Volume 1: Technical Reports Summary

Comprehensive Truck Size and Weight Limits Study

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U.S. Department of Transportation

Federal Highway Administration

EXECUTIVE SUMMARY

This summary describes the approach and presents the technical results of the U.S. Department of Transportation's (USDOT) Comprehensive Truck Size and Weight Limits Study (CTSWL Study or "the study") required by Section 32801 of the Moving Ahead for Progress in the 21st Century Act (MAP-21) (P.L. 112-141).

The statute directed the Secretary of Transportation, in consultation with States and appropriate Federal agencies, to conduct a comparative analysis of the impacts from trucks operating at or within current Federal size and weight regulations to trucks operating above those limits. The legislation also specified that the analysis include six-axle tractor-trailers and other alternative configurations. In response to the congressional direction, the study analyzes:

- Highway safety and truck crash rates, vehicle performance (stability and control), and inspection and violation patterns;
- Pavement service life;
- Highway bridge performance; and
- Truck size and weight enforcement programs.

FHWA 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.

A key required step in the analysis was to estimate the effects that changes in current Federal truck size and weight limits could be projected to have on the movement of freight by truck type, by roadway type, and by freight transportation mode. The projected shifts in goods movement among truck types and between modes generated estimates of travel demand changes and affected the magnitude of potential impacts in the areas of highway safety, vehicle performance, and violation patterns; pavement and bridge performance; and in the delivery of effective truck enforcement programs in each of the scenarios. Estimated changes in truck travel demand also provided the basis for analyzing projected fuel consumption, air quality, and traffic and modal operations.

The last comprehensive study of this type was completed by the Federal Highway Administration (FHWA) in 2000. That was followed by the Western Uniformity Scenario Analysis, which was published for the Western Governors' Association by FHWA in 2004 and focused on the impacts of expanding Longer Combination Vehicle (LCV) operations in the Western States. Since then, other agencies and organizations have looked at various aspects of truck size and weight regulations in individual States or regions and at freight transportation issues in general. These reports present a range of findings that address changes in truck size and weight regulations and the impacts of those changes on industry productivity, infrastructure, safety, and the environment. To understand these diverse views, FHWA conducted extensive outreach and a thorough literature search of prior research at the outset of this Study.

This Study builds off of the body of previously completed work, introducing improved models and data sets. Nevertheless, significant limitations in data availability persist, which also affected prior studies. For example, the lack of descriptive information regarding commercial motor vehicles involved in crashes continues to prevent adequate analysis of highway safety and truck crashes. The lack of data on gross vehicle weight (GVW), number of axles on a vehicle, and the spacing between the axles imposed significant constraints in drawing national-level conclusions. In addition, the lack of crash data relevant to oversize trucks impeded the study team's ability to project crash rates of different truck sizes and configurations on a national scale.

Section 32801 also required an assessment of the impacts that a six-axle and other alternative tractor-trailer combinations would have if they were allowed to operate throughout the Nation. Accordingly, the USDOT selected six alternative truck configurations to examine, each the subject of a separate scenario analysis with a related control vehicle that meets current Federal size and weight standards. The six different scenarios were developed to see what the likely results would be if an alternative truck configuration were allowed to operate on a specified highway network in comparison to a control vehicle. In general, the scenarios' alternative truck configuration uses the nationwide network and access rules of the control—with the exception of the triple truck configuration, which has a restricted network and access rules. Table ES-1 shows the vehicles that were considered under each scenario as well as the existing configuration from which the most traffic would likely shift.

The balance of this executive summary presents the high level Study process and results.

About the Study Process

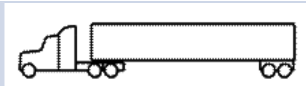
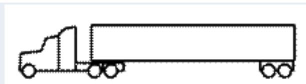
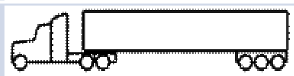
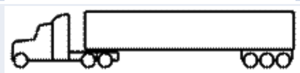
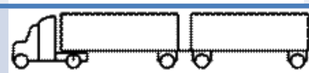
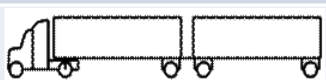
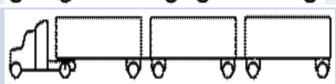
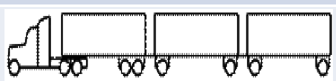
The study process included: 1) analysis in five separate focus areas, 2) extensive stakeholder and public input, 3) peer reviews by the National Academies of Science, and 4) website publication of all focus area project plans and desk scans. Furthermore:

- Section 32801 of MAP-21 established the requirement for the study;
- Congress specified the technical areas of focus;
- USDOT chose the alternative truck configurations and scenarios, incorporating stakeholder input;
- The study team conducted a Desk Scan (literature searches) of previous work on truck size and weight issues;
- The study team proposed data and models for the analysis;
- Detailed project plans were prepared for each focus area, identifying approaches to analyze the impacts on safety, pavement, bridge and enforcement and on modal diversion;

- USDOT-led teams conducted the analysis; and,
- Technical reports were prepared for each of the five focus areas.

The key findings, assumptions and limitations by focus area are summarized below.

Table ES-1: Truck Configurations and Weights Scenarios Analyzed in the 2014 CTSWL Study

Scenario	Configuration	Depiction of Vehicle	# Trailers or Semi-trailers	# Axles	Gross Vehicle Weight (pounds)	Roadway Networks
Control Single	5-axle vehicle tractor, 53 foot semitrailer (3-S2)		1	5	80,000	STAA[1] vehicle; has broad mobility rights on entire Interstate System and National Network including a significant portion of the NHS
1	5-axle vehicle tractor, 53 foot semitrailer (3-S2)		1	5	88,000	Same as Above
2	6-axle vehicle tractor, 53 foot semitrailer (3-S3)		1	6	91,000	Same as Above
3	6-axle vehicle tractor, 53 foot semitrailer (3-S3)		1	6	97,000	Same as Above
Control Double	Tractor plus two 28 or 28 ½ foot trailers (2-S1-2)		2	5	80,000 maximum allowable weight 71,700 actual weight used for analysis[2]	Same as Above
4	Tractor plus twin 33 foot trailers (2-S1-2)		2	5	80,000	Same as Above
5	Tractor plus three 28 or 28 ½ foot trailers (2-S1-2-2)		3	7	105,500	74,500 mile roadway system made up of the Interstate System, approved routes in 17 western states allowing triples under ISTEA Freeze and certain four-lane PAS roads on east coast[3]
6	Tractor plus three 28 or 28 ½ foot trailers (3-S2-2-2)		3	9	129,000	Same as Scenario 5[3]

[1] The network is the 1982 Surface Transportation Assistance Act (STAA) Network (National Network or NN) for the 3-S2, semitrailer (53'), 80,000 pound gross vehicle weight (GVW) and the 2-S1-2, semitrailer/trailer (28.5'), 80,000 pound. GVW vehicles. The alternative truck configurations have the same access off the network as its control vehicle.

[2] The 80,000 pound weight reflects the applicable Federal gross vehicle weight limit; a 71,700 gross vehicle weight was used in the study based on empirical findings generated through an inspection of the weigh-in-motion data used in the study.

[3] The triple network starts with the network used in the 2000 Comprehensive Truck Size and Weight (CTSW) Study and overlays the 2004 Western Uniformity Scenario Analysis. The LCV frozen network for triples in the Western States was then added to the network. The triple configurations would not have the same off network access as its control vehicle, the 2-S1-2, semitrailer/trailer (28.5'), 80,000 pound GVW. Use of the triple configurations beyond the triple network would be limited to that necessary to reach terminals that are immediately adjacent to the triple network. It is assumed that the triple configurations would be used in Less-Than-Truck Load (LTL) line-haul operations (terminal to terminal). As a result, the 74,454 mile triple network used in this Study includes: 23,993 mile network in the Western States (per the 2004 Western Uniformity Scenario Analysis, Triple Network), 34,802 miles in the Eastern States, and 15,659 miles in Western States that were not on the 2004 Western Uniformity Scenario Analysis, and the Triple Network used in the 2000 Comprehensive Truck Size and Weight Study (2000 CTSW Study).

Modal Shift

The modal shift analysis provides the foundation for assessing a range of potential impacts associated with the truck size and weight scenarios analyzed in this study. “Modal shift” refers to shifts in freight usage between truck and rail modes as well as across vehicle types and operating weights within the truck mode.

- The FHWA is projecting a 45 percent growth in freight tonnage by 2040 that will generate an increase in demand for capacity to move freight, regardless of any changes in truck size and weight limits. However, for study purposes, the amount of freight to be moved was held constant at 2011 levels. If growth in freight were considered, the VMT reductions calculated by the model would be offset in 1 year by the forecasted growth due to freight demand. In light of this, the following results should be considered for their effects relative to other scenarios, but they are not predictive of real, long-term effects on truck VMT.
- Several data limitations were encountered including:

  1) Lack of precise origins and destinations of shipments,
  2) Unknown routes used to ship commodities,
  3) Limited WIM data availability off the Interstate System, and
  4) A model that does not account for state weight exemptions for truck hauls of certain commodities in bulk to rail or water head.

  USDOT does not believe that these limitations affect overall study conclusions, but the limitations must be kept in mind when considering study implications.
- The vehicle miles traveled (VMT) needed to haul the volume of freight estimated in the 2011 Freight Analysis Framework declined under all six scenarios relative to the control or base case VMT. As would be expected, changes in VMT mostly varied by the gross vehicle weight allowed in each scenario.
- Total logistics costs for transporting freight declined for all scenarios relative to the control situation, with greater declines estimated for Scenarios 1 through 3. This reflects higher transportation costs for shipping bulk commodities in the more lightly loaded control vehicle.
- The modal shift analysis assessed shifts between the truck and rail modes, as well as shifts in vehicles and operating weights within the truck mode. The amount of freight that shifted from existing truck types to the other truck scenario types was significantly higher than shifts estimated from rail to truck for each of the scenarios modeled. The greatest projected level of truck-to-truck shifts occurred in Scenarios 1, 2 and 3.
- Truck and rail modes are partners in some transportation markets, but are competitors in other markets. Although diversions from rail to alternative configuration trucks were seen under all six scenarios, these diversions were much greater for the five-axle, 88,000-lb. configuration in Scenario 1, the six-axle, 91,000-lb. configuration used in Scenario 2

and the six-axle, 97,000-lb. configuration used in Scenario 3. Scenario 3 produced the largest impact on rail share of freight with approximately $562 million in rail shipments shifting to the six-axle 97,000-lb. truck configuration trucks.

- Special attention was applied to assessing the impacts that the scenarios could have on regional (Class II) and short line (Class III) railroads. Estimates of the impacts on regional and short line railroads were completed using data reported on the Surface Transportation Board's Carload Waybill Sample. The commodities hauled by short lines are moved in quantities that would only be affected by the truck size and weight changes in Scenarios 1, 2, and 3. Using the same general methods as were used to analyze rail impacts for Class I railroads, short line railroads were estimated to lose between one and four percent of total revenue under each of Scenarios 1, 2, and 3. Revenue losses under Scenario 3 would be somewhat greater than losses under Scenarios 1 and 2. Losses for some individual short line railroads could be greater. Although the analysis identified waybills that would be diverted under Scenarios 4, 5 and 6, the results were not included in the analysis due to significant data constraints with reported revenue.
- As a result of reduced truck VMT, road congestion-related costs would decline, with cost savings ranging from $256 million in Scenario 1 to $875 million in Scenario 4. All truck configurations used in the six scenarios would result in a decline in fuel costs; carbon dioxide emissions, the most prevalent greenhouse gas; and emissions of nitrogen oxide, an air pollutant, when compared to the control situation.

Safety

The safety comparative analysis explores the differences in safety risk and truck crash frequency between truck configurations currently operating on the Nation's roadways at and below current Federal limits to those operating above such limits. The safety analysis also compares crash frequency and severity associated with base-line control vehicles with the six alternative truck configurations. To accomplish these purposes, three different analytical approaches were pursued: 1) crash-based analyses; 2) vehicle stability and control analyses; and, 3) safety inspection and violations data analyses.

- It is not possible to draw national conclusions or present findings concerning national crash rates due to a lack of relevant crash data. In many cases, crash data are drawn from a very limited sample of one or two States due to the actual range of operation of some of the truck configurations and problems with the quality of the data.
- Safety analysis results were, in part and to the extent possible, based on crash data from actual operations on U.S. roads. **Weight data was not present in State truck crash reports,** so an axle-based comparative analysis was completed. This analysis included data from those States that allow truck weights at or close to the alternative configuration weights as a proxy data set for weight.
- 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.

- The study did not analyze five-axle, 88,000-lb. trucks in Scenario 1 and 33-ft., twin-trailer combinations in Scenario 4. The five-axle, 88,000-lb. trucks could not be separately identified in State truck crash data reports due to the lack of weight information. In addition, the twin 33-ft. trailer combination is not in current use in the U.S. (other than in limited application on one route in one State), so no crash data was available.
- For analysis of maneuvering capability, the six-axle combinations used in Scenarios 2 and 3 did not differ appreciably from the five-axle semitrailer (maneuvering includes low- and high-speed off-tracking, stopping distance, and avoidance). Both the triple- and twin-trailer combinations used in Scenarios 4, 5, and 6 were most challenged by the avoidance maneuver. The "amplification" response of the third trailer in Scenarios 5 and 6 was greater than that of the second trailer in the control vehicle.
- The weight or size of a truck was not a strong predictor of the probability of driver and vehicle inspection violations (which included all driver and vehicle violations excluding over-weight violations). Other factors like driver age, vehicle age, and company "out-of-service" records were identified as stronger predictors of the probability of a violation. Note that the violations analysis excluded vehicles with over-weight violations to be consistent with the crash comparisons and the effort to compare legally operating vehicles in excess of 80,000 lbs. This analysis of violation data showed that trucks operating at or below current Federal weight limits had 2.8 to 3.5 violations per inspection, whereas trucks operating legally above those limits had 6.3 to 7.6 violations per inspection.

Pavement

The purpose of the pavement analysis is to address two major questions: how will changes in axle weights and types resulting from each scenario affect pavement performance and expected pavement costs, and how much pavement damage is currently caused by trucks operating above the current Federal weight limit versus trucks operating at or below those limits?

- For the pavement analysis, the study considered only Interstate and National Highway System (NHS) roads.
- The estimated impacts of the truck size and weight scenarios vary among both the scenarios and the pavement type and service conditions considered in the analysis.
- For the purposes of this study, life-cycle-cost (LCC) is defined as the agency cost for pavement rehabilitation (e.g., overlays, retexturing) over a 50-year analysis period. User costs, while important, were not considered in order to avoid complicating the analysis with the assumptions required for the estimation of user costs. Two interest rates were used in estimating the LCC for the pavement sections analyzed: a conservative rate of 1.9 percent was used, and a higher rate of 7.0 percent was used. As a result, the LCC estimates are reported as ranges.
- On average, the twin 33-ft. trailer combination used in Scenario 4 resulted in the largest overall LCC with an increase of 1.8 to 2.7 percent from the base scenario.

- The six-axle, 91,000-lb. configuration used in Scenario 2 resulted in a 2.4 to 4.2 percent decrease in predicted Life Cycle Costs (LCC) from the base scenario. This configuration features an additional axle with a weight increase of 11,000 lbs. compared to the five-axle, 80,000-lb. combination used as the base in the comparison. The six-axle, 97,000-lb. configuration used in Scenario 3 resulted in a 2.6 to 4.1 percent decrease in predicted LCC from the base scenario.
- The five-axle, 88,000-lb. configuration used in Scenario 1 and both triple trailer combinations used in Scenarios 5 and 6 showed small increases in LCC due to the higher axle weights as compared with the control vehicles.

Bridge

The bridge technical analysis work is focused on two main analytical objectives: a structural analysis and a bridge damage cost allocation.

The bridge structural analysis was designed to determine and assess the implications of the structural demand on U.S. bridges due to the introduction of the proposed alternative truck configurations.

The bridge damage cost allocation was designed to determine the increase or decrease in bridge damage-related costs expected to accrue over time due to the introduction of the proposed alternative truck configurations as compared with the costs attributable to the current truck fleet. For these analyses:

- The impacts of each scenario truck were assessed independently. The total number of bridges included in the sample that was assessed on the NHS, including the Interstate System, is 490 comprising 153 Interstate System bridges and 337 non-Interstate NHS bridges.
- 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.
- The introduction of the Scenario 2, 3, and 6 trucks affected the greatest number of bridges with posting (i.e., the need for strengthening or replacing a bridge) issues. The Scenario 3 truck configuration is projected to result in 6,215 bridges that would require strengthening or replacement, or 4.6 percent of Interstate bridges and 9.5 percent of other NHS bridges. The introduction of the Scenario 2 and 6 trucks is expected to produce 4,845 and 5,425 bridges with posting issues, respectively.
- Costs were estimated for bridge strengthening and replacement using project cost information from FHWA's Financial Management Information System (FMIS). A unit cost for this type of work was calculated ($235.00 per square foot of deck space), applied to bridges requiring strengthening or replacement and summarized for each scenario modelled. Bridges requiring improvement action on the Interstate System (IS) and National Highway System (NHS) were flagged for improvement when a rating factor

equal to or less than 1.0 was observed. Costs by span length for IS and NHS bridges are found in Table 23 of the Bridge Structure Comparative Analysis Report.

- The upper bound for projected one-time strengthening or replacement costs resulting from the introduction of alternative vehicles ranges from approximately $400 million for Scenario 1 to approximately $5.4 billion for Scenario 6.
- Relatively heavier axle loads and axle groupings tend to affect bridge fatigue life negatively when compared to the existing truck fleet. For the steel bridge analysis, the following ranges represent the incremental (per truck pass) effects on remaining fatigue life for each scenario truck as compared to the corresponding control vehicle:

  1) Scenario 1 – 25 to 27 percent greater incremental effect on fatigue life,
  2) Scenario 2 – 29 to 41 percent greater effect,
  3) Scenario 3 – 42 to 54 percent greater effect,
  4) Scenario 4 – 10 percent less to 17 percent greater effect,
  5) Scenario 5 – 29 percent less to 31 percent greater effect, and
  6) Scenario 6 – 54 to 64 percent greater effect.

  The overall effect on bridge fatigue life depends on the number of relatively heavier trucks that are in the traffic stream and the truck and axle weights.

Compliance

This area of the study assesses the cost and effectiveness of enforcing truck size and weight (TSW) limits for trucks currently operating at or below current Federal truck weight limits as compared with a set of alternative truck configurations in six scenarios.

- States spent approximately $635 million on truck size and weight enforcement in 2011. Personnel costs accounted for 85 percent of the spending, while facilities (including technology investments) accounted for the remainder.
- In all six scenarios, personnel costs for enforcement showed a slight decrease of approximately 1 percent or less relative to the base-case personnel costs, reflecting a reduction in truck vehicle VMT projected by the compliance analysis. This is not viewed as a significant finding. It should be noted that the reduction in personnel costs does not necessarily translate into lowering the level of enforcement; rather, it should be interpreted to mean that enforcement officials are able to weigh more trucks per truck mile of travel or shift investments toward emerging technologies. Either strategy adds effectiveness to enforcement programs.
- Comparisons of 13 States that use the 80,000-lb. weight limit as the beginning point for overweight enforcement to 16 States that allow higher weights under grandfather clauses showed little difference in enforcement costs relative to truck VMT in the State or in

program effectiveness using the relationship between citation rate and enforcement intensity as the measure.

Table ES-2 summarizes the technical results of the study for each of the five focus areas: 1) modal shift, 2) safety, 3) pavement, 4) bridge, and 5) compliance. Following the Table is a compilation of Study highlights from each of the technical reports.

Table ES-2a. Study Results: Scenario Configuration Compared to Control Vehicle 1; Heavier Single Semi-Trailer Trucks

Scenarios	Modal Shift		Safety			Bridge Projected One Time Costs	Pavement Changes in Life-Cycle Cost	Enforcement Program Costs and Effectiveness
	Truck VMT	Total Logistics Costs	Crash	Vehicle Stability and Control	Violations and Citations			
Five-axle truck @ 88k pounds	-0.6%	-1.4%	No national data or results; no analysis completed.	- Longer stopping distances - No difference in vehicle path or tracking	-Overall slightly higher violation rate and slightly lower out-of-service and citation rates -Configurations operating over 80k pounds had 18% more brake violations and a higher number of brake violations per inspection -Vehicle weight or configuration not predominant factors in predicting a violation	$.4 B	+0.4% to +0.7%	-0.3%; Positive (185,000 more trucks could be weighed for the same cost)
Six-axle truck @ 91k pounds	-1%	-1.4%	No national data or results; significant crash rate increase (+47%) in the one State (WA) analyzed.	6-axle heavy truck configurations did not differ significantly from the control vehicle in any of the maneuvers.	-Overall slightly higher violation, out-of-service and citation rates -Configurations operating over 80k pounds had 18% more brake violations and a higher number of brake violations per inspection -Vehicle weight or configuration not predominant factors in predicting a violation	$1.1 B	-2.4% to -4.2%	-0.4%; Positive (266,000 more trucks could be weighed for the same cost)
Six-axle truck @ 97k pounds	-2%	-3.2%	No national data or results; significant crash rate increases in the two States (ID +99%, MI +400%) analyzed.	6-axle heavy truck configurations did not differ significantly from the control vehicle in any of the maneuvers.	-Overall slightly higher violation, out-of-service and citation rates -Configurations operating over 80k pounds had 18% more brake violations and a higher number of brake violations per inspection -Vehicle weight or configuration not predominant factors in predicting a violation	$2.2 B	-2.6% to -4.1%	-1.0%; Positive (625,000 more trucks could be weighed for the same cost)

Table ES-2b. Study Results: Scenario Configuration Compared to Control Vehicle Longer Combination Trucks

Scenarios	Modal Shift		Safety			Bridge Projected One Time Costs	Pavement Changes in Life-Cycle Cost	Enforcement Program Costs and Effective-ness
	Truck VMT	Total Logistics Costs	Crash	Vehicle Stability and Control	Violations and Citations			
Twin 33' trailers @ 80k pounds	-2.2%	-6.3%	N/A [Configuration not in common use]	-Did not perform as well as the control vehicle in avoidance maneuver -Slightly longer stopping distance -Path deviation not affected by the ABS malfunction	-Twin trailers generally have higher vehicle inspection violation rates than five-axle 80k pound single trailers	$1.1 B	+1.8% to +2.7%	-1.1%; Positive (653,000 more trucks could be weighed for the same cost)
Triple 28' trailers @ 105.5k pounds	-1.4%	-5.1%	No national data or results; Decrease in crash rate (-42%) in one State (ID) analyzed.	- Did not perform as well as the control vehicle in avoidance maneuver -Amplification of the third trailer's response was greater than in the control -Some performance differences between the triples and twins in terms of braking or in the ABS malfunction -Off-tracking was greater than the control	-Sample size too small to conduct analysis	$0.7 B	+0.1% to 0.2%	-0.7%; Positive (452,000 more trucks could be weighed for the same cost)
Triple 28' trailers @ 129k pounds	-1.4%	-5.3%	No national data or results; Minimal decrease in crash rate (-1%) on one roadway (KS Turnpike) analyzed.	- Did not perform as well as the control vehicle in avoidance maneuver -Amplification of the third trailer's response was greater than in the control -Some performance differences between the triples and twins in terms of braking or in the ABS malfunction -Off-tracking was greater than the control	-Sample size too small to conduct analysis	$5.4 B	+0.1% to +0.2%	-0.7%; Positive (446,000 more trucks could be weighed for the same cost)

Box 1. Moving Ahead for Progress in the 21st Century (MAP-21)
(Public Law 112-141)

SEC. 32801. COMPREHENSIVE TRUCK SIZE AND WEIGHT LIMITS STUDY.
(a) 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

Box 1. (continued)

(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.

Table ES-3 provides a reference guide to Section 32801 requirements, FHWA responses to the legislative provisions, and where to find the study results in both the Volume 1 summary report and in the Volume II technical reports. The table is organized by Section 32801 subsections:

- Subsection (a)(1) to (a)(4): Provisions Related to Vehicles Currently Operating Above and Below Federal Truck Size and Weight (TSW) Limits
- Subsections (a)(5) to (a)(6): Provisions related to Alternative Configurations: Compare and contrast the potential safety and infrastructure impacts of current Federal TSW law and regulations;
- Subsection (a)(6) A to D: Under the assumption the Alternative Configuration is allowed, estimate extent to which freight would likely be diverted to other surface modes and to principal arterial routes and NHS intermodal connectors; and the effects of the diversion on public safety, infrastructure, cost responsibilities, fuel efficiency, freight transportation costs, and the environment; effect on the transportation network; and increases/decreases in total number of trucks on principal arterials and NHS connectors.
- Subsection (a)(7): Identify all Federal rules and regulations impacted by changes in truck size and weight limits.

Table ES-3. How and Where Study Addressed MAP-21, Section 32801 Requirements

Table ES-3. How/Where Study Addressed MAP-21, Sect. 32801 Requirements		
Subsection (a)(1) to (a)(4): Provisions Related to Vehicles Currently Operating Above and Below Federal Truck Size and Weight (TSW) Limits with regard to:		
Legislative Requirement	**How Addressed**	**Where Addressed**
Subsection (a)(1) Accident frequency	Crash-based analyses, using data from States and limited data from fleets.	Highlights: Volume 1. Technical Reports Summary**,** Chapter 3.2 (Safety Analysis) Technical report: Highway Safety and Truck Crash Comparative Analysis
Subsection (a)(1) Factors Relating to Accident Risk	Desk scan; analysis of vehicle stability and control, and analysis of safety inspection and violations data.	Highlights: Volume 1. Technical Reports Summary**,** Chapter 3.2 (Safety Analysis)
Subsection (a)(2) Impacts on Infrastructure (See also Bridge Impacts below)	Seven-step process employing latest pavement models, with existing databases to ascertain pavement impacts on specific sample pavement sections.	Highlights: Volume 1. Technical Reports Summary, Chapter 3.3 (Pavement Analysis) Technical report: Pavement Comparative Analysis
Subsection (a)(2) Costs and Benefits of infrastructure Impacts (in dollars)	Identification of life-cycle costs related to highway agency costs for pavement rehabilitation.	Highlights: Volume 1. Technical Reports Summary, Chapter 3.3 (Pavement Analysis) Technical report: Pavement Comparative Analysis
Subsection (a)(2) Percentage of Trucks Operating in Excess of Federal size and weight limits	Estimation of Vehicle Miles of Travel for truck traffic currently operating within and above existing Federal truck size and weight regulations.	Highlights: Volume 1. Technical Reports Summary, Chapter 2.1, Table 3. Technical report: Modal Shift Comparative Analysis
Subsection (a)(2) Ability of States to Recover Costs or Realize the Benefits	States could raise user fees or permit fees on vehicles operating above current Federal limits.	Highlights: Volume 1. Technical Reports Summary, Chapter 1.4
Subsection (a)(3) Frequency of enforcement violations of vehicles in excess of the Federal size and weight laws and regulations	Comparison of 13 States that enforce the 80,000 pound Federal truck weight limit with 16 States that allow higher weights under exemptions and grandfather clauses.	Highlights: Volume 1. Technical Reports Summary, Chapter 3.5.4 Technical report: Compliance Comparative Analysis

Table ES-3. How/Where Study Addressed MAP-21, Sect. 32801 Requirements		
Subsection (a)(1) to (a)(4): Provisions Related to Vehicles Currently Operating Above and Below Federal Truck Size and Weight (TSW) Limits with regard to:		
Legislative Requirement	**How Addressed**	**Where Addressed**
Subsection (a)(3) Cost of Enforcement	Estimations made from enforcement costs and resources data in State Enforcement Plans.	Highlights: Volume 1. Technical Reports Summary, Chapter 3.5.4 Technical report: Compliance Comparative Analysis
Subsection (a)(3) Effectiveness of Enforcement Methods	Analysis and comparison of: (1) enforcement program activities (e.g., weighings, citations, citation rates); and (2) compliance for various vehicle types.	Highlights: Volume 1. Technical Reports Summary, Chapter 3.5.4 Technical report: Compliance Comparative Analysis
Subsection (a)(4) Bridge Impacts	A structural analysis was performed on about 500 bridges representing the 12 most common bridge types. An axle-load based cost allocation approach was used to estimate costs related to different truck weight configurations.	Highlights: Volume 1. Technical Reports Summary, Chapter 3.4 Technical report: Bridge Structure Comparative Analysis
Subsections (a)(5) to (a)(6): Provisions related to Alternative Configurations: Compare and contrast the potential safety and infrastructure impacts of current Federal TSW law and regulations in relation to:		
Subsection (a)(5) Six-axle and other alternative configurations of tractor-trailers	USDOT selected six alternative scenarios, each involving one alternative configuration and control vehicle. The methods discussed above under Section (a)(1) to (a)(4) were then applied to produce the comparison for each scenario.	Highlights: Volume 1. Technical Reports Summary, Chapter 2 Technical reports: Each of the five technical reports compares the six scenarios for the specific topic addressed.
Subsection (a)(6) Safety records of other nations with different truck size and weight limits than U.S. Federal limits	Desk scan (Literature search) of selected foreign nations.	TS&W limits in other countries: Volume 1. Technical Reports Summary, Chapter 1 Foreign country safety records: Draft Safety and Truck Crash Analysis Report, Appendix A, Safety Analysis Desk Scan, A.4 International experience.

Table ES-3. How/Where Study Addressed MAP-21, Sect. 32801 Requirements		
Legislative Requirement	**How Addressed**	**Where Addressed**
Subsection (a)(6)(A) Freight diverted from other surface modes to principal arterial routes and NHS intermodal connectors	Mode shifts estimated using the Intermodal Transportation and Inventory Cost (ITIC) model. The Freight Analysis Framework (FAF) was the primary commodity flow data base. The Carload Waybill Sample was used for rail diversion analysis	Highlights: Volume 1. Technical Reports Summary, Chapter 3 Technical report: Draft Modal Shift Comparative Analysis
Subsection (a)(6)(A) Effect diversion would have on: other modes of transportation	Developed assumptions necessary for the modal shift analysis and identify limitations in the data and analytical methods that will affect the analysis. Estimated modal shifts associated with each scenario using the analytical tools and data chosen for the analysis.	Highlights: Volume 1. Technical Reports Summary, Chapter 3.1 Technical report: Modal Shift Comparative Analysis, Chapter 6 and Table 34
Subsection (a)(6)(B) Effect diversion would have on:		
Public safety	The approach taken in (a)(1) above was applied to each of the six alternative scenario vehicles and their control vehicles.	See (a)(1) above.
Infrastructure	The approach taken in pavement and bridge (a)(2) and (a)(4) above was applied to the scenario vehicles.	See pavement and bridge (a)(2) and (1)(4) above.
Cost responsibilities	See pavement and bridge descriptions in (a)(2) and (a)(4) above.	See pavement and bridge (a)(2) and (a)(4) above.
Fuel efficiency	Change in fuel consumption (gallons) was estimated for each scenario.	Highlights: Volume 1. Technical Reports Summary, Chapter 3.1.4. Technical report: Modal Shift Comparative Analysis, Chapter 5. Highlights: Volume 1. Technical Reports Summary, Chapter 3. Technical report: Modal Shift Comparative Analysis, Chapters 3 and 4

Table ES-3. How/Where Study Addressed MAP-21, Sect. 32801 Requirements		
Legislative Requirement	**How Addressed**	**Where Addressed**
Freight transportation costs Environment	Estimation of total logistics costs for the alternative scenarios. Change in carbon dioxide emissions and oxides of nitrogen emissions were estimated for each scenario.	Highlights: Volume 1. Technical Reports Summary, Chapter 3.1.4 Technical report: Modal Shift Comparative Analysis, Chapter 5
Subsection (a)(6)(C) Effect on Transportation Network	Diversion between truck types and diversion from rail to truck under each scenario. Highway user delay and congestion costs were assessed using three traffic simulation models—one for Interstate highways, one for rural two-lane highways, and one for urban arterials.	Highlights: Volume 1. Technical Reports Summary, Chapter 3.1 and Tables 6 and 7 Technical report: Modal Shift Comparative Analysis, Chapter 6, and Table 34
Subsection (a)(6)(D) Increases/decreases in total number of trucks on principle arterials and NHS intermodal connectors	The study analysis used changes in VMT and did not use an estimate of trucks.	
Subsection (a)(7): Identify all Federal rules and regulations impacted by changes in truck size and weight limits.		
	Reviewed statutes and regulations on all roads/highways on which Surface Transportation Assistance Act vehicles now operate.	Highlights: Volume 1. Technical Reports Summary, Chapter 3.5.4 Technical report: Compliance Comparative Analysis, Chapter 4. 4.4.

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List of Acronyms

Acronym	Definition
ABS	anti-lock braking system
AASHTO	American Association of State Highway and Transportation Officials
ASLRRA	American Short Line and Regional Railroad Association
BTS	Bureau of Transportation Statistics
CMV	commercial motor vehicle
CTSW	Comprehensive Truck Size and Weight Limits Study
DA	data agreement
FAF	Freight Analysis Framework
FHWA	Federal Highway Administration
FMIS	Financial Management Information System
FRA	Federal Railroad Administration
GCW	gross combined weight
GVW	gross vehicle weight
HPMS	Highway Performance Monitoring System
IHS	Interstate Highway System
ITIC	Intermodal Transportation and Inventory Cost Model
LCV	longer combination vehicles
LFR	load factor rating
LTPP	Long-Term Pavement Performance
LTL	less than truckload
LRFR	load resistance factor rating
LTBP	Long-Term Bridge Performance Program
MARAD	Maritime Administration
MCMIS	Motor Carrier Management Information System
M-EPDG	Mechanistic-Empirical Pavement Design Guide
NAS	National Academy of Sciences
NATS	National Truck Stop Survey
NBI	National Bridge Inventory
NDA	non-disclosure agreement
NESCCAF	Northeast States Center for a Clean Air Future
NHTSA	National Highway Traffic Safety Administration
NREL	National Renewable Energy Lab
OOS	out-of-service
ORNL	Oak Ridge National Laboratories
PBS	Performance-based standards
PCE	passenger car equivalents
POG	Policy Oversight Group
STB	Surface Transportation Board
STAA	Surface Transportation Authorization Act
STCC	Standard Transportation Commodity Code
SwRI	Southwest Research Institute
TOC	Technical Oversight Committee

Acronym	Definition
TRB	Transportation Research Board
USDOT	U.S. Department of Transportation
VMT	vehicle miles traveled
VIUS	Vehicle Inventory and Use Survey
VSC	vehicle stability and control
WHVC	World Harmonized Vehicle Cycle
WIM	weigh-in-motion

CHAPTER 1 – CURRENT TRUCK SIZE AND WEIGHT REGULATIONS IN THE UNITED STATES AND OTHER COUNTRIES

Introduction and Context

This document is organized into three chapters. **Chapter 1** describes current truck size and weight regulations in the United States, Mexico, Canada, the European Union, and Australia.

Chapter 2 discusses the technical scope and methodology used in assessing the impacts that trucks operating above current Federal size and weight limits compared to the impacts associated with trucks operating at or below current Federal limits. In this Chapter, the impacts that changes to U.S. Federal truck size and weight limits may be expected to have are assessed, including:

1) Shifts in truck types, roadways, and modes used;
2) Highway safety (truck crash rates, vehicle performance, and violation patterns);
3) Pavement service life;
4) Bridge performance; and
5) Enforcement program delivery and effectiveness.

It also discusses the approaches used to encourage public input and provides an overview of the study review process, including a peer review by the National Academy of Sciences, ongoing internal USDOT reviews, and a comprehensive examination of prior truck size and weight studies in the desk scans (literature searches). These prior studies form the foundation and provide a guide for the current study.

Finally, **Chapter 3** summarizes the analytical results of each of the five technical study areas noted above. It includes information on the data and models used, the assumptions that were applied to each study area, and the limitations encountered during the analysis.

Background

Goods are moved throughout the United States on an extensive network of highways, railroads, waterways, and pipelines, as well as air-cargo routes. Each transportation mode plays a distinct role in moving goods, and multiple modes are used often to transport shipments; for example, most goods transported by air arrive at or are taken from the airport by trucks. Trucks move a substantial percentage of the tonnage and value of goods in our economy, which relies on dependable, quick, and efficient freight transportation to move goods to markets and link businesses to suppliers. Over the last two decades, increasing demand for freight services has put more pressure on our transportation system's capacity and has heightened concerns about transportation reliability, safety, security, energy consumption, and impacts on the environment. The need to understand and address these concerns has become a priority for decision makers at all levels of government and in the private sector. A major safety concern relates to the mix of trucks and passenger vehicles competing for use of the highway system. Today's fast-paced global economy requires just-in-time operations, bringing a greater number of trucks and passenger vehicles into close proximity. Another safety concern relates to whether an expansion of the highway network on which heavier and longer trucks can legally operate could expose the public to greater safety risks.

The safety of the traveling public is the top priority of the USDOT and a major goal of public- and private-sector transportation programs. Many safety-related initiatives have been undertaken by the USDOT and other public sector transportation organizations, often in cooperation with the private sector, to mitigate the impacts of growing volumes of freight shipments on transportation safety. These initiatives include improved occupant protection equipment, enhanced enforcement, and hours-of-service regulations that specify rest requirements for truck drivers. Since 2000, truck-involved crashes have declined by 26 percent. Even so, in 2012 crashes involving large trucks claimed 3,921 lives. Of that total, 82 percent were occupants of other vehicles or bystanders, according to the National Highway Transportation Safety Administration (NHTSA).

The U.S. transportation system moves a massive volume of goods each year. Nearly 20 billion tons of goods valued at approximately $18 trillion were moved in 2012, according to the Federal Highway Administration's (FHWA) Freight Analysis Framework (FAF). This amounts to almost 54 million tons of freight moved every day. Trucks hauled approximately two-thirds of the total tonnage and value of goods moved in 2012. Moreover, trucks carried the greatest share of shipments moving 500 or fewer miles; rail and pipelines together moved more than half of all tons shipped distances between 750 miles and 2,000 miles. FAF forecasts show that freight volumes will grow to close to 29 billion tons, valued at approximately $39 trillion, by 2040. All indications are that trucks will continue to carry the largest share of freight in the near future (USDOT FHWA 2014).

To meet the growing demand for freight transportation services, the U.S. truck fleet has increased substantially both in number and average weight over the last 25 years. According to the latest Vehicle Inventory and Use Survey (VIUS), conducted by the Census Bureau, the number of heavy-heavy trucks (i.e., those weighing more than 26,000 lbs.) grew by nearly 50 percent from 1987 to 2002.[1] Trucks weighing between 60,000 lbs. and 80,000 lbs. comprised the largest category in both number of trucks and in vehicle-miles traveled (VMT).

The growth in demand for goods also contributed to the increase in combination truck VMT by 15 percent from 2002 to 2012. Combination trucks are the various configurations of tractor-semitrailers and tractor-trailers operating on U.S. highways. Despite the overall growth in highway traffic over the past decade, combination truck VMT remains a relatively small share of total traffic, accounting for 5.5 percent in 2012. Nearly one-half of combination truck-miles occur on the Interstate System (USDOT FHWA 2014a and 2014b).

Freight volumes are forecast to continue growing, increasing 45 percent by 2040. This expected growth suggests that any changes in truck size or weight limits will only slow the increase in trucks on the road.

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[1] Previously conducted on a 4- or 5-year cycle going back to 1963, the Vehicle Inventory and Use Survey was discontinued after the 2002 survey. Prior to 1997, it was called the Truck Inventory and Use Survey.

Truck Size and Weight Regulations

One of the MAP-21 study requirements directs the examination of the safety of truck size and weight standards that differ from those in the United States. Most countries regulate commercial vehicle size and weight by prescribing maximum and minimum limits. These limits are intended to protect equity in transport markets, ensure highway safety, and keep damage to transportation infrastructure within manageable bounds.

In general, size and weight standards are established at the national level, but States or provinces may allow heavier vehicles to operate on their roadways under special permits or exemptions. Larger vehicles are typically subject to route restrictions. In the United States, Federal weight limits apply only to the Interstate System. The maximum gross vehicle weight (GVW)[2] of the most commonly used long-haul vehicles ranges from 80,000 lbs. (approximately 36.3 metric tonnes[3]) on the U.S. Interstate System to 45-55 metric tonnes (roughly 99,208 lbs. to 121,254 lbs.) in Mexico, Canada, and Australia. Gross vehicle weight limits in European Union (EU) member States range from 40 metric tonnes (88,184 lbs.) in France and Germany to 50 metric tonnes (110,231 lbs.) in the Netherlands.

In addition to variations in weight allowances, some countries have different standards for their infrastructure, (matching bridge and pavement specifications to greater vehicle weights) and different regulatory requirements for vehicles and drivers.

Examples of several countries' approaches to commercial vehicle size and weight regulations and their current truck weights and dimensions are presented below.

United States

Since 1956, the U.S. Federal Government has regulated commercial vehicle weight on the Interstate System. Before that time, the States established truck weight limits and continued to set weight limits off the Interstate System (See Box 2 for a brief history of U.S. truck size and weight regulations.) The Federal Government also regulates the States' ability to set limits on the dimensions for trucks defined as Surface Transportation Assistance (STAA) vehicles[4] as they travel on the National Network. The Federal Government does not have statutory authority to set weight limits for trucks on non-Interstate System roads. This authority rests with the States. Each State sets weight limits in some cases above Federal weight limits and in other cases below Federal limits. Through the use of "grandfathered rights," 16 States have retained the right to continue the practice of permitting divisible load movements that exceed Federal weight limits on the Interstate System at the time when Federal regulations were enacted. All States have the

[2] Gross vehicle weight (GVW) is the weight of the vehicle or vehicle combination plus the load.
[3] A metric tonne (1,000 kilograms) is equal to 2,204.6 pounds.
[4] A tractor with one semitrailer (3-S2) up to 48 feet in length or a tractor with one 28 or 28 ½-foot semitrailer (2-S1-2) and one 28 or 28 ½-foot trailer, as defined in the Surface Transportation Assistance Act of 1982 (P.L. 97-424).

authority to permit the movement of non-divisible loads[5] on both State roadways and the Interstate System. An electrical transformer is an example of a non-divisible load. Between 2008 and 2012, the total reported number of permits increased from 2.1 million to about 4.2 million.[6]

Box 1. Truck Size and Weight Limits in the United States

- Up to 20,000 pounds (9.1 metric tonnes) for single axles on the Interstate System
- Up to 34,000 pounds (15.4 metric tonnes) for tandem axles on the Interstate System
- Application of the Federal Bridge Formula for other axle groups up to the maximum of 80,000 pounds gross vehicle weight (36.3 metric tonnes) on the Interstate System.
- Up to 102 inches for vehicle width on the National Network (NN)
- Up to 48-foot semitrailers in a semitrailer combination on the NN are defined as STAA vehicles; longer semitrailer lengths are grandfathered in half of the States
- Either 28 or 28 1/2-foot trailers in a twin-trailer combination on the NN are defined as STAA vehicles.
- No Federal limit for commercial motor vehicle height. State standards generally range from 13.6 feet to 14.6 feet.

[5] FHWA defines a non-divisible load on vehicles operating on the Interstate System as: any load or vehicle exceeding the applicable length or weight limits that, if separated into smaller loads or vehicles, would 1) compromise the intended use of the vehicle; 2) destroy the value of the load or vehicle, or 3) require more than eight work hours to dismantle using appropriate equipment. (See Part 658 of Title 23, Code of Federal Regulations.)
[6] These numbers reflect the sum for 44 reporting States.

Box 2. History of Federal Size and Weight Limits

The Federal Government began regulating the size and weight of commercial vehicles in 1956 to protect its substantial investment in the construction of the Interstate Highway System. The Federal-Aid Highway Act of 1956 (P.L. 84-627) placed weight limits of 18,000 lbs. for a single axle, 32,000 lbs. for tandem axles (set of two closely spaced axles), and set a maximum gross vehicle weight (GVW) of 73,280 lbs. on Interstate highways. The 1956 Highway Act also established a width limit of 96 inches to support roadway designs standards that were applied to Interstate highways being constructed.

The Federal-Aid Highway Amendments of 1974 (P.L. 93-643) raised maximum weight limits on the Interstate Highway System to 20,000 lbs. for a single axle, 34,000 lbs. for tandem axles, and 80,000 lbs. for the GVW. The law also codified the Federal Bridge Formula to reduce the risk of damage to highway bridges by requiring more axles, or increasing the distance between axles, to compensate for increased vehicle weight. The Bridge Formula established weight limits on vehicle axle groups for different distances between axles and set a maximum GVW of 80,000 lbs.. The formula may require a lower gross vehicle weight, depending on the number and spacing of the axles in the combination vehicle. Congress enacted the Bridge Formula to limit the weight-to-length ratio of a vehicle crossing a bridge. This is accomplished either by spreading weight over additional axles or by increasing the distance between axles.

All truck size and weight legislation, including the Federal-Aid Highway Act of 1956, include provisions that allowed States to retain vehicle size and weight limits exceeding Federal limits on Interstate highways if the State's weight laws or regulations were in effect in 1956. This legislative provision is called a grandfather clause. Most States that have grandfather clauses have used the Federal exemption for economic reasons.

The Surface Transportation Assistance Act (STAA) of 1982 (P.L. 97-424) increased the width limit to 102 inches for commercial trucks. The 1982 STAA also established a designated network on which the Federal length and width provision applied to include both the Interstate System and certain Federal-aid Primary System roadways; this roadway network is the National Network. Congress also established a minimum length standard for most commercial truck tractor-semitrailers and for twin trailers pulled behind a truck tractor. Congressional involvement in setting vehicle length reflected its desire to standardize allowable vehicle lengths traveling on the National Network and to eliminate barriers to interstate commerce caused by differing State provisions regarding commercial vehicle width and length.

The Intermodal Surface Transportation Efficiency Act of 1991 [(ISTEA), P.L.102-240] prohibited all States from expanding LCV routes or removing LCV restrictions after 1991. ISTEA required each State to submit information on LCV restrictions and requirements to the FHWA by June 1, 1991. It also required States to certify each year to the FHWA that it is enforcing the freeze.

As shown in **Table 1**, non-divisible trip permits accounted for between 80 and 83 percent of total permits in each year while non-divisible annual permits accounted for six percent. Divisible trip permits accounted for two percent and divisible annual permits accounted for between nine and twelve percent over the 2008-2012 period. Several of the study's scenario truck configurations are in current use in the United States. Specifically, the 88,000-lb., 91,000-lb., and 97,000- lb. GVW trucks operating under State-issued permits where grandfathered rights enable commercial motor vehicles to operate above Federal weight limits. The Scenario 4 truck configuration with a twin 33-ft. (2-S1-2) semitrailer/trailer is not currently in wide use in the United States.[7]

Table 1. Nationwide Number of Permits Issued for 44 Reporting States: 2008-2012

	Nationwide Number of Permits by Year [1] *Percent Change of Permits from Previous Year*				
Permit Type	**2008**	**2009**	**2010**	**2011**	**2012**
Non-divisible trip	3,411,636	2,987,590 *-14%*	3,222,452 *7%*	3,446,444 *6%*	3,490,566 *1%*
Non-divisible annual	263,082	244,736 *-7%*	242,776 *-1%*	260,290 *7%*	272,939 *5%*
Divisible trip	65,401	89,703 *27%*	79,236 *-13%*	97,389 *19%*	88,918 *-10%*
Divisible annual	358,731	359,201 *0%*	503,871 *29%*	369,897 *-36%*	383,333 *4%*
Total	**4,098,850**	**3,681,230** ***-11%***	**4,048,335** ***9%***	**4,174,020** ***3%***	**4,235,756** ***1%***

[1] The statistics shown in the table are summed for the 44 States that reported total (non-zero) values for each year from 2008 to 2012. The issued permits were for travel both on and off Interstate highways.

Federal regulations regarding vehicle size place limits on the States' ability to regulate truck size if the truck is defined as a STAA vehicle and is traveling on the National Network that includes the Interstate Highway System and sections of the Federal-aid Primary System. Congress authorized the National Network in the Surface Transportation Assistance Act of 1982 (P.L. 97-424) to guarantee mobility rights to trucks defined as STAA vehicles thereby protecting interstate commerce. A description of the National Network can be found in 23 CFR Part 658 Appendix A and is shown in **Figure 1**.

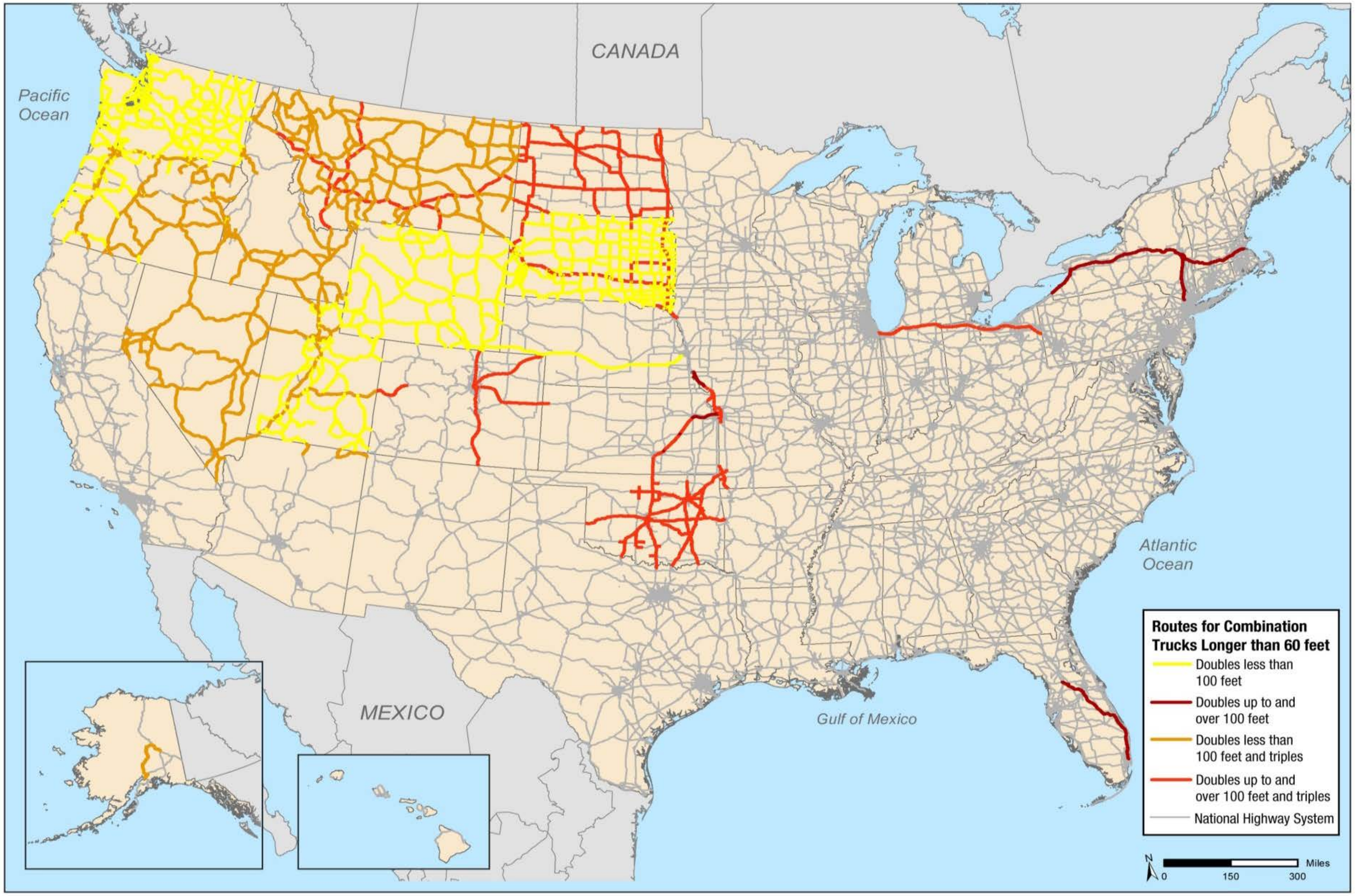
All States must allow STAA vehicles to operate on their highways; only 14 States and 6 turnpike authorities allow LCVs that weigh more than 80,000 lbs. on some parts of their road networks (**Figure 2**) (USDOT FHWA 2014). Since June 1, 1991, Congress has frozen the weights and dimensions of vehicles and the roadways on which LCVs can operate. States do not have the authority to remove restrictions related to the operation of LCVs, referred to as the ISTEA Freeze.[8] In addition, 17 States allow triple-trailer combination trucks to operate on their roadways (**Table 2**). Most of these States are located in the Western United States.

[7] USDOT understands FedEx has recently been testing 33 foot twin trailer combinations in Florida
[8] Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), P.L. 102-240.

Figure 1. National Network for Conventional Combination Trucks: 2013

Notes: The National Network was authorized by the Surface Transportation Assistance Act of 1982 (P.L. 97-424) and specified in the U.S. Code of Federal Regulations (23 CFR 658) to require that States allow conventional combinations on "the Interstate System and those portions of the Federal-aid Primary System serving to link principal cities and densely developed portions of the States on high volume routes utilized extensively by large vehicles for interstate commerce. Conventional combinations are tractors with one semitrailer up to 48 ft. in length or with one 28-ft. semitrailer and one 28-ft. trailer up to 102 inches wide. The National Truck Network (NN) differs in extent and purpose from the National Highway System (NHS), which was created more than a decade later by the National Highway System Designation Act of 1995 (P.L. 104-59) and modified in 2012 by the Moving Ahead for Progress in the 21st Century Act (P.L. 112-141). The NN was originally established in 1982 to protect interstate commerce by prohibiting restrictions on trucks of certain dimensions on a national network of roads, while the NHS supports long distance interstate travel such as connecting routes between principal metropolitan areas and industrial centers important to national defense and the national economy.

Figure 2. Permitted Longer Combination Vehicles on the NHS: 2011



Notes: Empty triples are allowed on I-80 in Nebraska. NHS mileage as of 2011, prior to MAP-21 system expansion.

As discussed above, larger and heavier trucks have been operating on our Nation's highways for decades. This experience has provided an empirical basis upon which to analyze the impacts of increasing truck size and weight limits in the United States, as required by MAP-21.

Table 2. Triple Trailer Combinations in Operation under "ISTEA Freeze"

State	Allowable Length - Cargo Carrying Units (feet)	Gross Vehicle Weight Limit (pounds)	Notes
AK	110	*	* Subject to State GVW Limits
AZ	95	123,500	Specifies limit of 20,000 lbs. on single-axle and 34,000 lbs. on tandems with FBF-B Compliance Required
CO	104.5	127,400	
ID	95	105,500	
IN	104.5	127,400	
IA	100	129,000	
KS	109	120,000	
MO	109	90,000/120,000	90,000 lb. limit if entering from OK and 120,000 if entering from KS
MT	100	131,600	
NE	95	**	** Must be empty
NV	95	129,000	
ND	100	105,500	
OH	95	115,000	
OK	95	90,000	
OR	96	105,500	
SD	100	129,000	
UT	95	129,000	

Source: Title 23 Code of Federal Regulations, Part 658, Appendix C.

Other Countries' Truck Size and Weight Regulations

The following discussion summarizes our North American neighbors' approach to regulating truck size and weight, followed by a review of regulations in the European Union and Australia. Mexico and Canada are two of our country's top trading partners, accounting for approximately $1.1 trillion in trade in 2012, or nearly 30 percent of the total value of United States trade. Trucks have carried about 60 percent of the value of goods traded with these two countries (USDOT FHWA 2014). Since NAFTA was established in 1994, the U.S. has not made major changes to its trucks size and weight regulations. Both Mexico and Canada have made several adjustments and have achieved substantial domestic harmonization (NCHRP 2010).

Mexico

Mexico has regulated commercial vehicle size and weight since the 1950s. Since then, the maximum allowable size and weight has changed several times. The Ministry of Communications and Transport establishes truck size and weight standards for the Federal highway system. States do not have authority to establish different standards from those promulgated by the Federal Government.

Standards are based on vehicle configuration (e.g., type and number of axles, wheels per axle, and suspension) and highway classification, of which there are five. Not all commercial vehicles can operate on all roadways. The highest category of roadways can accommodate vehicles with the maximum allowable capacity and size. LCVs, for example, are allowed only on the highest category of highways that have the geometric and structural characteristics to accommodate vehicles with maximum capacity and dimensions.

The 2008 revision to truck size and weight standards is the latest and is in use today; it should be noted that Mexico is currently examining its truck mass and dimension limits for trucks. In general, Mexico allows higher axle and gross vehicle weights than those allowed in the United States. Because of this, many Mexican trucks carrying goods to the United States must offload their cargo before crossing the border in order to comply with United States laws. Mexico's size and weight regulations also include exemptions and special permits. Current commercial truck configurations range from vehicles with 3-axles/10 tires to 8-axles/30 tires. The typical five-axle combination vehicle operating in Mexico is similar in dimensions to the five-axle vehicles operating in the United States. (NCHRP 2011).

Recently, Mexico has engaged the USDOT to seek technical assistance in its effort to evaluate current Mexican national truck size and weight limits and the network of roadways that certain trucks can operate on.

Box 3. Truck Size and Weight Limits in Mexico

- Maximum allowable length is 101.71 ft. (31.0 meters).
- Maximum allowable width is 8.5 ft. (2.6 meters), not including mirrors.
- Maximum height is 4.25 meters (14 ft.).
- The maximum vehicle weight is determined by vehicle type and roadway classification.
- The maximum allowable weight on the highest classification of highway is 58.5 metric tonnes (128,970 lbs.).
- Maximum allowable weight for a single power axle is 11 metric tonnes (24,250 lbs.).
- Maximum allowable weight for a double power axle (eight tires) is 18 metric tonnes (39,683 lbs.).

Canada

Canada has been a pioneer is using performance-based standards as a basis for developing commercial vehicle size and weight limits for inter-province operations. Through the Memorandum of Understanding (MOU) Respecting a Federal-Provincial-Territorial Agreement on Vehicle Weights and Dimensions, Canada has improved uniformity in truck size and weight regulations across its provinces and territories. Since its approval by all provinces and territories in 1988, the MOU has been amended six times in order to add truck configurations and to adjust standards. The latest amendment was added in 2009. Technical studies of truck dynamics and impacts conducted by provinces and the Federal Government provided the basis for the MOU (ITF/JTRC/OECD 2010). Recently, the Province of Ontario completed a study evaluating the operational feasibility of allowing 60-ft. semi-trailers.

The current MOU establishes specifications for seven truck configurations and provides a list of roads that each province has identified. A vehicle that meets MOU configuration specifications can operate on roads identified in the MOU (provided all other regulatory conditions are met, such as an appropriate driver's license and possession of a safety fitness certificate). Canada has higher weight limits than the United States for three types of trucks with six, seven, and eight axles (CMRTHS 2005).

Box 4. Canada Truck Size and Weight Limits

- Maximum height of 4.15 meters (13.6 ft.), including load.
- Maximum width of 2.6 meters (8.5 ft.), including load but excluding mirrors, lamps and loads coverings or securing devices.
- Maximum length limits vary by vehicle, but the maximum allowable length for any combination truck is 25 meters (82 ft.).
- GVW also varies by truck configuration, but the maximum allowable weight is 62,500 kilograms (137,788 lbs.).

European Union (EU)

Commercial vehicle size and weight limits are largely consistent among member countries for cross-border travel. Country-imposed limits for national travel vary but must not be lower than EU requirements except in cases where the infrastructure along secondary roads cannot support the load (USDOT FHWA 2007).

Box 5. European Union Truck Size and Weight Limits

- Maximum length of 16.5 meters (54 ft.) for conventional tractor-semitrailer combinations.
- Maximum length of 18.75 meters (61.5 ft.) for truck-trailer combinations.
- Maximum width is 2.55 meters (8.37 ft.), 2.60 meters for refrigeration containers (8.53 feet).
- Maximum height is 4.00 meters (13.1 ft.).
- Maximum allowable GVW is 40 metric tonnes (88,184 lbs.), except for intermodal vehicles with 40-ft. containers.
- Prescribed maximum axle weights are 10 metric tonnes (22,046 lbs.) for a single axle.
- Weight limits for tandem and tridem axles depend on axles spacing, but range from 11-20 metric tonnes (24,250 lbs. to 44,092 lbs.) for tandem axles and 21-24 metric tonnes (46,297 lbs. to 52,910 lbs.) for tridem axles.

A 1996 EU directive defined length, width, and height limits for trucks and various other commercial vehicles traveling between EU member States (EC Directive 96/53/EC of July 25, 1996) for the purpose of facilitating trade and ensuring the free movement of goods in Europe. Noncompliant trucks registered before September 1997 are allowed to operate under a grandfather clause, but no new vehicles registered after 2006 were allowed to operate without meeting the length, width, and height requirements. Axle weight limits depend on axle spacing.

The EU is considering allowing longer and heavier vehicles (LHV), also known as mega-trucks and Eco-Liners, to transport goods across Europe. The proposed vehicles would measure 25.25 meters (82.84 ft.) in length and weigh 60 metric tonnes (132,277 lbs.), exceeding the size and weight of any commercial vehicle operating in the United States. Although LHVs have not been approved by many European countries, Sweden and Finland have permitted LHVs to operate on their roadways for more than 40 years, but they are not allowed to cross into other European countries. Other member countries, including the Netherlands, Denmark, and Germany are conducting trials that allow LHVs to operate on their national road network. In these cases, a special temporary permission is given, in line with EU legislation allowing for exemptions, and the vehicles can be operated under prescribed conditions on certain parts of the national road network (ITF/OECD/JTF 2010).

Currently, Directive 96/53/EC is under review by the EU with truck size and weight limits being evaluated. Broader international mobility privileges have been extended to LHVs in situations where two countries agree to allow their operation and the mass and dimension characteristics of the LHV do not exceed the limits in place in each of the countries. The LHV international mobility issue is under debate as part of the EU's initiative to evaluate and update 96/53/EC.

The EU does not actively monitor the application of directives. After implementation, member countries are required to enforce the directives. Moreover, there are no reporting requirements on day-to-day operations. Usually, the European Union is notified of a problem through a complaint process. After a complaint is received, the EU notifies the member country, requests an explanation, and initiates a judicial procedure, if appropriate, through the EU Court of Justice (USDOT FHWA 2007).

Australia

Although state and territorial governments control the size and weights of heavy vehicles, there is a high degree of uniformity in commercial vehicle size and weight regulations, especially for trucks with a GVW of up to and around 46 metric tonne (101,412 lbs.). GVW and vehicle length vary by truck configuration.

Australia, like Canada, uses a performance-based approach to regulate size and weight. This approach considers safety and environmental objectives but does not prescribe how to achieve those objectives. Performance-based standards (PBS) are applied in the custom construction of certain trailers designed to accommodate a specific load movement and are more stringent in high-risk areas (high populations) than in low-risk areas such as the State of Western Australia also commonly known as the "Outback." The PBS program in Australia has been in operation since the mid-2000s and has recently transitioned from operating under a single, national regulator scheme to a State- and Territory-based regulatory framework.

The largest trucks in the world are found in Australia. The State of Victoria, Australia, began testing trucks with a length limit of 30 meters (98 ft.) and a load limit of 77.5 metric tonnes (170,858 lbs.) in 2009 (ITF/JTRC/OECD 2010). More recently, a pilot was conducted in Victoria to evaluate the safety implications of operating B-Train triples[9] in urban areas. Until now, the B-train triples were restricted to rural motorway segments under the Australian Intelligent Access Program.

Australia is a leader in using technologies to actively monitor compliance with allowances extended through a special permit. Special devices must be plugged into the vehicle's CAN-BUS (a digital communications network) to emit signals to the regulating body. Adherence to weight and dimension allowances and the approved route for the load movement is monitored remotely by the regulating body with intervention by enforcement personnel in cases where non-compliance with the terms of the special permit is observed. Australia views the issuance of a special permit to operate above weight and dimension limits as a privilege and routinely requires concessions from the transporter as a condition for receiving the special permit.

[9] "B-Train triples" is a commonly used term in Australia to describe a tractor that pulls three semitrailers.

Box 6. Australia Truck Size and Weight Limits

- Maximum axle mass is 6.5 metric tonnes (14,330 lbs.) for a steering axle, nine metric tonnes (19,841 lbs.) for other single axles, 16 metric tonnes (36,376 lbs.) for tandem axles, and 20 metric tonnes (44,092 lbs.) for tridem axles. Tandem and tridem axles are permitted an additional 0.5 metric tonnes (1,102 lbs.) and 2.5 metric tonnes (5,511), respectively, if they are fitted with road-friendly suspensions (subject to route restrictions for tridem axles).
- A six-axle tractor-semitrailer (the most common long-haul vehicle in Australia) has a maximum length of 19 meters (62 feet) and a maximum mass of 43 metric tons (94,798 lbs.)—6.5 metric tons (14,330 lbs.) on the steering axle, 16.5 metric tons (36,376 lbs.) on the tandem drive axle, and 20 metric tonnes (44,092 lbs.) on the tridem axle); or 46 metric tonnes (101,412 lbs.) (6.5 + 17.0 + 22.5) if the axles are fitted with road-friendly suspensions. For the additional mass on the tridem axle, accreditation under the Mass Management module of the National Heavy Vehicle Accreditation Scheme is also required.
- Width is limited to 2.5 meters (8 ft.) and height to 4.3 meters (14 ft.), except for livestock trailers and car carriers which are allowed a height of 4.6 meters (15 ft.). Truck-trailer combinations of above 42.5 metric tonnes (93,696 lbs.) are subject to State/Territory regulations, with consequent variations in mass limits. Mass limits for these vehicles range up to 55 tonnes (121,254 lbs.).
- Larger vehicles, such as double and triple "road trains" are subject to the same limits on height, width, and axle weight as other vehicles and their access to the road network

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CHAPTER 2 – SCOPE AND GENERAL METHODOLOGY

This section discusses the overall scope of the analysis conducted under the study to address the directives identified in MAP-21. (See **Box 1** for the specific provisions in the law.) Section 2.1 identifies the six alternative truck configurations examined and how they were selected and also presents the six highway network scenarios studied. Section 2.2 presents the general methodology underlying the analysis, including the study process set in place, steps to ensure public input, and the peer review at all critical junctures in the study process.

More specific and detailed information on the scope and methods used in the study and a summary of results of the technical analysis for each of the project focus areas are provided in **Chapter 3** of this Technical Reports Summary.

Scope

Congress directed USDOT to compare the impacts of vehicles currently operating above Federal truck size and weight limits to those operating at or below these limits as well as to assess the safety, enforcement and pavement and bridge infrastructure impacts of "six-axle and other alternative configurations of tractor-trailers" if they were allowed to operate above current weight regulations. FHWA 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 provisions in MAP-21 require the USDOT to conduct a study that:

- Addresses differences in safety risks, infrastructure impacts, and the effect on levels of enforcement between trucks operating at or within Federal truck size and weight limits and trucks legally operating in excess of Federal limits;
- Estimates changes in freight movements by truck types and by various modes caused by the introduction on alternative truck configurations;
- Assesses the impacts that alternative configurations examined in the study may have on highway safety, infrastructure service life, fuel consumption, the environment, traffic operations and costs; and
- Identifies all Federal rules and regulations impacted by changes in Federal size and weight limits.

To answer these questions, USDOT structured the analysis around the following five major study areas:

- Modal Shift Analysis
- Safety Analysis
- Pavement Analysis
- Bridge Analysis
- Compliance Analysis

Each of the five study focus areas was the subject of a technical report, the results of which are summarized later in Chapter 3. Box 7 provides an overview of the subjects addressed in these technical reports. The modal shift analysis is listed first not because the issue was given a higher priority, but because it produced a common vehicle miles of travel dataset that was the foundation for analyzing safety, pavement, bridge, and compliance topics, in addition to the modal shifts topic.

At the outset of the study, USDOT identified the roadway networks on which to conduct the comparative analysis. These networks are the Interstate System, the National Highway System (NHS),[10] and the National Truck Network (NN). The evaluation also included "Reasonable access roadways," which are those roadways connecting the Interstates or other National Network roads with freight terminals or distribution centers.

More than 80 percent of total annual truck miles traveled occurs on the NHS. There are more than 4 million center line miles of public roadways in the United States, with most of those miles located off of the NHS. There is generally little quantitative information available regarding travel by facility on this non-NHS roadway network and on how pavements on the local road system are designed, built, and maintained.

Except in rare cases, there is minimal to no history of travel or pavement characteristic data on local roads. These data limitations make it prohibitive to perform an accurate and representative study on the impacts of loading scenarios on local roads. The lack of pavement structure characteristics, pavement surface type, and typical travel levels for local system roadways prevent sampling-based approaches that would produce results supported with adequate statistical confidence. Data limitations also made it impossible to perform an accurate and representative study on the impacts of loading scenarios on local roads.

A review of the low-volume NHS sample section results suggests the impacts that scenario configurations may have on local roads and local roads are generally built to lower design standards than roadways on the higher functionally classified roadway networks. However, it is also understood that daily travel demand levels and daily truck travel on local roads is typically low, consistent with the lower design standards to which they are built, so it is not possible in this study to draw definitive conclusions about the impacts of any potential changes in truck sizes or weights on local roads.

[10] MAP-21 designates the entire Principal Arterial System (PAS) as part of the National Highway System.

Box 7. The Five Focus Areas for the Study

The results of the Study were produced from extensive comparative analyses in five focus areas. These analyses have been combined into a Technical Summary Report, summarized in more detail in **Chapter 3**.

The Modal Shift Analysis assesses how the use of alternative truck configurations might shift freight commodities among truck types and between modes and examines how such shifts could affect traffic operations, fuel consumption, distribution of cost responsibilities among the different types of vehicles, cost recovery, and the overall impacts on the U.S. freight system and the environment.

The Highway Safety and Truck Crash Comparative Analysis compares the impacts that trucks operating at and below Federal truck size and weight limits have on highway safety and crash frequency and severity compared to trucks operating above those limits. It also assesses the impacts that the six alternative truck configuration vehicles as compared to the control vehicles used in the Study in terms of their highway safety records, safety risk factors, and vehicle stability and control under six network scenarios.

The Pavement Comparative Analysis compares the impacts that trucks operating at and below Federal truck size and weight limits have on highway pavement infrastructure compared to trucks operating above those limits. It also compares the costs and benefits for pavement performance, pavement maintenance, and rehabilitation under the relevant network scenarios of the six alternative truck configurations with trucks operating at current Federal size and weight limits terms for a range of paving materials, climatic, geographic and environmental conditions.

The Bridge Structure Comparative Assessment compares the impacts that trucks operating at and below Federal truck size and weight limits have on highway bridge infrastructure compared to trucks operating above those limits. It also compares the structural effects of the six alternative truck configurations with trucks operating within Federal limits (the control vehicles) for a representative sample of bridges selected from the National Bridge Inventory.

The Compliance Comparative Analysis evaluates violation rates for commercial motor vehicles not complying with Federal truck size and weight limits by type (for example, Federal bridge formula, gross vehicle weight, single-axle-weight, and tandem-axle weight violations), and examines enforcement costs. In addition, as required by MAP-21, this analysis identifies all Federal laws and regulations that would be affected by a change in Federal truck size and/or weight limits.

To conduct the structural bridge impact comparative analysis, a representative sample of 490 bridges from the National Bridge Inventory was selected as the number of bridges that could be analyzed within the project period. These bridges are located on the Interstate System, the NHS, or the NN. The sample database of bridges provides a diverse representation of the bridges that make up the NHS inventory. The bridge types selected for the study were determined based on the material of construction, distinct structural behavior, and span configurations. Bridge selection was further refined to include additional considerations including year built, maximum span length, and live load capacity to get a diverse sample space.

Selecting a representative mix of alternative truck configurations for examination was critical, as MAP-21 only specified that the six-axle combination be included among the mix of alternatives. As discussed in Chapter 1, many countries, including Canada and Mexico, allow trucks to operate on their roadways in excess of U.S. truck size and weight limits. Even in the United States, “grandfather clauses” in Federal law allow some States to permit heavier or longer trucks to operate on some sections of the Interstates, the NN or the NHS than would be allowed under the Federal limitations. Table 3 summarizes current U.S. combination truck traffic operating at weights within and above the 80,000 pound Federal gross vehicle weight limit on the Interstate System, other National Highway System (NHS) routes, and highways off the NHS. For purposes of this Study, truck configurations are defined in terms of the number of trailers and the number of axles on the vehicle.

Table 3. Vehicle Miles of Travel by Vehicle Configuration and Highway System

Operating Weight (thousands of pounds)	2011 Vehicle Miles of Travel (in millions)								
	Single Trailers			Twin Trailers			Triple Trailers		
	Interstate	Other NHS	Non-NHS	Interstate	Other NHS	Non-NHS	Interstate	Other NHS	Non-NHS
< = 60	44,821	23,212	21,193	2,625	1,200	1,090	9	5	10
61-70	11,720	5,667	4,520	1433	540	484	9	4	10
71-80	15,522	7,483	5,978	813	419	388	15	8	17
81-90	4,540	2,199	1,848	327	213	249	19	10	22
91-100	867	430	405	171	130	184	13	7	15
101-110	314	161	162	151	124	171	7	3	8
111-120	149	75	75	111	92	114	3	2	4
121-130	72	37	36	91	71	86	1	1	2
>130	63	35	32	239	162	196	0	0	1
Total	78,068	39,299	34,248	5,961	2,951	2,962	76	39	88

Source: Study, Modal Shift Comparative Analysis Technical Report.

The table shows that there is appreciable truck traffic above the 80,000-lb. Federal GVW limit that applies to the Interstate System on the Nation’s roads. Much of this travel in vehicles weighing more than 80,000 lbs. is off the Interstate System where State weight limits apply, but some also is on the Interstate System. Some Interstate System travel in vehicles weighing more than 80,000 lbs. occurs in States with grandfathered weight limits over 80,000 lbs., some travel is under non-divisible load permits, and some travel reflects illegal overloads.

Early in the study, USDOT determined that up to six alternative truck configurations could be examined as part of the comparative analysis in the timeframe established in MAP-21. Also, to be selected for study, USDOT proposed that alternative truck configurations needed to be currently in use in the United States, Canada, or elsewhere, and practical for use in the United States. USDOT then identified three candidate truck configurations and solicited input from stakeholders regarding the selection of the additional configurations to include in the mix.

After extensive public and stakeholder input, USDOT identified the six alternative truck configurations to compare with control or baseline vehicles meeting current Federal size and weight limitations. In addition, two truck configurations that now meet Federal size and weight limitations were selected to serve as “baseline” or “control” vehicles. The comparisons would be conducted over six illustrative network scenarios, using data analysis, modeling, and other state-of-the-art methods to derive technical results in each of the five study focus areas. All but one of the vehicles selected for analysis are currently in common use on some U.S. highways, providing some baseline data and experience with these vehicles. The outlier, Scenario 4, had strong support for inclusion from stakeholder input and is in limited use in one State.

Box 8 shows the reasons why each alternative configuration was selected for inclusion in this Study.

Box 8. Reasons for Selecting the Alternative Truck Configurations and Control Truck Configurations

The rationale for selecting the six alternative truck configurations to compare with control or baseline vehicles is discussed here.

<u>Control Vehicle for Comparison with Single Trailer Combinations</u>: A five-axle, tractor-semitrailer combination (3-S2), 80,000 lbs.; this is the standard configuration of a three-axle tractor (the “3” in 3-S2) with a 53-ft.-long, two-axle semitrailer (the "S2" in 3-S2) and a gross vehicle weight (GVW) of 80,000 lbs. that operates on U.S. Interstates and other roadways. This combination is used in the study to compare with alternative truck configurations 1 through 3 below. It is an STAA vehicle meeting current Federal size and weight limitations.

<u>Alternative Truck Configurations with One 53-Foot Semitrailer</u>

1. Five-Axle, Tractor-Semitrailer Combination (3-S2), 88,000 lbs.: The same vehicle as the Control but loaded to the gross manufacturers weight rating (GMWR) of 88,000 lbs. This configuration was identified at the outset of the study to understand the performance implications of trucks operating at the manufacturers’ gross vehicle weight rating;
2. Six-axle, Tractor-Semitrailer Combination (3-S3), 91,000 lbs.: This six-axle, 91,000-lb. configuration was selected to evaluate a six-axle truck that complies with the Federal Bridge Formula. (See Box 2 for description of the Bridge Formula.)
3. Six-axle, Tractor-Semitrailer Combination (3-S3), 97,000 lbs.: A tractor-semitrailer configuration with a three-axle tractor and a three-axle semitrailer (hence 3-S3) and a GVW of 97,000 lbs. This configuration was selected because of the reference to analyzing the impacts of a six-axle truck in Section 32801, and the 97,000-lb. weight was identified due to Congressional interest (U.S. House of Representatives Bill HR 612, as introduced in the 113th Congress in 2013).

Box 8. (continued)

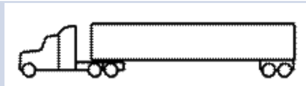
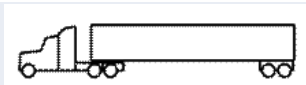
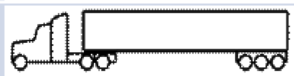
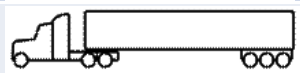
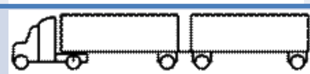
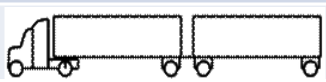
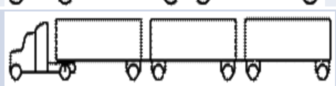
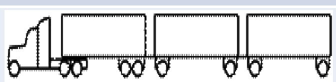
Control Vehicle for Combinations with More Than One Trailer: A tractor with twin 28.5-ft. trailers weighing 80,000-lbs. This standard configuration is in widespread use. Like the control vehicle for single trailer combinations described above, this vehicle is used to provide "baseline" data in the comparative analyses and is defined as an STAA vehicle that meets current Federal size and weight limitations.

Alternative Configurations with More than One Semitrailer/Trailer

4. Twin 33-ft. trailers, 80,000-lbs. (2-S1-2): A configuration with two twin trailers, each 33-foot long and a GVW of 80,000 lbs. This combination was selected because of the strong interest expressed by carriers specializing in Less-Than-Truckload (LTL) shipments. This is the only alternative configuration not currently in general use in the United States. (During the analysis phase of the Study it was learned that FedEx is piloting this configuration on the Florida Turnpike.)
5. Triple 28.5-ft. trailers, 105,000 lbs. (2-S1-2-2): A triple-trailer configuration with three 28.5-foot trailers, seven axles, and a GVW of 105,000 lbs. This combination was selected because of the high level of interest from diverse Stakeholders.
6. Triple 28.5-foot trailers, 129,000 lbs. (3-S2-2-2): The triple-trailer configuration with three 28.5-foot trailers and a GVW of 129,000 lbs. It was selected to evaluate the upper GVW limit allowed to operate under the "ISTEA Freeze" discussed in Box 2.

Table 4 shows the vehicles that would be allowed under each scenario as well as the current vehicle configuration from which most traffic would likely shift (the control vehicle).

Table 4. Truck Configurations and Weights Scenarios Analyzed in the Study

Scenario	Configuration	Depiction of Vehicle	# Trailers or Semi-trailers	# Axles	Gross Vehicle Weight (pounds)	Roadway Networks
Control Single	5-axle vehicle tractor, 53 foot semitrailer (3-S2)		1	5	80,000	STAA[1] vehicle; has broad mobility rights on entire Interstate System and National Network including a significant portion of the NHS
1	5-axle vehicle tractor, 53 foot semitrailer (3-S2)		1	5	88,000	Same as Above
2	6-axle vehicle tractor, 53 foot semitrailer (3-S3)		1	6	91,000	Same as Above
3	6-axle vehicle tractor, 53 foot semitrailer (3-S3)		1	6	97,000	Same as Above
Control Double	Tractor plus two 28 or 28 ½ foot trailers (2-S1-2)		2	5	80,000 maximum allowable weight 71,700 actual weight used for analysis[2]	Same as Above
4	Tractor plus twin 33 foot trailers (2-S1-2)		2	5	80,000	Same as Above
5	Tractor plus three 28 or 28 ½ foot trailers (2-S1-2-2)		3	7	105,500	74,500 mile roadway system made up of the Interstate System, approved routes in 17 western states allowing triples under ISTEA Freeze and certain four-lane PAS roads on east coast[3]
6	Tractor plus three 28 or 28 ½ foot trailers (3-S2-2-2)		3	9	129,000	Same as Scenario 5[3]

[1] The network is the 1982 Surface Transportation Assistance Act (STAA) Network (National Network or NN) for the 3-S2, semitrailer (53'), 80,000 pound gross vehicle weight (GVW) and the 2-S1-2, semitrailer/trailer (28.5'), 80,000 pound. GVW vehicles. The alternative truck configurations have the same access off the network as its control vehicle.
[2] The 80,000 pound weight reflects the applicable Federal gross vehicle weight limit; a 71,700 gross vehicle weight was used in the study based on empirical findings generated through an inspection of the weigh-in-motion data used in the study.
[3] The triple network starts with the network used in the 2000 Comprehensive Truck Size and Weight (CTSW) Study and overlays the 2004 Western Uniformity Scenario Analysis. The LCV frozen network for triples in the Western States was then added to the network. The triple configurations would not have the same off network access as its control vehicle, the 2-S1-2, semitrailer/trailer (28.5'), 80,000 pound GVW. Use of the triple configurations beyond the triple network would be limited to that necessary to reach terminals that are immediately adjacent to the triple network. It is assumed that the triple configurations would be used in Less-Than-Truck Load (LTL) line-haul operations (terminal to terminal). As a result, the 74,454 mile triple network used in this Study includes: 23,993 mile network in the Western States (per the 2004 Western Uniformity Scenario Analysis, Triple Network), 34,802 miles in the Eastern States, and 15,659 miles in Western States that were not on the 2004 Western Uniformity Scenario Analysis, and the Triple Network used in the 2000 Comprehensive Truck Size and Weight Study (2000 CTSW Study).

Six different scenarios, each involving one of the alternative truck configurations, were developed to see what the likely results would be if an alternative truck configuration were allowed to operate on a specified highway network. The study focus areas used these scenarios as a framework for simulating or modeling the performance of an alternative truck configuration in comparison to a control vehicle that meets the current Federal size and weight standards. Each scenario includes one alternative truck configuration, the network on which it would operate if allowed, and the access assumptions off that network. In general, the scenarios' alternative truck configuration uses its control vehicle's nationwide network and access rules with the exception of the triple truck configuration, which has a restricted network and access rules.

As shown in **Table 4**, the Network and access off the Network are the same for both control vehicle and the specific alternative vehicle configuration examined in Scenarios 1 through 4. However, the network for the two triple combinations in Scenarios 5 and 6 is more limited than for its control vehicle, as the existing triple network used for modeling is limited to the Interstate System, the current Western State highways allowing triple trailers, and some four-lane non-Interstate highways in the East. In addition, it is assumed that the triple-trailer configurations would have limited off-network access to terminals located just off the highways.

The first three scenarios would allow heavier tractor semitrailers than are generally allowed currently under Federal law. Scenario 1 would allow a (3-S2) five-axle tractor-semitrailer to operate at a GVW of 88,000 lbs. while Scenarios 2 and 3 would allow (3-S3) six-axle tractor semitrailers to operate at GVWs of 91,000 and 97,000 lbs., respectively. The control vehicle for these scenario vehicles is the (3-S2) five-axle tractor-semitrailer with a maximum GVW of 80,000 lbs. This is the most common vehicle configuration used in long-haul, over-the-road operations and carries the same kinds of commodities expected to be carried in the scenario vehicles.

Scenarios 4, 5, and 6 examine vehicles that would serve primarily less-than-truckload (LTL) traffic that currently is carried predominantly in (3-S2) five-axle tractor-semitrailers and (2-S1-2) five-axle twin trailer combinations with 28 or 28.5-ft. trailers with a maximum GVW of 80,000 lbs. Scenario 4 examines a (2-S1-2) five-axle double trailer combination with 33-ft. trailers that have a maximum GVW of 80,000 lbs. Scenarios 5 and 6 examine triple-trailer combinations with 28.5-ft. trailer lengths and maximum GVWs of 105,500 lbs. (2-S1-2-2) and 129,000 lbs. (3-S2-2-2), respectively. The five-axle twin trailer with 28-ft. trailers is the control vehicle for Scenarios 4, 5, and 6.

Once the scenarios were identified, and in order to assure consistency and uniformity across the five study areas, the task of preparing estimates of potential freight diversions from one truck configuration to another or truck/other modes diversions as compared to the base case was undertaken for each scenario. For example, there could be freight diversions from one truck configuration to a different truck configuration. There might be changes in the distribution of operating weights for different truck configurations, and there might also be diversions from rail to truck. These scenario freight diversion estimates were used in evaluating impacts for each of the five task areas.

For analytical purposes, the triple trailer combinations in Scenarios 5 and 6 are assumed to be restricted to about 74,500 miles of Interstate and other principal arterial highways. Access off this network to terminals and facilities for food, fuel, rest, and repairs is assumed to be restricted to a maximum of two miles. These restrictions recognize that the length, stability, and control properties of triples may make them unsuitable for travel on roads with narrow lanes or restrictive geometry.

Analyses from the *2000 Comprehensive Truck Size and Weight (CTSW) Study* and the *2004 Western Uniformity Scenario Analysis* report, combined with the vehicle stability and control analysis for slow-speed off-tracking in the study, provide the basis for the Scenarios 5 and 6 triple network and access off the network, as shown in **Table 4**.

Study Process and Methodology

USDOT determined early on that the study would be conducted as an objective, transparent, and data-driven initiative using the most current, best suited analytical methods, tools, and models. To this end, the study Process described below was set in place to ensure that these characteristics were applied to the study technical work. Plans and procedures were established and applied across the project, in terms of public input, peer review, guidelines to apply when necessary to use commercial or proprietary data, and project planning. The purpose was to ensure that the best available data, models, and analytical tools were used to answer relevant questions.

To provide overall direction, a USDOT Policy Oversight Group (POG), with representatives from USDOT operating administrations with relevant jurisdiction, was established to guide the overall process on an on-going basis from the beginning, including the technical work discussed here. Representatives from each of the following USDOT Operating Administrations serve on the POG:

- Federal Highway Administration (FHWA) has the lead responsibility for the study
- Federal Motor Carrier Safety Administration (FMCSA)
- National Highway Traffic Safety Administration (NHTSA)
- Maritime Administration (MARAD)
- Federal Railroad Administration (FRA)
- Bureau of Transportation Statistics (BTS)
- The Office of the Secretary of Transportation (OST)

USDOT's approach to managing the technical aspects of the study was to form a Technical Oversight Committee (TOC), a group of subject-matter-experts with expertise directly relevant to the work being conducted to complete the study. On a day-by-day basis, the TOC oversaw the technical work, and on-going reviews of study products. The TOC also helped craft statements of Work to procure contractor services. In addition to FHWA, FMCSA, FRA, and NHTSA have representatives on the TOC.

Public Involvement and Transparency of Information

Engaging stakeholders and other interested members of the public has been a key part of the study process. Public outreach efforts have been guided from the early days of the project by a stakeholder outreach and engagement plan aimed at ensuring that diverse communities with a view on Federal truck size and weight limits had opportunities to register their positions at key junctures during the study. Goals stated for public involvement included:

- Interpreting and understanding critical issues and elements desired by stakeholders;
- Offering stakeholders the opportunity to recommend models and data that would beneficially contribute to the study as well as prior work relevant to the work being undertaken to complete the study;
- Providing stakeholders with opportunities to participate in the study as appropriate, including defining scenario configurations for evaluation and helping stakeholders understand the potential impacts and opportunities of changes to TSW limits (study, project management plan).

USDOT held three outreach sessions with interactive public access available through the Internet or on the telephone. In May 2013, prior to the commencement of the technical analysis and modeling work activities, a "listening session" was conducted at the USDOT Headquarters building for people wishing to attend in person. This session was also made available to the public as an interactive webinar. As indicated above, this gave participants an opportunity to share their thoughts on alternative configuration vehicles that should be included in the study, and at least two of the proposed configurations were selected based on this input.

In addition to the alternative configuration discussion, a breakout session on data, modeling and methodology prompted 120 comments from people attending in person as well as 45 additional comments from the webinar attendees on which project staff followed up. The session was divided into several rooms each covering the one of the following topics: pavement impacts, bridge impacts, modal shift, safety, and compliance and enforcement,

Two additional public input sessions were conducted during the course of the technical work: in December 2013 and in May 2014. At the December 2013 webinar session, the public was briefed about the rationale behind decisions for selecting the alternative configurations; the networks to examine; and the methods, data and modeling approaches to be used, all of which were influenced by the public comment process. Desk scan activities were also discussed. At the May 2014 meeting, the USDOT study team provided stakeholders and the public with an update on the status of the study, focusing on issues of concern to the public on the basis of prior input sessions, and presented a review of progress in each study area. USDOT solicited and received comments at each of these sessions and afterwards. For example, approximately 154 comments, questions, and recommendations were made by stakeholders at the December 2013 public input session and were subsequently evaluated for inclusion in the technical work. Similarly, the May 2014 session received 38 comments that were evaluated for inclusion in the study.

Transparency was a key objective in the study process; for example, all contract and subcontract personnel working on the project in support of USDOT were identified by name and affiliation on the study page on the FHWA Web site: (http://ops.fhwa.dot.gov/freight/sw/map21tswstudy/outreach/ publicimput052913.htm). Project plans and desk scans for each of the five study focus areas also were posted on the Web site, and public comment was encouraged throughout the study. A docket was created and made publicly available hosting written comments submitted by stakeholders and interested parties. Comments were invited throughout the project with an e-mail account set up for receiving input at any time from stakeholders and interested parties.

FHWA also contracted with the National Academy of Sciences to form a Peer Review Panel to conduct an independent review of the Desk Scan Reports and the Technical Reports.

Technical Analysis Approach

USDOT identified the five study focus areas, specified in Box 3, at the outset of the project. The topics were selected to ensure that all seven topic areas identified in MAP-21 would be addressed in the study. One of the topic areas, modal shift, encompasses more than one of the topic areas in the law, and the safety topic includes the international safety comparisons required in the law.

USDOT procured contractor services to assist in completing the data collection and technical work needed to conduct the modeling and analysis required to develop the technical results to complete the study. A request for technical proposals was issued to pre-qualified indefinite demand/indefinite quantity contract holders asking firms qualifying in this area to specify in detail how they would conduct the work for each of the five study focus areas.[11]

CDM Smith successfully competed for the contract to provide the technical and analytical support. Under the contract with FHWA, CDM Smith committed to:

- Conduct the data collection and technical and analytical work required to complete the study;
- Generate results from the completion of the technical work in each of the study's five areas of investigation;
- Produce a Compiled Technical Report (of which this report is a Volume I) for USDOT to consider as a basis for its Report to Congress; and
- Support and assist in the delivery of public input sessions.

[11] The indefinite demand/indefinite quantity (IDIQ) contracting approach was used. Such IDIQ contracts are competed as full and open under Federal Acquisition Regulations (FAR). Firms selected for IDIQ awards compete for subsequent proposals in the areas in which the Government has found them to be qualified.

Project teams, consisting of subject matter experts in areas germane to the specific study topics, were proposed for each analysis area. The contractor also provided information on previous work by these experts so USDOT could determine the team's qualifications and ability to complete the work. Over 45 subject matter experts carried out the study, which was conducted by the successful bidder with additional expertise secured by subcontracts with individuals at universities, research institutions, and other consulting firms.

The USDOT study team made extensive efforts to determine that each project team member was unbiased. All project team members committed to forego any other truck size and weight work during the course of the project. The contractor established a review process to evaluate each team member for indicators of bias.

Desk Scans

The USDOT study team conducted a review of relevant worldwide research pertinent to the specific subject area. The purpose of these "desk scans" was to identify the most relevant and current data, useful methodologies, and most important studies available. The desk scans were also intended to identify the most important past studies, such as prior USDOT truck size and weight studies, and analyses carried out by the Transportation Research Board (TRB) of the National Academies of Sciences pertinent to the specific topic. Relevant materials from the desk scans helped to shape the project plans for each of the five study areas. Once desk scan reports for each of the five study areas were completed, they were posted to the study Web site and input was sought. In addition, a panel of experts from the TRB reviewed these desk scans for relevancy and inclusiveness (see Peer Review on page 30 below for further discussion).

The initial desk scan reports were updated after their initial release to the public to address comments shared by the NAS Peer Review Panel and to reflect the information and reports shared by Stakeholders and the public throughout the course of the project. Based on recommendations provided in the Peer Review Panel's Report #1, several actions were taken to address these recommendations (see Peer Review section for a more thorough discussion of the Peer Panel and how recommendations were addressed).

Study Focus Area Project Plans

Relying in part on the results from the desk scans, a detailed individual project plan and schedule was developed for each of the five study areas to guide the work. In some study areas, the technical work was divided into subtasks carried out concurrently, with sub-topic plans prepared and incorporated into the overall project plan. These plans identified the questions to be addressed, the general approach to be taken, the specific methodology to be employed, and the schedule for completion of tasks. The draft project plans were posted on the study Web site, and public comments were received and considered. The individual project plans for each study task are discussed in greater detail in **Chapter 3** below.

<u>Role of Data and Modeling in the Technical Analysis</u>

As noted earlier, USDOT determined at the outset that the study would be data driven and would use modeling and other technical analytical approaches best suited to a particular topic. The study team used a wide range of data sets, most of which are publicly available from USDOT or State agencies, including, among others:

- State-submitted data through FHWA's Highway Performance Monitoring System (HPMS) and Traffic Monitoring Program;
- FHWA's Freight Analysis Framework (FAF);
- Rail-based data available on the Surface Transportation Board's Carload Waybill Sample to measure the impact that "alternative truck configurations" have on rail operations;
- FHWA's Long-Term Pavement Performance (LTPP) data, supplemented by data needed to meet the input requirements of the Mechanistic-Empirical Pavement Design Guide (M-EPDG) software of the American Association of State Highway and Transportation Officials (AASHTO);
- Data models previously constructed by State DOTs for 490 bridges in order to operate the analysis using the AASHTO's Bridge Rating Program;
- Compliance and enforcement data submitted by the States through annual certifications and state enforcement plans submitted to FHWA.
- Data needed to operate the TruckSims™ software for vehicle stability and control analysis of the "alternative truck configurations;"
- Violation and Inspection information maintained by FMCSA's Motor Carrier Management Information System (MCMIS) database.

Several limitations in available data sets exist. For example, weigh-in-motion (WIM) data availability is an important aspect of completing truck size and weight comparative assessments. WIM data coverage for the Interstate System was adequate to complete the analyses included in the various areas of Study. WIM data availability on the non-Instate National Highway System was insufficient. In certain areas of the study, the lack of sufficient WIM data for the NHS presented itself as a significant limitation on the work completed. In the safety assessment area of the study, State crash reports do not include information on the GVW or vehicle configuration (for example, number of axles or number of cargo carrying units) information. This precluded development of an adequate comparative assessment of the various scenario vehicles which are defined by gross weight and configuration. In conducting the comparative assessment of violations and citations, GVW provided on the Federal Motor Carrier Safety Administration's Motor Carrier Management Information System (MCMIS) could not be used due to variations on how the States reported this data element.

Data Acquisition Technical Analysis Plan

A data acquisition and technical analysis plan was developed providing common guidelines for data/model accessibility and data custody, and also a generic data agreement to use where proprietary or confidential data were needed to conduct the study. (Table 5 shows these guidelines.) The data plan also describes the key data sets to be used and the technical analysis methods (including analytical models) in each study task or subtask, and the sources for each data type.

While each of the five study areas used subject-area specific datasets, the entire study analysis for the five technical reports (safety, pavement, bridge, compliance, and modal shift) shared a common set of data for the base case as well as for the six scenarios. The common data is vehicle miles of travel (VMT) for the base case in 2011. The base case VMT (reflecting the current fleet's use of the highway network system) was used to estimate the change in VMT for each of the alternative truck configurations (six scenarios) introduced into the existing fleet. Modal shift analysis included both shifts between the truck and rail modes, and shifts in vehicles and operating weights within the truck mode.

Table 5. Study Data/Model Accessibility and Data Custody Guidelines

Data/Model Accessibility Guidelines	▪ **In Summary –** The study data/models used to conduct analysis will be available to USDOT and third parties. The availability of some data/models may have specific requirements: usage agreement specific to the study only, usage fee to vendor, and compliance with a non-disclosure agreement (NDA) or data agreement (DA). ▪ **Safety Carrier Data –** Proprietary individual carrier safety data will be available under a NDA/DA and will not be available to the USDOT and third parties. The individual carrier data will be blended for use in the safety analysis. This blended database will be available to the USDOT and third parties, per the NDA/DA requirements. ▪ **Truck Flow Data –** The truck flow data used will be a county-to-county disaggregation of USDOT's FAF database that will be available to third parties. ▪ **Vehicle Stability and Control Model –** The vehicle stability and control (VSC) analysis will use the commercially available TruckSim® model. The TruckSim® model is available to third parties for a fee. ▪ **Truck Cost Data –** The proprietary truck cost data used will be made available to USDOT and third parties.
Data Custody Guidelines	▪ **Safety Carrier Data** - Proprietary individual carrier safety data will have an established and documented path of communication and control between the carrier and project team. The study team will keep custody of the carrier data per an NDA/DA (between the carrier and the study team) with direct transfer of the individual carrier data between the carrier and the study team. The University of North Carolina (UNC) and the individual carrier will be parties to a NDA/DA for usage and handling of the carrier safety data. The study team will not share the names of the individual carriers outside of the study team. ▪ **Truck Cost Data –** An NDA/DA between the vendor and FHWA limits the geographic detail of rate data.

Box 9. Data Used Involving a Non-Disclosure Agreement (NDA) or Usage Fee

While most data used in the Study are readily available for examination at no cost to the public or third parties, there are a few exceptions.

Safety Carrier Data – Some individual carriers made proprietary safety data available to the Study under an NDA. Under this NDA, the names of the individual carriers and the data will not be available to the USDOT and third parties. As discussed in Section 3, the individual carrier data was blended for use in the safety analysis. This blended database is available to the USDOT and third parties, as allowed under the NDA/DA requirements.

Truck Flow Data – The truck flow data used by the Study will be a county-to-county disaggregation of USDOT's Freight Analysis Framework database that will be available to third parties.

Vehicle Stability and Control Model – The vehicle stability and control (VSC) analysis used the commercially available TruckSIM® model. The TruckSIM® model is available to third parties for a fee with a NDA/DA.

Pavement Analysis Model – The pavement cost analysis task used the AASHTOWare Pavement ME Design® model, which is commercially available from the American Association of State Highway and Transportation Officials for an annual license fee.

Confidential Waybill Sample – In cases where rail flow data from the USDOT Surface Transportation Board (STB) confidential waybill sample is used for the rail traffic impact analysis, STB's standard NDA governing the restricted use of the data will apply. These data were acquired with USDOT Federal Railroad Administration's cooperation. Third parties wishing to see this data will have to request the data directly from the STB.

Peer Review

USDOT engaged the National Academy of Sciences (NAS) to provide an independent, objective peer review of the desk scan reports (literature reviews) and the compiled technical report. The peer review process was an important element in developing and completing the study. The National Academy of Sciences selected a well-balanced peer review panel, chaired by Dr. James Winebrake of Rochester's Institute of Technology and 15 experts from both the private and public sectors and from academia to conduct the reviews. The USDOT Technical Oversight Committee (TOC) met with the panel in December, 2013, to brief the panel on the contents of the desk scan reports. In April 2014, the TOC presented the data, models, and approach for completing the work needed to finalize the compiled technical report. Assumptions applied in each study area and limitations imposed on the technical work due to data availability or modeling capacity were also presented to the Panel at that meeting.

The peer review panel released its Report #1 on the desk scan reports for each of the five study areas in early April 2014. The Report reviewed the thoroughness of the literature search, analysis of existing models and data for conducting the study, and the overall synthesis of previous research as it relates to the present Study. The report noted:

- Desk scans are a logical step in conducting a study where significant prior work has been completed.
- No superior models and data sets were omitted.
- A synthesis of models and data used in previous research needs to be prepared to strengthen the case for models and data used in the study.
- The linkage between the desk scan reports and the project plans needs to be strengthened.

As a result of the findings, a comparison of results report and linkage report were prepared. The comparison of results report identifies models, data, and results produced in prior related studies and evaluates the relevancy of the results to the results produced under this Study. The Linkage Report shows how previously completed similar work was considered and, in some cases, used at a starting point for the work conducted under this Study. Also, the Desk Scan Reports were updated to show how studies not included in the original Reports were considered during the operation of this Study. The Peer Review Panel's recommendations on studies that should be included in the various Desk Scans are included in the revised Reports. More detailed information on the NAS Peer Review Panel and its work is available at http://www8.nationalacademices.org/cp/projectview.aspx?key=49568

The peer review panel will review the compiled technical report, including this summary, shortly. USDOT will schedule a meeting to present the report to the panel.

Changes in Methodology from Prior Studies

Several methodological changes characterize this Study in comparison to prior truck size and weight studies. It uses the FHWA's FAF, a more refined data set for assigning vehicles to freight corridors, more advanced models to assess truck impacts on pavements and on bridges, and a careful examination of modal shift impacts on short-line and regional railroad operations caused by the introduction of the scenario vehicles. Also, a unique feature in the approach for completing highway safety and truck crash analysis was to simultaneously analyze truck safety on three tracks: State crash data analysis, corridor-based crash analysis, and fleet-based crash data analysis.

FAF: FHWA's Freight Analysis Framework data set was not available for use in prior comprehensive truck size and weight studies. FAF integrates data from several sources to provide more detailed estimates of freight movement among States and major metropolitan areas by all modes of transportation. For the study, the FAF was disaggregated to the county level, which allows analysis of certain configurations on limited highway networks. The FAF data were used in the Intermodal Transportation and Inventory Costing (ITIC) Model to estimate modal shifts that were then used to estimate changes in truck VMT by configuration and weight group.

Modeling of Pavement Impacts: The pavement analysis used new pavement impact modeling software not available when prior nationwide truck size and weight studies were conducted. The software reflects an 8-year effort by the National Cooperative Highway Research Program (NCHRP) to develop a mechanistic-empirical pavement design guide. The software, available commercially as AASHTOWare™ Pavement Mechanistic-Empirical Pavement Design Guidelines (M-EPDG) software, is considered superior to prior software because it incorporates material mechanics, geo-technic considerations, stress due to hydraulic conditions, climate data, axle-load spectra, and other advances that allow more precise prediction of pavement performance.

Modeling the Impacts on Bridges: The AASHTOWare Bridge Rating® (ABrR) software was employed to complete the structural analysis of load bearing capacity of 490 representative bridges on the Interstate Highway System (IHS) and non-IHS National Highway System roadway systems. Bridge models previously prepared by 11 different State DOTs were used in completing the structural analysis work. The ABrR analytical software enabled a more precise estimate of the load bearing capacity of the bridges selected for analysis to be made and to evaluate the ability of the structures to accommodate the alternative scenario trucks versus the 80,000-lb. control vehicles.

Modal Shift Analysis on Regional and Short-line Railroads (Class II and III): It was decided that the rail component of the modal shift analysis must include impacts on Regional and Short-line Railroads. Members of USDOT and the study team met with the American Short Line and Regional Railroad Association (ASLRRA) and solicited input on establishing an analytical framework for evaluating potential mode shifts in freight traffic caused by the operation of the scenario vehicles. Access to freight pricing needed by the modal shift model is highly proprietary and the importance of the confidentiality of that data is understood by USDOT; as a result, this data was not able to be used in this study. However, consultation with ASLRRA was very instrumental in developing the estimates of mode shift of short line and regional railroad freight from the introduction of heavier, (3-S3) six-axle trucks.

CHAPTER 3 – RESULTS OF FOCUS AREA ANALYSIS

This chapter summarizes the Technical Reports conducted for the five study focus areas and briefly describes the primary results. The summaries are discussed in the following order:

- Modal Shift Analysis
- Safety Analysis
- Pavement Analysis
- Bridge Analysis
- Compliance Analysis

Each summary discusses the purpose, methodology (including data and models used), assumptions/limitations, and the technical results of each of the focus areas. In keeping with the MAP-21 legislation, the study presents results for each of the assessments outlined by Congress in §32801 of MAP-21. No conclusions or recommendations on national truck size and weight policy were developed as part of the study.

The study examines vehicles that are much closer to current Federal weight and size limits than those that were assessed in previous studies. Specifically, the study examines six alternative truck configurations in six scenarios. The first three scenarios would allow heavier tractor semitrailers than are, in some cases, allowed under current Federal law. Scenario 1 would allow five-axle (3-S2) tractor-semitrailers to operate at a GVW of 88,000 lbs., while Scenarios 2 and 3 would allow six-axle (3-S3) semitrailers to operate at GVWs of 91,000 lbs. and 97,000 lbs., respectively. Scenarios 4, 5, and 6 examine vehicles that would serve primarily less-than-truckload (LTL) traffic. Scenario 4 examines twin trailer combination trucks with 33-ft. trailers (2-S1-2) with a GVW of 80,000 lbs. Scenarios 5 and 6 examine triple-trailer combination vehicles with 28- or 28.5-ft. trailers with a GVW of 105,500 lbs. (2-S1-2-2) and 129,000 lbs. (3-S2-2-2), respectively. **Table 4** shows the six alternative truck configurations and summarizes the scenarios examined in this Study.

Modal Shift Analysis

The modal shift analysis provides the foundation for assessing a range of potential impacts associated with the truck size and weight scenarios analyzed in this Study. "Modal shift" refers to shifts in freight usage between truck and rail modes as well as across vehicle types and operating weights within the truck mode.

The purpose of the modal shift analysis is to quantify the potential nationwide impacts of changes in trucks size and weight limits. Specifically, the work conducted in the modal shift area included:

- Estimating freight shifts between trucks and between truck and other modes due to the introduction of alternative truck size and weight limits under the six scenarios examined in the study;

- Estimating other impacts from shifts in the vehicle or mode carrying freight, including energy, emissions, traffic operations; and
- Providing a framework for assessing the potential impacts if one or more of the six scenarios were implemented in terms of:
  1) The total number of trips and VMT required to haul a given quantity of freight,
  2) The transportation mode chosen to haul different types of freight between origin and destination,
  3) The truck configuration and weights used to haul different types of commodities,
  4) The costs of enforcing Federal truck size and weight limits,
  5) Energy requirements to haul the Nation's freight,
  6) Emissions harmful to the environment and to public health,
  7) Traffic operations on different parts of the highway system,
  8) Total transportation and logistics costs to move freight by surface transportation modes,
  9) The productivity of different industries, and
  10) The competitiveness of different segments of the surface transportation industry; and
- Providing data to aid in comparing the studied effects of the alternative configurations under possible modal shifts.

Modal Shift Analysis Methodology

This section summarizes the data and methods used in the modal shift analysis. The analysis begins with an estimation of current (base case) truck traffic (vehicle miles of travel) by vehicle configuration (number of trailers, number and types of axles, etc.), operating weight, and highway functional class. Data sources for base-case traffic estimates included:

- The volumes of truck traffic by highway functional class from the FHWA's Highway Performance Monitoring System (HPMS),
- The distribution of trucks by vehicle configuration from vehicle classification data collected by the States and reported to FHWA, and,
- The distribution of vehicle operating weights from weigh-in-motion (WIM) data reported to FHWA by the States.

The USDOT study team conducted a desk scan (literature search) to identify and evaluate potential analytical tools and data sources for the modal shift analysis. It revealed that data and analytical tools have improved over the past 20 years, allowing for a much more robust picture of current commodity flows across the country. Data used in this analysis are primarily from 2011, the analysis year for the study, although in some cases WIM data were supplemented by 2010 and 2012 data to provide a more robust distribution of operating weights on different highway functional classes. A summary of base case traffic is presented in *Modal Shift*

Comparative Analysis in Volume II of this *2014 Comprehensive Truck Size and Weight Study* (2000 CTSW Study).

Based on research and desk scan results, the FHWA's Freight Analysis Framework (FAF) was selected as the commodity flow database for this Study. The FAF integrates data from several sources to provide detailed estimates of freight movement among States and major metropolitan areas by all modes of transportation. One limitation of the FAF for the modal shift analysis is that origins and destinations in the database are reported for only 123 regions representing, overall, the largest markets in the country. This level of detail was too coarse for purposes of the modal shift analysis since it would not allow a detailed assessment of potential impacts of limiting the highway networks available for certain scenario vehicles. The Oak Ridge National Laboratory (ORNL) disaggregated the FAF and provided commodity flows for origins and destinations at the county level. Disaggregation of the FAF data did not produce a data set presenting higher accuracy, but this activity was a necessary step in developing data suitable for use in estimating truck-to-truck and intermodal shifts that may occur as produced in the assessment of each of the scenarios.

The analytical tool used for the modal shift analysis itself was the Intermodal Transportation and Inventory Cost Model (ITIC). The USDOT developed this model during the course of and immediately following the issuance of its *2000 Comprehensive Truck Size and Weight Study* (2000 CTSW Study), and it was used for subsequent studies by both FHWA and the Federal Railroad Administration (FRA). The ITIC model is described in detail in the *Modal Shift Comparative Analysis* report.

In general the model estimates transportation and non-transportation logistics costs for shipments of different commodities by different vehicle configurations and transportation modes between various origins and destinations. Specific costs considered in the ITIC model include vehicle operating costs, shipping rates that vary by market, and inventory carrying costs such as safety stock, cycle costs, and in-transit costs. If the costs for moves by scenario vehicles are lower than the costs for the same move in existing vehicle configurations at current size and weight limits, the move would be assumed to shift to the heavier scenario vehicle. Likewise if shipments by scenario vehicles cost less than shipments by rail, traffic would be assumed to shift from rail to truck.

In the ITIC model, railroads are assumed to respond to increased competition from more productive trucks by lowering their rates to the point where rates equal variable cost. If lowering the rates reduces total transportation and logistics costs for rail below rates for the scenario vehicles, traffic will remain on the railroads, but the contribution of those shipments to covering railroad fixed costs will be reduced.

Modal Shift Analysis Assumptions and Limitations

The USDOT study team made several assumptions when conducting the modal shift analysis:

- Cargo less than 75,000 lbs. GVW will not divert to (3-S3) six-axle tractor-semitrailers.

- Traffic currently moving as (3-S2) five-axle tractor-semitrailers that cannot benefit from the added weight allowed on a six-axle tractor-semitrailer will not shift to the six-axle vehicle.
- Carriers would not shift their entire fleets over to (3-S3) six-axle vehicles simply to increase the flexibility of their fleets.
- All scenario vehicles except triples have the same access to cargo origins and destinations as base case vehicles. In the short run, bridge or other highway improvements may have to be made before scenario vehicles could use the same routes as base case vehicles, but in the long run it is assumed that such improvements would be made. The modal shift analysis is based on this long-run assumption.
- Triple configurations operate in less-than-truckload (LTL) line haul (terminal to terminal) operations. In actuality there may be a few markets where heavy triples could be used for truckload shipments under the network and access restrictions placed on triples operations, but based on discussions with industry experts, those are believed to be localized and would have very little impact nationally.
- Equipment currently being hauled in specialized configurations such as truck-trailer combinations will not shift to scenario vehicles. Specialized configurations are used because of unique commodity characteristics that would not be met by the scenario vehicles.
- The Surface Transportation Board's (STB's) Carload Waybill Sample data were used to analyze the potential shifts from rail to truck because it includes more detailed origin, destination, and other shipment characteristics than FAF. The Waybill Sample data also includes information on rates paid for each series of moves. 90 percent of short-line carloads interline with Class 1 railroads and thus are reflected in the Surface Transportation Board's Carload Waybill Sample.
- The analysis year for the study is 2011. To the maximum extent possible all data used for the study are from 2011 or have been adjusted to reflect 2011 values.
- The analysis assumes Federal and State highway user fees on the scenario vehicles are unchanged.
- The base year for vehicle-miles-of-travel data was set at 2011. No projections of future travel levels were made since results projected for future years may impact the quality of the comparative assessments Congress outlined in MAP-21. Questions and concerns about future projections would have negative effects on the quality of the assessments completed in the study.

Several data limitations affected the analysis, including:

- The precise origins and destinations of shipments are unknown from the FAF. Origins and destinations are assumed to be county centroids[12] for inter-county shipments.

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[12] A county centroid is the latitudinal and longitudinal (i.e., geographic) center of a county. See http://opengeocode.org/tutorials/USCensus.php for more information.

- The precise routes used to ship commodities between origins and destinations are unknown. Shortest path routes between each origin and destination pair are calculated for purposes of estimating transportation costs.
- Characteristics of specific commodities within broad commodity groups may vary significantly.
- Shipment sizes and annual usage rates for freight flows between individual origins and destinations cannot be discerned from the FAF and must be estimated from VIUS and other sources. This affects non-transportation logistics costs.
- Truck/rail intermodal origins and destinations are not reported in the Carload Waybill Sample and have been estimated using the same assumptions that were used in the 2000 CTSW Study.
- Multi-stop truck moves to accumulate and/or distribute freight from/to multiple establishments are not captured in the FAF.

Such limitations are unavoidable in a nationwide study such as this. They also were encountered in USDOT's 2000 CTSW Study and in other national studies. It is not believed that these limitations affect overall study conclusions, but the limitations must be kept in mind when considering study implications.

Cost Responsibility Issue

The issue of cost responsibility often arises in connection with truck size and weight policy studies. Many truck size and weight policy options, including those examined in the current study, have highway investment implications, both in the near term and over time. These costs can be linked to changes in highway travel by different vehicle configurations at different weights as the result of the truck size and weight policy changes. Many costs including pavement and some bridge costs estimated in this study are related not just to operating weight, but also to specific axle loadings for the various vehicle classes. To estimate the responsibility of different vehicle classes for changes in highway investment requirements, the distribution of axle loadings by vehicle classes affected by introduction of the alternative configurations would have to be known. Estimates on the allocation of highway costs are conducted in the Highway Cost Allocation studies periodically prepared by FHWA and follow a methodology that identifies the cost implications of operating a wide variety of vehicle types and identifies user charges and fees paid by the vehicles studied. This Study did not extend beyond the boundary of identifying the impacts that each alternative configuration was estimated to have or identifying impacts that trucks operating above current Federal size and weight limits have on highway infrastructure and safe roadway operations. This is consistent with the comparative assessments outlined in MAP-21.

Summary of Modal Shift Analysis Results

A common set of 2011 vehicle miles of travel (VMT) data was constructed to analyze the base case and the six scenarios; this dataset also was used for assessing safety, pavement, bridge, and compliance impacts (See **Table 3** in Chapter 2). The modal shift analysis assessed the shifts between the truck and rail modes, as well as the shifts freight among base case and scenario vehicle types and operating weights within the truck mode. Estimating the impacts on railroads is particularly important as the truck and rail modes are partners in some transportation markets, but are competitors in other markets. Increasing truck productivity could have serious economic consequences not only on railroads but also on the communities they serve. Finally, the analysis also estimated how modal shifts affect energy consumption, emissions, and traffic operations.

The modal shift analysis provides the basis for assessing the range of potential impacts associated with the truck size and weight scenarios analyzed in this Study. These various impacts are discussed in each of the five technical reports in Volume II. Impacts are quantified to the greatest extent possible.

The modal shift analysis comprised the following elements:

- Developing a detailed project plan describing how the modal shift analysis was conducted using analytical tools and data identified during research and through the desk scan.
- Estimating truck traffic currently operating within and above existing Federal truck size and weight regulations.
- Specifying truck size and weight scenarios for analysis in the study. The basic vehicle configurations to be analyzed in the study were identified by USDOT, but specifications for those vehicles and how they would operate were developed for use in the various study tasks.
- Developing assumptions necessary for the modal shift analysis and identify limitations in the data and analytical methods that will affect the analysis.
- Estimating modal shifts associated with each scenario using the analytical tools and data chosen for the analysis.

In **Table 6,** a summary of the impacts is presented for each scenario on total truck VMT required to haul freight included in the 2011 FAF, the cost of moving that freight, and the impact of shifts from rail to truck on railroad profitability. As would be expected, impacts on VMT generally vary with the allowable GVW assumed in each scenario. Percentage changes in VMT reflect changes in VMT from the base case to the scenario size and weight limits for those vehicle configurations affected by each scenario. They do not reflect the percentage change in total VMT or total truck VMT, both of which would be much smaller than the percentage changes in VMT for just those truck configurations affected by the size and weight limits used in each of the scenarios. In terms of cargo tonnage that shifts from base case configurations to scenario configurations, the vast majority of the shifts occur among truck types rather than from rail to truck. Scenarios 1, 2, and 3 affect more tonnage because they primarily affect the movement of bulk commodities while Scenarios 4, 5, and 6 only affect LTL shipments.

Changes in total logistics costs and railroad contribution were much higher for Scenarios 1, 2, and 3 than for Scenarios 4, 5, and 6. Transportation costs are relatively higher for the bulk commodities most affected by Scenarios 1, 2, and 3, and there are few, if any, savings in non-transportation logistics costs associated with changes in the sizes of vehicles used to haul less-than-truckload freight. The greatest reduction in total logistics costs was associated with Scenario 3, where costs decreased by over $13 billion.

Table 6. Scenario Impacts on VMT, Total Logistics Costs, and Railroad Revenue: 2011

Scenario	Change in VMT (millions)	Quantity of Freight Shifted (000s of tons)		Change in Total Logistics Costs ($ millions)	Change in Railroad Contribution ($ millions)
		From Truck	From Rail		
1	-861 (-0.6%)	2,658,873	2,345	-5,749 (-1.4%)	-197 (-1.1%)
2	-1,200 (-1%)	2,622,091	2,311	-5,655 (-1.4%)	-196 (-1.1%)
3	-2,878 (-2%)	3,197,815	4,910	-13,193 (-3.2%)	-562 (-3.1%)
4	-2,953 (-2.2%)	578,464	1,473	-2,326 (-6.3%)	-22 (-0.1%)
5	-1,896 (-1.4%)	716,838	2,374	-1,901 (-5.1%)	-17 (-0.1%)
6	-1,944 (-1.4%)	716,838	2,363	-1,971 (-5.3%)	-15 (-0.1%)

The percentage change in total logistics costs (transportation and non-transport logistics costs) for Scenarios 1, 2, and 3 is based on a comparison of total logistics costs associated with moving all traffic in the configurations affected by each scenario to total transportation and non-transport logistics costs associated with hauling the same traffic at the size and weight limits for each scenario. Changes in total logistics costs for Scenarios 4, 5, and 6 are calculated differently because those scenarios are assumed to apply only to LTL traffic. Total logistics costs associated with moving all LTL traffic both by truck and by rail in the base case are compared with total logistics costs associated with moving the same traffic under the size and weight limits assumed for each scenario. For all scenarios, the percentage change in railroad contribution reflects the difference between total revenues and total freight service expense. This contribution represents the amount available to cover fixed cost, income taxes, shareholder profits and capital investment to improve and maintain the system. The negative values indicate that net revenues fell more than freight service expense.

Stakeholders have expressed concerns about the potential impacts of changes in truck size and weight limits on short line railroads. Short lines provide regional/intrastate rail service, 90 percent of which connects to the larger Class 1 railroads. Data on short line operations in the Carload Waybill Sample are limited, but most commodities hauled by short lines are moved in carload quantities that would only be affected by the truck size and weight changes analyzed in Scenarios 1, 2, and 3. Using the same general methods that were used to analyze impacts to Class 1 railroads, estimates produced through the analysis indicated that short line railroads would lose between 1 and 4 percent of total revenue under each of Scenarios 1, 2, and 3. Revenue losses under Scenario 3 would be somewhat greater than those under Scenarios 1 and 2. Losses for some individual short line railroads could be greater. Although the analysis identified waybills that diverted under Scenarios 4, 5 and 6, due to data constraints with the reported revenue, the results were not included in the analysis.

As shown in **Table 7,** scenario impacts on energy consumption, emissions, and traffic operations reflect the reduced VMT presented in **Table 6.** Percentage changes in fuel consumption, carbon dioxide (CO_2), and nitrogen oxides (NO_x) were calculated in the same way that changes in VMT were calculated: changes in base-case fuel consumption and emissions for the vehicle configurations affected by each scenario were compared to fuel consumption and emissions for those same vehicles under the assumed size and weight limits for each scenario. Congestion costs decreased under all scenarios, reflecting changes in the relative VMT for each scenario. Congestion cost savings ranged from $256 million in Scenario 1 to $875 million in Scenario 4. The percentage change in congestion cost is estimated by comparing congestion costs for all vehicles operating on the highway under base case size and weight limits to congestion costs for all vehicles assuming the scenario size and weight limits. Impacts on congestion are not limited just to the vehicles whose VMT is affected by each scenario, but they accrue to all vehicles in the traffic stream. It should be noted that reductions in VMT calculated by the model due to the introduction of alternative configurations are very short in duration. It is estimated that these reductions will be offset by reasonably expected VMT increases in about 1 year.

Table 7. Scenario Impacts on Energy Consumption, Emissions, and Traffic Operations: 2011 (Millions)

Scenario	Change in Fuel Consumption (gallons)	Change in CO_2 Emissions (kilograms)	Change in NO_x Emissions (grams)	Change in Congestion Costs ($ millions)
1	-107 (-0.5%)	-1,086 (-0.5%)	-406 (-0.5%)	-256 (-0.02%)
2	-109 (-0.5%)	-1,107 (-0.5%)	-414 (-0.5%)	-358 (-0.03%)
3	-309 (-1.4%)	-3,138 (-1.4%)	-1,175 (-1.4%)	-857 (-0.08%)
4	-244 (-1.1%)	-2,483 (-1.1%)	-929 (-1.1%)	-875 (-0.08%)
5	-233 (-1.1%)	-2,366 (-1.1%)	-886 (-1.1%)	-505 (-0.05%)
6	-230 (-1.1%)	-2,343 (-1.1%)	-877 (-1.1%)	-525 (-0.05%)

Key: CO_2 = carbon dioxide; NO_x = nitrogen oxides.

Safety Comparative Analysis

This section summarizes the approaches and methods used and the results of the *Highway Safety and Truck Crash Comparative Analysis* in Volume II of this 2014 CTSW Study. The comparative analysis explores the differences in safety risk and truck crash frequency between truck configurations currently operating on the Nation's roadways at and below current Federal limits to those operating above such limits. The safety analysis also compares crash frequency and severity associated with base-line control vehicles with the six alternative truck configurations shown in **Table 4** (page 22).

To determine these safety impacts, three different analytical approaches were pursued: 1) crash-based analyses; 2) vehicle stability and control analyses; and, 3) safety inspection and violations data analyses. The use of multiple approaches provides a richer understanding of the safety performance of the current and alternative truck configurations examined in this Study, particularly in light of the crash data uncertainties discussed below. Each of the three approaches has its own advantages and limitations, but the results of the safety task analysis provide a broad picture of the potential safety implications of changes to the current Federal truck size and weight limitations.

Central to the approach was the recognition that Federal size and weight limits (e.g., 80,000 lbs. GVW)[13] apply to trucks operating on the Interstate Highway System and are frequently supplanted by grandfathering clauses and other statutory provisions that allow the legal operation of vehicles exceeding the Federal limits. In addition, State weight limits that apply to trucks traveling off the Interstate System differ from the Federal limits in several cases. These exceptions to national weight limits were considered in designing an approach and methodology that sought to analyze and compare 80,000-lb. control vehicles that operate on most U.S. roads with vehicles weighing more than 80,000 lbs. that operate on a more limited set of U.S. roads.

To ensure a consistent comparison, the study teams used the same data years for analysis, where possible (i.e., 2008 to 2012) and multiple sources of information were sought to reflect accurately the safety performance of the control and alternative configurations on the highway systems noted in **Table 4**. The main focus of the safety analyses was to estimate the changes in safety for each of the scenarios for multiple functional roadway classifications.

There were several challenges to producing nationally representative estimates of changes in truck safety associated with the scenarios in **Table 4:**

- Due to a lack of truck weight data for individual trucks in crash databases, the project team found it necessary to compare groups of control and alternative trucks based on the number of axles on the vehicle rather than comparing vehicles at specific weights (e.g., crash rates for an five-axle, 80,000-lb. 3-S2 control vehicle compared to crash rates for a six-axle 97,000-lb. 3-S3 configuration).
- Data limitations in annual average daily traffic (AADT) and WIM data restricted the crash analysis to rural and urban Interstates. These data limitations did not affect the vehicle stability and control and inspection and violation analyses.

[13] Although Title 49 (Transportation) of the Code of Federal Regulations differentiates between the gross weight of single vehicles [Gross Vehicle Weight (GVW)] and combination vehicles [Gross Combination Weight (GCW)], Title 23 (Highways) only refers to vehicle weights. Because this Study addresses truck size and weight assessments, it uses the term GVW to refer to the gross weight of combination vehicles.

- Most State crash databases lacked the data elements needed to identify the configuration of the truck (e.g., 3-S2). As a result, the State crash analysis and the development of crash estimates for Scenarios 2, 5, and 6 were based on configuration data from only one State, while Scenario 3 was based on data from only two States. Scenario 1 could not be analyzed due to the lack of truck weight in the crash data and Scenario 4 could not be analyzed since that alternative truck configuration did not currently begin its limited operations in the United States until very recently and thus does not have sufficient data for analysis.
- Due to the limited number of States with suitable data, the analysis of crash rates cannot be extended to other States or be used to draw meaningful conclusions on a national basis.
- In light of the lack of truck weight data on State crash reports, it was not possible to complete a comparative assessment between trucks operating at and below current Federal limits and trucks that operate above those limits.

Each of these challenges and their implications are discussed further in the *Highway Safety and Truck Crash Comparative Analysis* technical report.

Crash Analysis

The analysis focused on estimating the changes in crash rates for the control and alternative configuration vehicles on the roadway networks described in **Table 4**. The crash rate analysis was conducted using crash data from actual operations on U.S. roads, to the extent possible. The data included police-reported crash data in State files, crash information collected by trucking companies, and truck exposure data developed from different sources. The road safety profession has stated that analysis of crash, injury, and fatality data are, in fact, the definition of "safety analysis" (AASHTO 2010 and TRB 2011).

Crash Analysis Methodology

The crash analysis relied on State-based data (e.g., number of axles and trailers) that were combined to infer vehicle configuration in crash and exposure data.

A detailed review of crash databases from 15 States that allow the operation of six-axle heavy semitrailers and 17 States that allow the operation of triple-trailer combination vehicles indicated the absence of one or more of the needed data variables for the analysis. The lack of data describing the weight of the truck involved on State crash reports was the most persistent problem found. State crash data included no information on truck weight; fleet data from carriers were only slightly better. This meant that the only weight data available were the allowable GVW limits for different vehicle configurations within a given State (e.g., the maximum allowable GVW for a triple-trailer configuration). These weight limits were used to define groups of vehicles that could be compared within a State, effectively representing the comparisons shown in **Table 8**. When the potential States were limited to those where the maximum GVW limits for both the control and alternative vehicle configurations closely matched one of the above scenarios and were then further limited to those that included trailer and axle counts in the crash data, only four States could provide the needed data—Kansas, Idaho, Michigan, and Washington. The *Highway Safety and Truck Crash Comparative Analysis* technical report describes in detail the process undertaken to review State crash data for suitability in the study. Because of the State database limitations, Scenario 1 could not be conducted with crash data (i.e., the control and alternative vehicle can't be differentiated in any State-based crash data set). Additionally, no crash data were available for the alternative configuration in scenario 4 as that vehicle type is not currently in wide use on U.S. roads.

All comparisons were conducted of configurations operating within the same State because State reporting practices and data records vary widely, making comparisons combining States inappropriate. Crash data also were obtained and used from three fleets operating triple-trailer combinations and from fleets operating six-axle semitrailer configurations above 80,000 lbs. but were insufficient for full analysis due to the small sample size. The carriers had difficulty in providing the exposure data for fleet-owned trucks in the selected States for the requested years. The primary difficulty was that carriers were not accustomed to analyzing safety based on road segment of travel, so their information systems could not readily supply the data requested. Crash report data and aggregate exposure data from some carriers was received. These data enabled the calculation of aggregate crash rates for triple trailer and double-trailer configurations, but the data were insufficient to allow for a more detailed comparison of configuration crash experience.

In addition to data describing crashes, VMT information was obtained from States and fleets as an exposure measure of the alternative and control configurations. The exposure data from the States was supplemented with WIM data. The limitations in WIM data (i.e., coverage) also limited the analyses done at the State level to the use of crash rates rather than to extensive regression modeling. Likewise, limitations in exposure data obtained from fleets provided a major challenge in the analysis of the fleet data. Crash records were generally available, but carriers did not consistently provide detailed route-level exposure data. As a result, simplified analyses were undertaken with fleet data.

Crash Analysis Assumptions and Limitations

Several key assumptions and limitations apply to the crash analysis. It was assumed that driver skills and management practices of firms in future operations will be similar to those in use today. This is an implicit assumption of the comparisons conducted in each scenario. While other studies have presented evidence from Canada and other nations that long combination vehicles (LCV) in general may experience very low crash rates if stringent restrictions are placed on drivers, routes, bad-weather operation, truck configuration equipment (e.g., dollies), truck components (e.g., brakes) and other safety-related factors (Woodrooffe, Anderson, et al. 2004), the crash analysis methodology used in this Study did not take into account the degree to which, if any, such stringent restrictions would apply to actual crash data from the United States.

As previously discussed, the limitations encountered during the analysis included the limited number of triples in the current truck fleet from which to gather data. The lack of vehicle weight and configuration information in State crash data severely limited the analysis of on-road safety. The WIM data and vehicle classification data reported to FHWA by the States was relied on.

Data limitations are more fully identified above and are addressed in the *Highway Safety and Truck Crash Comparative Analysis* technical report.

Another limitation is the lack of crash data for non-NHS/NN/IHS roads. The NN/NHS/IHS only account for around 35 percent of truck crashes, which leaves a large gap in what is measured and known regarding truck crashes on the other roadways.

Summary of Crash Analysis Results

Table 8 summarizes the results of the crash analyses. It includes the results of successfully conducted analyses as well as information on analyses that could not be successfully completed due to data-related issues. This information is included to support the study's conclusion regarding needed changes in truck safety data. The *Highway Safety and Truck Crash Comparative Analysis* technical report provides more details concerning each of the crash analysis results.

Because of the small sample sizes available for some of the crash analyses, particularly for the triple-trailer configurations, the results of the test for statistical significance, reported in **Table 8,** have a p-value that is higher (i.e., $p \leq 0.15$) than what is typically reported (i.e., $p \leq 0.05$) in road safety research. The use of this broader range of significance levels has been suggested by others (e.g., Hauer 2004). In the table below, the term “significant” is used to refer to findings at the $p \leq 0.05$ level, and the term “marginally significant” is used for findings with p-values between 0.05 and 0.15.

Table 8. Summary of Crash Analyses by Scenario

Scenario	Data and Analysis Type	Results
Scenario 2 Target – 3-S3, 91,000 lb. semitrailer vs. 3-S2, 80,000 lb. semitrailer Limited State Crash Analysis – six-axle semitrailer with maximum allowable GVW of 91,000 lb. vs. five-axle semitrailer with maximum allowable GVW of 80,000 lb. (Washington data) Fleet Analysis – No fleet analysis conducted for this Scenario	State Involvement Rates	• Crash rates for the six-axle alternative truck configuration in Washington State are significantly higher than the five-axle control truck rates. (+47%) (See Table 8 in the full *Highway Safety and Truck Crash Comparative Analysis Technical Report*.) However, it is not possible to draw national conclusions or present findings concerning national crash rates due to a lack of relevant crash data.
	State Regression Modeling	• Effect of AADT on crash rate in Washington State is similar for the six-axle alternative truck configuration and the five-axle control vehicle.
	State Injury Severity Distributions	• No differences were found between the involvement severities of the alternative and control trucks.
	State Longitudinal Barrier Analysis	• The critical variables needed for this analysis were not found in the Washington crash data. No analysis was possible.
	Fleet Crash Rates	• No analysis could be conducted due to the small sample size of 3-S3 crashes in the fleet data received.
	Fleet Severity Distributions	• No analysis could be conducted due to the small sample size of 3-S3 crashes in the fleet data received.
Scenario 3 Target – 3-S3, 97,000 lb. semitrailer vs. 3-S2, 80,000 lb. semitrailer Limited State Crash Analysis – six-axle semitrailer with maximum allowable GVW of 105,500 lb. vs. five-axle semitrailer with maximum allowable GVW of 80,000 lb.	State Crash Involvement Rates	• With one exception (Idaho rural Interstate), crash rates for the six-axle alternative truck configuration are higher than the crash rates for the five-axle control vehicle in both Michigan and Idaho. (ID +99%, MI+400%) (See Table 8 in the Technical Report cited above.) It is not possible to draw national conclusions or present findings concerning national crash rates due to a lack of relevant crash data.
	State Regression Modeling	• Michigan crash involvements of the six-axle alternative truck configuration increase at a much faster rate as AADT increases compared to five-axle controls. • No reliable model could be developed for Idaho due to sample size issues.

Scenario	Data and Analysis Type	Results
(Idaho data) and 86,000 lb. (Michigan data) Fleet Analysis – No fleet analysis conducted for this scenario	State Injury Severity Distributions	• In Idaho, the analysis of the severity of six-axle alternative truck involvements found that the level of severity is lower than for the five-axle control vehicles on rural Interstates (p=0.07), urban Interstates (p=0.14) and when urban and rural are combined (p=0.01). In Michigan, the severity of six-axle alternative truck involvements on rural Interstates appear to be lower than five-axle involvements (p=0.14), but there are no differences in the distributions for the urban or combined situations. (See Tables 13 and 14 in the Technical Report cited above.)
	State Longitudinal Barrier Analysis	• The small samples of six-axle alternative vehicles involved in barrier impacts in Idaho (i.e., three) and Michigan (i.e., one) made drawing conclusions concerning behavior after impact impossible.
	Fleet Crash Rates	• No meaningful analysis could be completed due to the very small sample size of 3-S3 crashes in the fleet data received.
	Fleet Severity Distributions	• No meaningful analysis could be completed due to the very small sample size of 3-S3 crashes in the fleet data received.
Scenario 5 Target – 2-S1-2-2, 105,500 lb. triple vs. 2-S1-2, 80,000 lb. twin Limited State Crash Analysis – Triple trailer configurations with maximum allowable GVW of 105,500 lb. vs. five- and six-axle double trailer configurations with maximum allowable GVW of 80,000 lb. (Idaho data) Fleet Analysis – Triple Trailer Configurations with unknown GVW vs. Twins with unknown GVW	State Crash Involvement Rates	• The crash involvement rate for triple-trailer combinations in Idaho is lower than for the twin-trailer combinations (-42%). The differences are marginally significant for rural Interstates and rural and urban Interstates combined. (See Table 9 in the Technical Report cited above.) It is not possible to draw national conclusions or present findings concerning national crash rates due to a lack of relevant crash data.
	State Regression Modeling	• The sample size of triple trailer configuration crashes in Idaho (n=15) was too small for reliable regression modeling.
	State Injury Severity Distributions	• The Idaho triple trailer configurations involvements appear to be somewhat less severe than the twin trailer configurations involvements on rural Interstates (p=0.09). No differences are seen on urban Interstates or when urban and rural are combined. (See Table 15 in the Technical Report cited above.)
	State Longitudinal Barrier Analysis	• The small sample of twins (one) and triple trailer configurations (none) involved in longitudinal barrier impacts in Idaho made drawing conclusions concerning behavior after impact impossible.

Scenario	Data and Analysis Type	Results
	Fleet Crash Rates	• While overall twin trailer and triple trailer configurations crash rates were calculated, there was no way to control for difference in road types where each operated (e.g., Interstate vs. non-Interstate). Thus the rates cannot be viewed as indicative of a difference in crash experience. (See Section 2.5 Fleet Analysis in the Technical Report cited above.)
	Fleet Severity Distributions	• There was no evidence of a difference in injury severity between twin and triple trailer configurations crashes for either all occupants or for truck occupants. Non-truck occupants were less severely injured in crashes with twin trailers vs. crashes with triple trailer configurations (p=0.02). (See **Tables 20-22** and related text in the Technical Report cited above.)
Scenario 6 Target – 3-S2-2-2, 129,000 lb. triple vs. 2-S1-2, 80,000 lb. twin Limited State Crash Analysis – Triple trailer configurations with maximum allowable GVW of 120,000 lb. vs. five- and six-axle double trailer configurations with maximum allowable GVW of 80,000 lb. (Kansas Turnpike data) Fleet Analysis – Triple trailer configurations with unknown GVW vs. Twins with unknown GVW	State Crash Involvement Rates	• The overall rate (for combined rural and urban sections) for twin trailer and triple trailer configurations on the Kansas Turnpike is almost identical (-1%). In rural sections, the rate for triple trailer configurations is slightly higher, and in urban sections, the rate for triple trailer configurations is lower. The number of both twin trailer and triple trailer configuration crashes is very low and none of the differences are even marginally significant. (See Table 10 in the Technical Report cited above.) It is not possible to draw national conclusions or present findings concerning national crash rates due to a lack of relevant crash data.
	State Regression Modeling	• The sample size of triple trailer configurations crashes on the Kansas Turnpike (n=10) was too small for reliable regression modeling.
	State Injury Severity Distributions	• Because of the small sample sizes, it is not possible to draw conclusions concerning severity differences. (See Table 16 and related text in the Technical Report cited above.)
	State Longitudinal Barrier Analysis	• The critical variables needed for this analysis were not found in the Kansas crash data. No analysis was possible.
	Fleet Crash Rates	• See results under Scenario 5.
	Fleet Severity Distributions	• See results under Scenario 5.

Based on the analyses conducted to quantify the safety of trucks on Interstate roads, several conclusions may be made.

- The lack of truck weight information recorded on State crash reports led to a comparative analysis of axle-based crash data. The cases analyzed, described previously, resulted in an investigation in truck crash information in three States and one roadway in a single State. The analysis is not robust enough to draw meaningful conclusions of crash relationships among the six alternative configuration vehicles and control vehicles at the regional or national level. Further research and sets of more robust truck crash data are required to present results better tailored to draw conclusions at the national level.
- In Michigan, Washington, and Idaho (the three States where tractor semitrailer data could be analyzed), the crash involvement rate for the six-axle alternative truck configurations is consistently higher than the rate for the five-axle control truck. The consistent crash involvement rates across these three States lend validity to this finding; however, additional study and research are required to develop an understanding of the causes contributing to the results.
- In Michigan, crash involvements of six-axle alternative truck configuration semitrailers increase much more quickly with an increase in exposure compared to the five-axle control vehicle. In Washington State, crash involvements of six-axle alternative truck configuration semitrailers increase similarly to those of the five-axle control as exposure increases. These contrasting results are explored in more detail in the *Highway Safety and Truck Crash Comparative Analysis* technical report.
- As has been noted in other research, the use of crash involvement rates based on truck crashes per truck VMT does not capture complete information because truck crash rates can vary based on changes in total AADT. Regression modeling was used to examine this issue. There was some indication in the regression modeling that the crash involvements of six-axle alternative truck configurations increase at a much faster rate with an increase in exposure when compared to five-axle semitrailers. This needs to be further verified in future studies in other States.
- Comparisons of crash injury severity distributions for the six-axle versus five-axle semitrailer configurations showed some indication of reduced severity for six-axle configurations. Analysis of Washington State data did not identify differences for the Scenario 2 distributions. Analysis of Idaho data for the Scenario 3 (97,000-lb. vehicle) indicated that the six-axle alternative truck involvements appear to be less severe than for the five-axle involvements on rural Interstates, urban Interstates, and when urban and rural are combined. Analysis of Michigan data for the same Scenario indicated that the six-axle alternative truck involvements on rural Interstates appear to be less severe than those for five-axle involvements, but no differences were found in the severity distributions for the urban or combined situations.
- Based on the Idaho data analysis, the Scenario 5 (2-S1-2-2) seven-axle vehicle crash involvement rates for triple-trailer combinations were lower than for the STAA twin semitrailer-trailer-trailer control vehicle on both rural Interstates and rural and urban Interstates combined, but the differences were marginally significant. (See Table 9 in the full technical report.) No differences were found in the Scenario 6 (3-S2-2-2) nine-axle semitrailer configurations vs. STAA twins semitrailer-trailer control configuration rates based on Kansas Turnpike data, even at the p=0.15 level of significance. (See Table 10

in the full technical report.) In both cases, the small sample of triple trailer configurations crashes makes drawing conclusions difficult.

- The results of the severity distribution analyses for triple trailer configurations and twin trailer configurations were mixed. The Idaho Scenario 5 (2-S1-2-2) seven-axle 105,500-lb. triple semitrailer study configuration appeared to be in somewhat less severe crashes than the STAA control vehicle twin semitrailer-trailer group. No differences were found in severity distributions for the study triple trailer configurations vs. control vehicle twin trailer configurations in the analysis of Scenario 6 (3-S2-2-2) nine-axle 129,000-lb. triple semitrailer configuration operating on the Kansas Turnpike. While the fleet data indicted no differences in severity distributions for twin trailer and triple trailer configurations for both all occupants and for truck occupants, there was a significant difference in the severity distributions of non-truck occupants who experienced less severe injuries in crashes with STAA twin trailer configurations.
- Due to data issues primarily related to either missing data or small sample sizes of the alternative truck configurations, planned analyses that could not be completed included the regression modeling for Idaho alternative truck configurations, the regression modeling for both Idaho and Kansas triple trailer configurations, the route-based analysis and the fleet crash rates analyses for the alternative truck configurations.

Vehicle Stability and Control Analysis

This analysis focused on the performance of the control vehicles and alternative configuration vehicles operating at various speeds under a variety of roadway geometric and braking ability conditions. These comparisons were completed in a simulation modeling environment with the exception of some supplemental braking distance testing that was previously completed and shared by the FMCSA.

Vehicle Stability and Control Analysis Methodology

A set of vehicle stability and control analyses was defined to compare the simulated performance of the control and alternative vehicle configurations during specific maneuvers. The maneuvers included low speed off-tracking, high-speed off-tracking, straight line stopping distance, brake in a curve, and avoidance maneuver. Performance metrics included stopping distance, maximum path deviation, off-tracking, rearward amplification and lateral load transfer ratio. The analyses were performed using TruckSim®, a widely available numerical modeling package.

Simulated performance under several braking conditions was also analyzed. To supplement the results of the braking assessments, data and results from actual field testing done by the Federal Motor Carrier Safety Administration (FMCSA) and ORNL was added to the analysis to provide a more robust evaluation of stopping performance associated with the control vehicle and heavier single-trailer configurations. The analyses did not include vehicles equipped with electronic stability control since this equipment was not required at the time of the study under the existing Federal Motor Vehicle Safety Standard.

Vehicle Stability and Control Analysis Assumptions and Limitations

The assumptions applied in the vehicle stability and control analysis included the following:

- Dry van trailers with fixed, rigid loads;
- Steer axles with two tires, all others with duals on both ends;
- Multi-trailer combinations modeled with pintle hitch between trailer and converter dolly;
- Air ride suspension, not leaf spring;
- Vehicle characteristics common to U.S. practice;
- Simulations on dry pavement except brake in curve;
- Three braking conditions simulated:
    1) Anti-lock braking system (ABS) on all axle ends,
    2) ABS malfunctioning on one axle or both axles in tandem, and
    3) Brake failure on one axle end or one tandem end.

Vehicle Stability and Control Analysis Results

The results of the vehicle stability and control analyses for each of the scenarios are discussed here. The maneuvers simulated and analyzed included low- and high-speed off-tracking, stopping distance, stopping distance with or without brake failure or ABS malfunction, and avoidance.

The results of the maneuver simulations indicated that the alternative truck configurations in Scenarios 1, 2, and 3 did not differ appreciably from those of the five-axle control vehicle. Specific results include:

- None of the maneuvers identified a condition where the stability of a single-semitrailer combination was severely impaired by the addition of payload weight or a third trailer axle.
- Low- and high-speed off-tracking results were changed by amounts that would be difficult to measure in practice.
- Adding weight to the payload increased the stopping distance on dry road by less than 10 percent; in the proportions selected for the study, the additional brakes on the third trailer axle compensated for the additional payload in Scenario 2.
- Simulating a complete right-side brake failure on both drive axles increased the stopping distance, and the effect of that failure on the scenarios was similar to its effect on the control vehicle.
- The ABS malfunction caused a jackknife on all single-semitrailer combinations as expected; its severity did not appreciably differ between scenarios.

- The differences between the results for the four single-trailer combinations are not significant. Off-tracking is minimal for all scenarios.

The vehicle stability and control analysis for the Scenarios 4, 5, and 6 was compared to the control truck. Note that the payload weights used in the simulations are different from the allowable maximum weights that define the scenario configurations. (See Figure 4 in the full safety report for the payload weights.) The analysis yielded the following findings:

- Multi-trailer combinations were most challenged by the avoidance maneuver, which was formulated for that purpose. The final trailer in all four vehicles (i.e., the three alternative truck configurations and the twin 28.5-ft. control configuration) traced a wider path, experienced greater lateral acceleration, and put more load on the outside tires than did the tractor. The greater length of the 33-ft. trailers in Scenario 4 lowered the response slightly below that of the control vehicle with 28-ft. trailers. The amplification of the third trailer's response in Scenarios 5 and 6 was greater than that of the second trailer in the control vehicle, as would be expected.
- Differences between the twins and the triples combinations in the off-tracking and braking maneuvers were present but not as significant as in the avoidance maneuver.
- The 33-ft. twin configuration (Scenario 4) had a higher average axle load than the other combinations and had a marginally higher stopping distance.
- When the ABS on the lead dolly malfunctioned during the brake in a curve, all 28-ft. combinations (i.e., twins and triples configurations) experienced a path deviation of 35 inches, which was short of a jackknife but would violate a 12-ft. lane. The 33-ft. combination of Scenario 4 was on the verge of instability, but its path deviation was not affected by the ABS malfunction under the specific conditions of this study.
- The high-speed off-tracking of the triple-trailer combinations was 8 to 9 inches greater than the control vehicle, but was still well within the width of a highway lane for that speed and curvature.
- All three multi-trailer study vehicles had a low-speed off-tracking roughly one-third higher than did the control double.

Inspection and Violation Analysis

The safety inspection and violation analysis compares vehicles currently operating at or below 80,000 lbs. with those operating above 80,000 lbs.. The focus was to examine patterns of violation rates, out-of-service rates, and citation rates among the alternative truck configurations and the control configurations for different scenarios.

Inspection and Violation Analysis Methodology

Analysis of inspection and violation patterns for the control vehicle and alternative truck configurations used Level 1 truck inspection[14] data from FMCSA's Motor Carrier Management Information System (MCMIS) database and GVW reported by roadside inspectors for select States over multiple years. MCMIS data from 2008-2012 were initially screened from 15 States allowing the operation of six-axle heavy semitrailers and from 17 States allowing the operation of triple-trailer combinations. After review of WIM data, 14 States were included in detailed statistical comparisons for vehicles in Scenarios 1, 2, and 3, and 10 States were included for detailed statistical comparisons for scenarios 5 and 6. (Note that the Scenario 4 alternative vehicle does not currently widely operate on U.S. roadways.)

A close inspection of the MCMIS data indicated that GVW data contained variable values, such as actual GVW versus manufacturers' weight ratings. Because of the variability of the weight values in the MCMIS database, MCMIS data were supplemented with data generated through a cooperative data collection project with the Commercial Vehicle Safety Alliance (CVSA). Violations were further segmented by tractor semitrailers, twin trailers, and triple trailers.

Inspection and Violation Analysis Assumptions and Limitations

The USDOT study team applied several assumptions and limitations to the safety inspection and violations analysis. The study team assumed that the majority of MCMIS inspection data came from roadside inspections at both fixed and roadside facilities. WIM was widely used as a prescreening tool, but there is no indicator in MCMIS to identify whether GVW was captured from WIM or static scales.

In terms of limitations, there is an insufficient number of triple-trailer level 1 inspections to allow a comparison to double-trailers. In addition, MCMIS does not include exposure data.

Safety Inspection and Violations Results

The main results of the inspection and violation analysis are:

- Compared with commercial motor vehicles (CMV) operating at or below 80,000 lbs., CMVs operating over 80,000 lbs. show a higher percentage (18 percent) of brake violations and a higher number (0.76) of brake violations per inspection
- Legally operated trucks (i.e., trucks without overweight violations) weighing over 80,000 lbs. had higher overall violation and out-of-service (OOS) violation rates compared to those at or below 80,000 lbs.
- Twin-trailer configurations had the highest violation and OOS violation rates compared to tractor semitrailer and triple-trailer configurations.

[14] There are six levels of DOT inspections. The comprehensive Level 1 inspection (referred to as the North American Standard Inspection) evaluates both the driver (license, medical certificate, and hours-of-service records, etc.) and the vehicle (brake and exhaust systems, suspension, steering mechanism, and frame, among other items).

- Triple-trailer configurations had four percent more brake violations (i.e., out of adjustment and all other violations) when compared with twin trailer configurations weighing 80,000 lbs.

Specific comparisons also were made between the 80,000-lb. 3-S2 configurations and the 88,000-lb. 3-S2, the 91,000-lb. 3-S3, and the 97,000-lb. 3-S3 configurations. A comparison of the 80,000-lb. twin trailer to the heavier triple-trailer configurations was considered, but could not be accomplished because of limited sample sizes. The results include the following:

- Alternative tractor semitrailer configurations (88,000 lbs., 91,000 lbs., and 97,000 lbs.) generally have higher violation, citation and OOS violation rates than the control semitrailer configuration group (80,000 lbs.). The exception is that the 88,000-lb. configuration had a lower out-of-service rate.
- Nevertheless, when placed in a regression model that accounts for other predictor variables, the 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 in the regression.
- Driver age, vehicle age, and carrier OOS rates were strong predictors of the likelihood of a violation. Driver age was negatively associated, while vehicle age and company OOS rate were positively associated with likelihood of a violation.
- Percentage of brake violations was roughly two percent higher in alternative semitrailer configurations than the reference configuration. This is mainly because of a higher percentage of “Brakes, out of adjustment” violations in those three alternative truck configurations.

Scenario Analysis Results: Estimating Changes in the National Number of Crashes

The concept underlying the development of the estimates of changes in truck crashes for each scenario required two components: nationally representative crash rates for each truck configuration and estimates of national VMT for both a base case of existing truck configurations and networks and for a scenario case involving alternative truck configurations and networks. Note that results were not generated for Scenario 1 and Scenario 4 since crash rates were not developed for the alternative truck configurations in these scenarios for the reasons previously noted.

- The impact associated with each scenario assessed in the study cannot be completed due to the lack of truck weight and vehicle characteristic information uniformly and reliably reported on State crash reports. This lack of information creates a situation where meaningful analysis leading to an understanding of the implications of each scenario cannot accurately be performed with an adequate degree of confidence.
- The findings for the Scenario 2 (91,000-lb. 3-S3) configuration and the findings for the Scenario 5 and 6 triple configurations were each based on crash rates for one State. The findings for the Scenario 3 (97,000-lb. 3-S3) configuration were based on crash rates

from two States. The use of rates from this limited number of States clearly raises questions as to whether these rates can be considered nationally representative and whether using them to predict nationwide estimates is appropriate.

- Because State crash data do not include information on operating GVW for each truck, the definition of truck crashes used in the different scenarios was based on trailer and axle counts and State GVW limits. Is it not known whether actual truck GVWs in the fleet analyzed in this study will be similar to actual GVWs in an expanded future fleet.
- The composition of future fleets of alternative truck configurations may differ in unknown ways from the current fleet that was analyzed in this report. For example, the same alternative truck configuration analyzed here (e.g., 129,000-lb. triple configurations) may carry different commodities in the future. If so, the carriers may differ, which in turn may cause the "safety culture" to differ (e.g., driver training and experience, truck maintenance procedures, equipment age, etc.). The effect of such possible differences could not be analyzed here. For example, while crash data contains information on driver age, there is no driver age-specific truck exposure data, a critical need in any analysis of driver age effects.

These data limitations raise significant questions concerning the accuracy, reliability, and validity of any nationally representative crash rate estimates that could be calculated for each truck configuration. As a result, meaningful national-level crash-rate results could not be developed for this Study.

Summary of Inspection and Violation Analysis Results

As noted earlier, the crash rates used in all scenario analyses were based on either one or two States. The use of rates from this limited number of States clearly raises significant questions concerning whether estimates could be considered nationally representative**. FHWA does not believe nationally representative estimates can be developed from the data.**

The analyses indicate that the safety implications of allowing alternative truck configurations to operate vary by vehicle. In general, for Scenarios 2 and 3, the six-axle configurations have higher crash rates than the five-axle tractor-semitrailer control configurations in Washington, Idaho, and Michigan. This is particularly evident in the two study States where six-axle trucks could run at weights close to the 97,000-lb., six-axle alternative configuration. Similar findings with respect to inspections and violations were observed. The six-axle configuration had higher violations, OOS rates, and brake-related violations per inspection when compared to the control group (i.e., the five-axle tractor semitrailer configurations at 80,000 lbs.).

The vehicle control and simulation analyses showed very marginal differences between the control and alternative truck configurations for the set of maneuvers evaluated. The differences between the crash and vehicle control and simulation results could stem from the fact that crash rates for actual operations versus simulation-based operations do not reflect the same range of operators and/or operating conditions. It was not possible to determine in this Study what factors led to these differences. Further exploration is needed.

Scenarios 5 and 6 results for triple-trailer alternative truck configurations also differed between the crash and vehicle stability and control methods. While no differences between triple-trailer and twin-trailer configurations were seen in the Scenario 6 Kansas Turnpike data, the crash rate analyses for Idaho (Scenario 5) indicated that the rates for the triple-trailer configuration were lower than those of the twin trailer configuration. The Level 1 inspection summary data for safety inspections and violations also showed that triple-trailer configurations tend to have lower violation rates than twin-trailer configurations. However, this is based on a very small sample size, and as a consequence, more rigorous analysis could not be conducted to explore this further.

A major result of this overall effort is that crash-based studies focusing on truck size and weight and using U.S. data are very difficult to conduct successfully. This is particularly true if the studies are based on the primary data sources in existence today – State crash files, State roadway inventory data, State AADT data, and additional data on VMT for specific truck configurations. Fleet supplied and MCMIS data were also inadequate to conduct the desired analyses. The issues found in this safety analysis are not new. These include the following:

- Crash data do not include precise information about the configuration (for example, number of axles and number of trailers and semitrailers) and the weight of trucks involved in crashes.
- The single source of State and national truck VMT information for the specific configurations of interest in this safety Study is FHWA's Traffic Monitoring Program traffic volume, vehicle classification and WIM data described earlier. WIM data is especially important since vehicle weight is a key factor used in in performing the several comparative analyses required. The number of current WIM data collection points is so limited that the estimate of truck travel by weight category was extremely constrained and limited to Interstate System roadways in a number of cases. Truck VMT using traffic volume and classification count data could only be provided at the State functional class level and not at finer levels, such as corridor-based comparative assessments as was proposed and attempted at the outset of this Study.
- The data used to support the inspection and violations analysis included the selection of the GVW variable from the MCMIS database. Discussions with FMCSA indicated that this variable is not always available in the database as a measured weight, and that no better variable exists in MCMIS for a description of combination vehicle weight.

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Pavement Analysis

This section summarizes the pavement analysis conducted as part of the study. The pavement analysis assessed the impacts that trucks operating at or below current Federal weight limits have on pavement infrastructure compared to trucks operating above those limits. The analysis also assessed the impacts on pavement infrastructure associated with potentially allowing alternative the truck configurations identified in the six scenarios described in **Table 4**.

The purpose of the pavement analysis is to address two major questions:

1. How will changes in axle weights and types resulting from each scenario affect pavement performance and expected pavement costs?
2. How much pavement damage is currently caused by trucks operating above the current Federal weight limit versus trucks operating at or below those limits?

Pavement Analysis Methodology

A multi-step approach was used to assess the impacts of various truck types and traffic scenarios on pavement performance and life-cycle costs. Key to the process was the selection of representative pavement sections (flexible and rigid along with their local materials and design inputs) within each of the four primary climate zones in the United States—wet freeze, dry freeze, wet no-freeze, and dry no-freeze—and a single location within each climate. Three truck traffic levels—high-, moderate-, and low-volume—were also identified.

Through the desk scan, a thorough understanding of the current state of research and practice regarding pavement cost analysis related to heavy-vehicle use was gained. The information gleaned from the scan assisted researchers in the selection and application of analytical tools and in the compilation of data required for those tools. Some of the sources evaluated are listed below.

The approach used differs from past truck size and weight studies in that the current AASHTOWare™ Pavement ME Design® software was used to assess the structural impacts of evolving vehicle types and traffic scenarios on pavements. The Pavement ME Design® software is the tool based on the AASHTO Mechanistic Empirical Pavement Design Guide (M-EPDG) procedure that was adopted by AASHTO in 2007. The MEPDG directly applies an axle-load spectrum to calculate the amount of damage produced by the estimated range of traffic loads. The axle load spectra data are obtained from processing WIM data and include axle-load distributions (e.g., single, tandem, tridem, quads) and axle-load configurations (e.g., axle spacing and wheelbase). Neither the AASHTO software nor the M-EPDG was available at the time of the 2000 CTSW Study.

Several FHWA data sources were used to estimate the pavement impacts, including the Highway Performance Monitoring System (HPMS); vehicle classification and weight data reported by the States, the Long-Term Pavement Performance (LTPP) database, and calibration data provided by four State departments of transportation for use in the AASHTOWare™ Pavement ME Design® model.

Pavement Analysis Assumptions and Limitations

Several key assumptions and limitations apply to the pavement analysis. Analysis of the relative impacts of one group of vehicles compared with another at the national-system level requires some simplification of assumptions about the vehicles themselves. For each scenario in this study, freight was shifted either from one vehicle to another, or to a vehicle of the same type but with a different weight. The approach used in this study assumed that both the before and after vehicles in each scenario had the same temporal use patterns, the same tire and suspension characteristics, were traveling at the same speeds, and behaved in similar ways. The only variables considered for pavement analysis were the change in axle weights and vehicle types.

The main limitation of this study is that it considers only the initial service lives predicted by the AASHTOWare™ Pavement ME Design® model, version 2.0, and only for the distresses and pavement types that the software could suitably model. By implication, this means the study concentrates only on a subset of the impacts of the proposed changes in truck size and weight on pavement life and consequent costs. Deterioration caused by the interaction of loads, construction deficiencies, or materials durability (e.g., deterioration of HMA[15] transverse cracks caused by low temperatures, deterioration of PCC "D" cracking[16]) are outside the scope of this Study, although it should be recognized that they can significantly impact the performance of pavements. In addition, the impacts of truck tire types (e.g., wide-based radial) and tire-pavement interaction (e.g., braking, torqueing, and other physical responses) are not considered. And again, a lack of data on local roads prevented the modeling of these facilities for the pavement analysis.

Pavement Analysis Summary of Results

The study analyzed the effect of overweight axles in current operations, defining overweight as single axles weighing more than 20,500 lbs. and tandem axles weighing more than 35,000 lbs. to be consistent with the axle weight group boundaries used in the vehicle weight analysis. Initial service intervals were found to increase significantly for both flexible and rigid pavement sections, except in the case of one rigid pavement section that did not reach the end of its initial service interval during the analysis period. Flexible pavement initial service intervals increased by between 19 percent and 34 percent and rigid initial service intervals increased by between zero percent and 10 percent when overweight axles were removed from the traffic mix.

The estimated impacts of the truck size and weight scenarios vary by scenario and by the pavement type and service conditions considered in the analysis. The use of the alternative truck configurations resulted in the following findings in comparison with the base case of current vehicle usage patterns:

- Scenario 1, which allows five-axle semitrailer configurations to operate at an 88,000-lb. GVW, resulted in a heavier array of tandem-axle loads;

[15] Hot mix asphalt is a combination of aggregate (stone, sand, or gravel) bound together by asphalt. It is used primarily as a surface course to provide structural strength and distribute loads to underlying layers of the pavement.
[16] Progressive deterioration of Portland cement concrete normally is caused by the winter freeze-thaw cycle.

- Scenarios 2 and 3, which allow six-axle, tractor-semitrailer configurations to operate at a 91,000-lb. GVW and a 97,000-lb. GVW, respectively, resulted in a transfer of some heavier tandem axles to tridem axles;
- Scenario 4, which allows five-axle, twin-trailer configurations with 33-ft. trailers to operate, showed an increase in the weight distributions of single-axle loads;
- Scenario 5, which allows seven-axle, triple-trailer configurations to operate at a 105,500-lb. GVW, resulted in the transfer of some tandem-axle loads to lighter single axles; and
- Scenario 6, which allows nine-axle, triple-trailer configurations to operate at 129,000 GVW, resulted in lower tandem axle weights as well as a similar shift from tandems to lighter single axles.

Table 9 summarizes the average impacts of each scenario, both in terms of time to first rehabilitation and in life-cycle cost. Flexible pavements exhibited more accelerated deterioration in Scenarios 1 and 4, while rigid pavements were more negatively impacted by Scenarios 4, 5, and 6.

The more significant modal shift impacts are predicted to occur on lower volume facilities, specifically the low volume Interstate highways and the low volume (other NHS) arterials, typically constructed with thinner cross-sections. The estimated impacts of the scenarios are relatively minor for the thicker pavement sections built to handle higher truck volumes. The range of impacts for each scenario results from varying pavement conditions, climatic conditions, and highway types

The life cycle cost (LCC) implications of the scenarios also varied. **Table 9** also summarizes the differences averaged over all pavement types, climate zones, and types of facilities. Two discount rates were employed in estimating the present value of the repair and restoration costs modeled for each pavement section sample. A conservative discount rate of 1.9 percent was applied and a more widely used discount rate of 7 percent was applied so as to frame the range that the results of the analysis completed. On average, Scenario 4 resulted in the largest LCC overall increase of 1.8 to 2.7 percent from the base case, whereas Scenarios 2 and 3 resulted in 2.4 to 4.2 percent and 2.6 to 4.1 percent decreases, respectively, in predicted LCC from the base case. Scenarios 1, 5, and 6 showed lower increases in LCC, which is defined herein as agency cost for pavement rehabilitation (e.g., overlays, retexturing) over a 50-year analysis period.

Table 9. Impacts of Study Scenario (Compared to Base Case) on Pavement Performance and Costs

Scenario		Weighted Average Change in Service Intervals	Weighted Average Change in Life Cycle Costs
1	88,000-lb., five-axle single-semitrailer combinations	- 0.3%	+0.4% to +0.7%
2	91,000-lb., six-axle single-semitrailer combinations	+2.7%	-2.4% to -4.2%

Scenario		Weighted Average Change in Service Intervals	Weighted Average Change in Life Cycle Costs
3	97,000-lb., six-axle single-semitrailer combinations	+2.7%	-2.6% to -4.1%
4	five-axle double-trailer combinations with 33-ft. trailers	-1.6%	+1.8% to +2.7%
5	105,500-lb., seven-axle triple-trailer combinations	0.0%	+0.1% to 0.2%
6	129,000-lb., nine-axle triple-trailer combinations	-0.1%	+0.1% to +0.2%

Note: Individual pavement sections were weighted based on the number of lane-miles of pavement of each type, thickness range, and highway type.

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Bridge Structure Comparative Analysis

This section summarizes the results of the *Bridge Structure Comparative Analysis* technical report and the methods used to assess the impacts that certain alternative truck configurations may have on bridge infrastructure. It provides estimates of the impacts to bridge infrastructure from trucks operating at or below the current Federal weight limits compared to trucks operating above those limits. Bridges located on the Interstate System (IS) and all other highways comprising the National Highway System (NHS) were assessed. The scope of the analysis was limited to the immediate structural effects on the existing bridge inventory and the impact on bridge load-induced fatigue that would result due to that change.

The bridge technical analysis work focused on two main analytical objectives:

- Structural Analysis: Determine and assess the implications of the structural demand on U.S. bridges due to the introduction of the proposed alternative truck configurations that have a GVW of more than 80,000 lbs. versus trucks in the current fleet that are subject to a maximum weight limit of 80,000 lbs. This task included an assessment of one-time bridge costs that might be incurred as a result of resolving posting issues (bridges that are not capable of handling the weight for which they were constructed legal loads are "posted" at a lower, safe weight) leading to the strengthening or replacement of those bridges).
- Bridge Damage Cost Allocation: Determine the increase or decrease in bridge damage-related costs expected to accrue over time due to the introduction of the proposed alternative truck configurations vs. the costs attributable to the current truck fleet. While it is strongly believed that an increase in axle load or number of axles accelerates bridge deck deterioration, because a suitable model based on generally accepted procedures was not available, this aspect of the analysis and the associated long-term costs were not included in the study results.

Bridge Structure Comparative Analysis Methodology

Both structural demand and bridge damage cost allocation analyses were conducted on bridges located on the three highway networks noted above. The load-induced, fatigue-related effects of trucks were evaluated regarding the impact on service life of bridges with respect to the degree to which structural fatigue may be affected by the introduction of the proposed alternative truck configurations on a national basis.

The results of the extensive desk scan and previous research affirmed the approach to the structural analysis of a representative sample of bridges screened from the National Bridge Inventory (NBI) database, and for determining bridge posting issues and one-time structural costs. Investigations into previously completed studies also assisted in the development of the framework for assessing the impacts that the alternative configurations would have on bridge load-induced fatigue.

<u>Structural Analysis Methodology</u>

The NBI database was first screened to determine both the total bridge count and the relative number of bridges on the NHS and NN by bridge type that are on the Interstate System and on the non-Interstate System within the two subject highway networks. The 12 most common bridge types were chosen for inclusion in the structural analysis, representing 96 percent of all bridges. More than 500 representative bridges were analyzed using AASHTO's

AASHTOWare™ Bridge Rating® Program (ABrR) using the load resistance factor rating (LRFR) method. Of these, 490 bridges were selected to best represent the mix of bridges in terms of bridge types, span length, and age, on the two highway networks referred to above. The only exceptions were for thru-trusses and girder-floor beam bridges for which there was not yet any LRFR capability in ABrR. The load factor rating (LFR) method was employed for those bridges.

The bridge models selected for analysis were in proportion to the number of bridges in the NBI by bridge type on the subject highway networks. The bridges were further screened to ensure that they were representative in terms of age, condition, and span length. The results of the analysis were recorded for maximum moment and shear, and the Rating Factors (RF) for the alternative truck configurations were compared to (normalized relative to) the 80,000-lb. control vehicles.

This analytical process is the basis for assessing the increase in the gross number of bridges that would have structural/posting issues potentially requiring strengthening or replacement as a result of the introduction of the alternative truck configurations. From this assessment, the one-time costs resulting from structural and posting related issues were derived.

Bridge Damage Cost Allocation Methodology

Prior work completed in the United States and around the world was exhaustively investigated, confirming that there is no generally accepted and applied approach for measuring the cost effects of heavy vehicles on bridges on a national scale. Consequently, a methodology for bridge damage cost allocation was developed as an axle-load based method, aggregated by truck class. Requests for alternative bridge deterioration models were made to stakeholders at publicly held meetings conducted by USDOT, and to the National Academy of Science, Peer Review Panel. Unfortunately, no generally accepted or state-of the-practice methodology was identified. Bridge Program subject matter experts recommended that this area of analysis be eliminated from the study due to a lack of a tool capable of estimating impacts at the national level.

However, the FHWA's Long-Term Bridge Performance Program (LTBP) is in the process of collecting useful data to better understand bridge element performance and heavy-vehicle interactions. This effort is intended to lead to the development of the tool needed to assess heavy truck impacts on bridge decks.

Bridge Comparative Analysis Assumptions and Limitations

Two of the key assumptions applied in conducting the bridge analysis were that:

- Maximum legal axle weights would be used for both the structural and load-induced fatigue analysis, and
- Bridge capital costs would be based on the 2011 Financial Management Information System (FMIS) cost summaries, including both State and Federal shares.

Limitations affecting the analysis include:

- Lack of a generally accepted methodology prevented the estimation of costs associated with accelerated bridge deck deterioration due to increased truck weights or number of axles at this time. This limitation resulted in the inability to provide a complete bridge impacts analysis in accordance with the statutory direction.
- Little segregated cost data was available for deck preservation and preventative maintenance;
- The limited load-induced fatigue analysis performed supported only a qualitative assessment;
- LRFR capability was not available in ABrR for structural analysis of trusses and girder-floor-beam bridges.

Summary of Bridge Comparative Analysis Results

The Bridge Analysis examined a multiplicity of contributing factors and issues, including two 80,000-lb. control vehicles, six scenario alternative truck configurations, two regions, and two primary highway networks. The following discussion presents the results for the two areas of assessment completed: 1) Bridge Structural Analysis and 2) Bridge Load-Induced Fatigue.

Bridge Structures

Based on the derived rating factors for each of the alternative truck configurations in each scenario, an assessment was made of how many bridges had posting issues and would potentially require either strengthening or replacement. A threshold Rating Factor (RF) value of 1.0 establishes a potential need for bridge strengthening or replacement. **Table 10** shows the projected number of posted bridges.

Table 10. Projected Number of Bridges with Posting Issues for the Entire NHS Inventory

Number Of Bridges In The Nbi		Load Rating Results					Projected Number Of Bridges W/ Posting Issues For Entire Inventory	
# of IS Bridges in the NBI	# of Other NHS Bridges in the NBI	# of IS Bridges Rated	# of Other NHS Bridges Rated	Vehicle Config-uration	IS Bridges Rated w/ RF < 1.0 (percent)	Other NHS Bridges Rated w/ RF < 1.0 (percent)	# of IS Bridges w/ Posting Issues	# of Other NHS Bridges w/ Posting Issues
45417	43528	153	337	Scenario 1	3.3	5.0	1485	2194
				Scenario 2	3.3	7.7	1485	3360
				Scenario 3	4.6	9.5	2080	4135
				Scenario 4	2.6	3.0	1185	1293
				Scenario 5	2.0	0.9	890	387
				Scenario 6	6.5	5.6	2970	2455

Comparing the number of bridges to be posted for each alternative truck configuration to the posting required for control vehicles (3-S2 and 2-S1-2) provided a reliable indication of how many additional bridges would need to be posted (or strengthened) if these alternative truck configurations were to be introduced as legal trucks on the NHS. **Table 11** shows both the percentages and the actual number of bridges that have posting issues.

In order to estimate the probable one-time cost effect of employing alternative truck configurations, the increase in the potential strengthening or replacement costs relative to the control vehicles was developed. The calculated one-time cost of bridge improvements addressed herein could pertain to either superstructure strengthening or superstructure replacement triggered by the need to increase live load capacity. Costs were estimated for bridge strengthening and replacement using project cost information from FHWA's Financial Management Information System (FMIS). A unit cost for this type of work was calculated ($235.00 per square foot of deck space), applied to bridges requiring strengthening or replacement and summarized for each scenario modelled. Bridges requiring improvement action on the Interstate System (IS) and National Highway System (NHS) were flagged for improvement when a rating factor equal to or less than 1.0 was observed. Costs by span length for IS and NHS bridges are found in Table 23 of the Bridge Structure Comparative Analysis Report. A full description of the cost analysis is found in Chapter 3 of the Bridge Structure Comparative Analysis Report.

The choice of strengthening vs. replacement would depend on superstructure type and whichever is the more economical alternative. The summary of what is considered the upper bound of these projected costs for each scenario's alternative truck configuration is presented in **Table 11. Projected One-Time Costs**.

Table 11. Projected One-time Bridge Costs for Alternative Truck Configurations (Scenarios)

Vehicle Configuration	Projected One Time Strengthening or Replacement Costs (2011 U.S. Dollars)
Scenario 1	0.4 Billion
Scenario 2	1.1 Billion
Scenario 3	2.2 Billion
Scenario 4	1.1 Billion
Scenario 5	0.7 Billion
Scenario 6	5.4 Billion

Bridge Fatigue

The USDOT study team also investigated load-induced steel fatigue resulting from truck loadings. Four steel bridges of various span lengths, configurations (simply supported and continuous), and fatigue category details were investigated using a comparative analysis approach.

Results from the analysis showed that relatively heavier axle loads and axle groupings tend to affect fatigue life negatively when compared to the control vehicles. However, any overall reduction in bridge fatigue life depends on the number of relatively heavier trucks that are in the traffic stream. In general, fatigue-related costs of steel bridges are small compared to total bridge program costs.

Bridge Deck Deterioration, Service Life, and Preventative Maintenance

Initially, bridge deck repair and replacement costs and bridge deck preservation and preventative maintenance were investigated together because the topics are innately linked. Bridge deck limit states include the ultimate deck strength limit and the deck durability service limit. AASHTO design criteria (AASHTO 2002, 2011) provide bridge decks with adequate strength to carry the potentially heavier alternative truck configuration axle loads. However, cyclic axle loadings diminish deck service life or durability.

As noted above, the lack of a bridge deck impact model suitable for estimating bridge deck wear caused by commercial motor vehicles of various weights limited USDOT's ability to evaluate the consumption of bridge deck service life and provide an estimate for related cost responsibility attributable to specific configurations and alternative gross vehicle weights. Because a suitable model based on generally accepted procedures and sound engineering principles was not available, this likely significant aspect of the analysis is not included in the study results.

References

American Association of Highway and Transportation Officials (AASHTO):

2011. *Load Resistance Factor Design Specifications, 6th Edition*, Washington, D.C.

2002. *Standard Specifications for Highway Bridges, 17th Edition*, Washington, D.C.

<u>Compliance Comparative Analysis</u>

The goal of this area of the study is to assess the cost and effectiveness of enforcing truck size and weight (TSW) limits for trucks currently operating at or below current Federal truck weight limits as compared with a set of alternative truck configurations in six scenarios.

At this point it is important to note that while the control double has an approved GVW of 80,000 lbs., the GVW used for the control double in the study is 71,700 lbs. based on actual data collected from WIM-equipped weight and inspection facilities and is a more accurate representation of actual vehicle weights than the STAA authorized GVW. Using the WIM-derived GVW also allows for a more accurate representation of the impacts generated through the six scenarios.

The cost analysis portion of this study includes a description of the principal TSW enforcement methods used in the U.S., including the application of enforcement technologies, meaning that the enforcement costs assessed reflect the resources required to undertake the truck size and weight enforcement task. The analysis examines national-level trends in enforcement program costs and conducts enforcement cost comparisons between States and for different truck configurations. Finally, the analysis estimates the enforcement cost impacts of introducing the alternative truck configurations into the traffic stream.

Enforcement program effectiveness reflects how the resources provided to the enforcement program translate into TSW enforcement actions and ultimately contribute to achieving regulatory compliance. The effectiveness analysis examines trends and relationships pertaining to enforcement program activities (such as weighing trucks) and compares the effectiveness among States and for different truck configurations. WIM data gathered at sites where alternative truck configurations currently operate provide the basis for comparing the compliance impacts of introducing these configurations into the traffic stream.

Compliance Comparative Analysis Methodology

Despite the widely held notion of a linkage between truck weight enforcement and compliance, there remains an inability to fully understand this relationship because of differences in how enforcement occurs and a lack of systematic and reliable evidence concerning overweight trucking. Additionally, understanding this relationship for specific truck configurations—one of the main issues of interest in this Study—has generally been constrained by insufficient data. Increasing investments in proven enforcement technologies, including tools for identifying non-compliant trucks or carriers and the expanded use of WIM devices for monitoring truck weights, provide some opportunity to address these historical data limitations; however, certain data gaps persist which preclude a definitive analysis of the subject.

The analysis of costs and effectiveness undertaken in this study takes a performance-based approach. This approach considers enforcement program performance (or effectiveness) in terms of inputs, outputs, outcomes, and pertinent relationships between these measures. Enforcement program inputs reflect the resources (i.e., personnel, facilities, technologies) available to carry out the TSW enforcement task. State Enforcement Plans (and the subsequent certification of these plans) submitted by each State are the principal data source used to analyze program inputs.

Outputs reflect the way enforcement resources are used, the scale or scope of activities performed, and the efficiency of converting allocated resources into a product (e.g., quantity of trucks weighed, weight citations). These output measures are sourced from the Annual Certifications of Truck Size and Weight Enforcement database. While these outputs on their own provide some indication of program effectiveness, additional outputs and inputs can improve the overall understanding of program effectiveness.

The relationship between citation rate and enforcement intensity (measured as the number of trucks weighed per truck VMT) is one example. Outcomes reflect the degree of success of the TSW enforcement program in achieving its goal which from an operational and programmatic perspective is to achieve compliance with TSW regulations. The outcome measures used in this study are the proportion of axle or truck observations that fall within the Federal weight compliance limits compared to the severity of overweight observations.

Applying the performance-based approach provides the supporting framework for a comparative analysis designed to reveal insights about the costs and effectiveness of TSW enforcement programs. Data limitations, consistency, and availability constrain a comprehensive, representative understanding of these costs and effectiveness, particularly regarding vehicle-specific comparisons. To accommodate these limitations and leverage existing datasets and institutional knowledge, this study applies two types of comparisons:

- At a broad level, readily available State-specific data provides the foundation for comparing costs and effectiveness between States that currently allow trucks above Federal weight limits and those that do not. As the State-level data used in these comparisons do not allow disaggregation by vehicle configuration, these comparisons can be understood as a surrogate way of revealing potential vehicle-specific differences at a State level.
- A more detailed comparative analysis of enforcement program costs and effectiveness involves vehicle-specific comparisons (where possible). These comparisons focus on enforcement cost and effectiveness differences between the control vehicles and the six alternative truck configurations introduced into the traffic stream for the six scenarios in the study. Therefore, the results of the vehicle-specific comparisons directly support the scenario analysis, which estimates system-wide cost and effectiveness impacts that could result from the operation of the alternative truck configurations relative to the 2011 base case.

Summary of Compliance Comparative Analysis Results

Owing mainly to a lack of systematic and consistent data, prior research on TSW enforcement identifies the need for improved understanding of how enforcement resources, methods, and technologies can be effectively deployed to achieve better compliance. A configuration-specific understanding is particularly needed when considering the potential introduction of alternative truck configurations into the traffic stream, as is the case in this Study. The State-level and particularly the vehicle-specific comparisons conducted in this analysis leverage existing datasets and, together, reveal insights about potential differences in enforcement costs and effectiveness for trucks operating within current Federal sizes and weight limits versus alternative truck configurations with higher sizes and weights. Additionally, these comparisons support a system-wide estimation of overall cost and effectiveness impacts that could occur under the scenario conditions.

Key findings concerning enforcement **costs** follow:

- From a national-level programmatic perspective, States spent a total of approximately $635 million (in 2011 U.S. Dollars) on their TSW enforcement programs in 2011. Personnel costs represented about 85 percent of total costs, while facilities expenditures (including investments in technologies) accounted for the remaining costs. Technologies play an important role in TSW enforcement and are increasingly deployed by State enforcement agencies.
- Based on the State-level comparisons, there is no indication of a change in enforcement costs that can be attributed to whether or not a State allows trucks to operate above

Federal limits. Rather, differences in how States deliver enforcement programs (e.g., methods of enforcement used, technologies, intensity of enforcement) may have greater influence on total costs.

- The vehicle-specific comparative analysis indicates that, because the alternative truck configurations have more axles or axle groups than the control vehicles (except the Scenario 4 configuration with two 33-ft. trailers); they will require more time to weigh using certain standard weighing equipment and thus result in higher personnel costs.
- When estimating cost impacts on a system-wide basis in the scenario analyses, personnel costs decrease because the reduction in VMT predicted by the scenarios necessitates fewer weighings overall (assuming the rate of weighing vehicles relative to VMT is held constant) and this outweighs the increased costs associated with weighing the alternative truck configurations. Viewed another way, the rate at which weighings occur (per VMT) or the time spent conducting a weighing could be increased under the scenario conditions for the same level of expenditures on enforcement personnel.

Key findings concerning enforcement **effectiveness** follow:

- Considering national-level trends, both the weighing cost-efficiency (personnel costs per non-WIM weighing) and citation rate (citations per non-WIM weighing) decreased during the period from 2008 to 2012. 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 lower overall enforcement intensity and a higher citation rate. 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.
- Based on the State-level comparisons, as with the cost results, there is no indication of a change in enforcement effectiveness (as measured by the relationship between citation rate and enforcement intensity) that can be attributed to whether or not a State allows trucks to operate above Federal limits.
- For the vehicle-specific comparison of enforcement effectiveness, an analysis of data from selected WIM sites indicates that, except for six-axle tractor semitrailers operating off Interstates, the alternative truck configurations exhibit a higher proportion of compliant GVW observations than the control vehicles—hence our use of the 71,700 pound average GVW for those calculations involving the control double configuration. However, for all the comparisons, the intensity of overweight observations is higher for the alternative truck configurations than the control vehicles.
- In each of the scenarios analyzed, the system-wide impact on the proportion of total weight-compliant VMT for the control vehicle and alternative truck configuration is limited relative to the base case.

Identification of Statutes and Regulations

A final component of this Compliance Task identifies statutes and regulations impacted by the potential allowance of alternative truck configurations on all roads and highways on which Surface Transportation Assistance Act (STAA) vehicles can now operate. The review focuses on relevant language contained in:

- US Code Title 23: Highways,
- US Code Title 49: Transportation, as well as the corresponding regulations in
- Code of Federal Regulations, Title 23, Part 658 and Title 49 Parts 390-399.

The impacts identified by this review principally involve:

- Enactment dates for all applicable sections in 23 USC 127, 49 USC Chapter 311 and 23 CFR Part 658 pertaining to vehicle size and weight limits, as identified in the analysis;
- Length provisions replacing references to the twin 28-ft. and twin 28.5-ft. trailer combination vehicles as STAA vehicles with the twin 33-ft. trailer combination;
- The Federal Bridge Formula to enable operation of non-compliant configurations being assessed in the study; and,
- The listing of States and vehicle and route specific allowances provided in Code of Federal Regulations Title 23, Part 658 Appendix C.