng and a PhD from Pennsylvania State University, all in civil engineering.

Christopher Caplice is Executive Director of the Center for Transportation and Logistics at MIT and founder of the MIT FreightLab, a research initiative that focuses on improving the way freight transportation is designed, procured, and managed. His research is in the design, procurement, and management of freight transportation systems. Before joining MIT, Dr. Caplice held senior management positions in supply chain consulting, product development, and professional services at several companies, including Logistics.com, Sabre, and Princeton Transportation Consulting Group. He is also the Chief Scientist for Chainalytics, an analytical supply chain consulting firm. Dr. Caplice served 5 years in the Army Corps of Engineers, achieving the rank of captain. He received a PhD from MIT in 1996 in transportation and logistics systems, an MS in civil engineering from the University of Texas at Austin, and a BS in civil engineering from the Virginia Military Institute.

Raymond Cook is a Lieutenant with the Pennsylvania State Police and the Director of the Commercial Vehicle Safety Division, a position he has held since 2008. He oversees the department’s Motor Carrier Safety Assistance Program and Pennsylvania’s Size and Weight Enforcement Program. Previously, he served as a station commander, a supervisor in the Bureau of Criminal Investigation’s Intelligence Division, a trooper in a patrol unit, and a special investigator for the Pennsylvania Office of the Inspector General. He holds a BS in administration of justice from Pennsylvania State University.

Georgene Geary is the Principal Engineer at GGfGA Engineering, LLC, in Stockbridge, Georgia. Until her retirement in 2014, she was State Research Engineer with the Georgia Department of Transportation

(GDOT). Earlier, she worked for the department as a geotechnical engineer, as the Assistant State Utilities Engineer, as the Office Head of the Information Services Office, and as the State Materials and Research Engineer, creating the first Pavement Management Branch in GDOT in 2001. Ms. Geary is Chair of the TRB Rigid Pavement Design Committee and the TRB Nanotechnology in Concrete Task Force. She holds a BS in civil engineering from the University of Illinois (Urbana–Champaign) and an MS in civil engineering from Georgia Institute of Technology and is a licensed engineer in Georgia.

Douglas W. Harwood is Program Director in the Transportation Research Center at MRIGlobal, a not-for-profit research institute in Kansas City, Missouri. Mr. Harwood has more than 40 years of research experience for federal, state, and local agencies, and he has served as principal investigator of numerous Federal Highway Administration and National Cooperative Highway Research Program (NCHRP) research projects concerning traffic safety, highway geometric design, and traffic operations. He has led research projects that have addressed the relationship of truck characteristics to highway geometric design and traffic safety. Mr. Harwood is a licensed professional engineer in Missouri, Kansas, and Montana. He is a member of TRB’s Committee on Highway Safety Performance and served as chair of the TRB Committee on Operational Effects of Geometrics. He holds a BS in civil engineering from Clarkson College and an MS in transportation engineering from Purdue University.

Susan Hida is the Assistant State Bridge Engineer for the California Department of Transportation (Caltrans) in Sacramento. Her professional experience includes the design and analysis of bridges, as well as structural reliability and probability-based design methods. She is a member of the AASHTO Subcommittee on Bridges and Structures and chairs the AASHTO Loads/Load Distribution Technical Committee. Previously, she was Chair of the Caltrans Loads Committee and Project Engineer for the Bayshore Viaduct Seismic Retrofit, Grass Valley–Yuba City Seismic Retrofit, and New River Bridge redesign, among others. Ms. Hida is a licensed professional engineer in California and Oregon. She received the James E. Roberts Award for Outstanding Structures Engineering in Transportation. She holds a BS and an MS in civil engineering (structural emphasis) from Purdue University and an MS in civil engineering (emphasis on structural mechanics) from Princeton University.

José Holguín-Veras is the William H. Hart Professor and Director of the Center for Infrastructure, Transportation, and the Environment at Rensselaer Polytechnic Institute and is Director of the Volvo Research and Educational Foundations’ Center of Excellence on Sustainable Urban Freight Systems at the Institute. He was previously a faculty member at California Polytechnic State University at San Luis Obispo and the City College of New York. He has served as Vice President for Logistics of the Pan-American Conferences of Traffic and Transportation Engineering, Elected Member of the Council for the Association for European Transport, member of the International Organizing Committee of the City Logistics Conferences, and member of technical committees and task forces on freight modeling at TRB. He is Review Chair for freight transportation at TRB and Transportation Editor at *Networks and Spatial Economics*. He received the 2013 White House Champion of Change Award for his contributions to freight transportation and disaster response research. He has a BS from the Universidad Autónoma de Santo Domingo, an MS from the Universidad Central de Venezuela, and a PhD from the University of Texas at Austin, all in civil engineering.

Brenda Lantz has been a researcher at the Upper Great Plains Transportation Institute since 1990, first as a graduate student and professionally since 1994. She specializes in the areas of intelligent transportation systems for commercial vehicle operations, business logistics and supply chain management, statistical modeling and diagnostics, and commercial vehicle safety. She is the Chair of the TRB Committee on Truck and Bus Safety and is a member of the TRB Committee on Trucking Industry Research. She is also a member of the Commercial Vehicle Safety Alliance Intelligent Transportation Systems and Information Systems committees. She holds a BS in sociology and an MS in applied statistics, both from North Dakota State University, and a PhD in business administration from Pennsylvania State University.

Sandra Q. Larson is the Systems Operations Bureau Director at the Iowa Department of Transportation, where she has served since 1988. She has also served as Research and Technology Bureau Director, Engineering Bureau Director, Bridges and Structures Office Director/State Bridge Engineer, a Resident Construction Engineer, and a Bridge Design Engineer. She is a member of the TRB Long-Term Bridge Performance Program Committee and TRB General Structures Committee and former Chair of the NCHRP Innovations Deserving Exploratory Analysis panel. She served on the Committee for the Strategic Highway Research Program 2 Implementation and the National Academies Committee for Pavement Technology Review and Evaluation. Ms. Larson is a past AASHTO Research Advisory Committee Chair, past AASHTO Standing Committee on Research Vice Chair, and past AASHTO Highway Subcommittee on Bridges and Structures Vice Chair. She has bachelor's degrees in civil engineering and general science and biology from Iowa State University and is a licensed civil and structural engineer in Iowa.

Ted R. Miller is a Senior Research Scientist and program director at the Pacific Institute for Research and Evaluation. He previously served on the staffs of the Urban Institute and the Granville Corporation. His publications analyze the incidence and costs of societal problems, evaluate programs, or analyze policies. His crash cost estimates have been used in safety planning or regulatory analysis by USDOT, state and foreign transportation agencies, and vehicle manufacturers. Dr. Miller has estimated benefit–cost ratios for health and safety measures, highway safety laws, and enforcement efforts. He is a Fellow of the Association for the Advancement of Automotive Medicine. He received the Excellence in Science Award from the American Public Health Association's Injury Control and Emergency Health Services Section in 1999 and the Vision Award from the State and Territorial Injury Prevention Directors Association in 2005. He serves on the editorial boards of *Accident Analysis and Prevention*, *Injury Prevention*, *Journal of Safety Research*, and *Ergonomics Open Journal*. Dr. Miller holds a BS from Case Western Reserve University and an MS in operations research, a master's in city planning, and a PhD in regional science, all from the University of Pennsylvania.

Eric Teoh is a Senior Statistician with the Insurance Institute for Highway Safety. He was previously a Mathematical Statistician at the National Institute of Environmental Health Sciences. He has published more than 20 papers and is a member of the American Statistical Association, the Washington Statistical Society, the Association for the Advancement of Automotive Medicine, and TRB's Committee on Motorcycles and Mopeds. He holds a BS and an MS in mathematics from the University of Alabama at Birmingham.

Michael Tooley is the Director of the Montana Department of Transportation, a position he has held since January 2013. Before that, he served in the Montana Highway Patrol for 28 years, including 4 years as colonel. He is also President of Tooley and Associates, which provides consulting services to the public safety community, and has extensive experience in highway safety project management and research. He has a BS in public safety administration from Grand Canyon University, and he has attended the Federal Bureau of Investigation National Academy at the University of Virginia and the Senior Executives in State and Local Government program at Harvard University's John F. Kennedy School of Government.