Vermont Truck Interstate Pilot Study

Report to Congress

(State of Vermont version for review)

summary report (DRAFT)

prepared for

Federal Highway Administration

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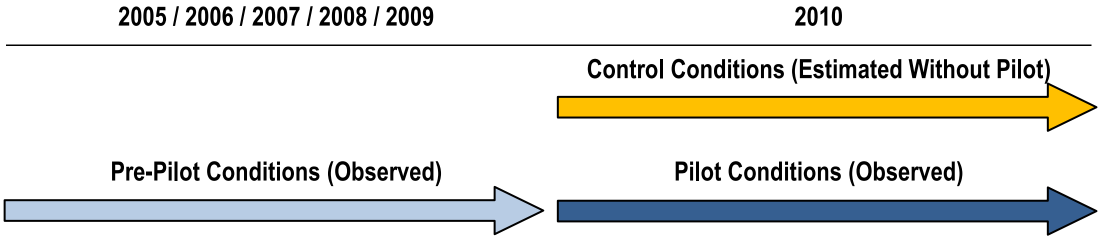
1.0 Analytical Approach

To understand the impacts of the one-year pilot on the Interstate system of Vermont, the research team developed an analytical approach to estimate conditions before the pilot, during the pilot, and in case the pilot had never happened. The scenario assumptions are:

- **Pre-Pilot** (2005 to 2009)– The "Pre-Pilot" period represents conditions before the one-year pilot. The "pre-pilot" data includes information on the state of bridges and pavements, highway safety performance, commerce, and traffic volumes. The data were obtained from the Vermont and Federal sources and with the input of stakeholders involved in the study.
- **Pilot** (2010) – The research team developed "Pilot" period estimates using information collected during 2010 by the Vermont Agency of Transportation, the Vermont Division of Motor Vehicles, and the US D.O.T.
- **Control** (2010) – The "Control" estimate simulates 2010 conditions *if the pilot had not taken place.* The research team developed the "control" estimates by averaging "pre-pilot" traffic data from 2006 to 2009. While the control group presents a plausible "alternative reality" from which comparisons can be drawn, a major challenge of this study is separating out the effects of the regulatory change from other intervening variables during 2010, including freight demand across the economy, fuel prices, labor availability, weather, road repair work, etc.

The main objective of the analysis is to isolate the difference in outcomes between the control conditions and the pilot conditions to demonstrate what happened during the pilot year 2010 versus *what would have happened without the pilot during 2010*. The following graphic illustrates the relationship between the "Pre-Pilot", "Pilot", and "Control Conditions."

Table 4.1 Scenario Assumptions



Using the difference between the control and pilot test groups the study evaluates the following broad questions:

- What change occurred?
- Was the change what was intended?
- How did the pilot affect bridge durability, pavement durability, highway safety, commerce, and energy consumption?

In order to answer these questions and ascertain the infrastructure and policy implications of the pilot, the research team developed an evaluation framework for each of the impact areas of the study. The framework identifies the issues, evaluation methods, and impacts on private and public sector. The remaining chapters of this report are organized around this framework approach, which is summarized below in Table 4.1.

Table 4.1 Evaluation Framework

Impact	Issue	Evaluation Method	Private Sector Impacts	Public Sector Impacts
Vehicles	What changes in vehicle types? Describe the pilot vehicles.	Conversion information from outreach; permit summary from VT DMV.	Trucks converted, purchased, leased, description of how industry adapted.	Equipment inspection, certification, how did VT DMV set up to handle the pilot?
Truck Volumes	What changes in routes, volumes, VMT .	Traffic counts and vehicle classifications, WIM data for the pre and pilot period.	Trips, routes, VMT.	Traffic volumes by configuration, but functional classification (Interstates vs. local rtes.)
Highway Safety	What changes in highway safety performance during pilot?	Analysis of crash data for the pre and pilot period	Safety measures, technology, other actions	Crash implications; inspection, enforcement,.
Commerce	Carrier impacts: What change in travel time, reliability, cost? State and regional indirect impacts: What change in industry productivity, competitiveness, jobs?	Carrier outreach Shipper / carrier outreach and analysis of available economic data	Service performance (travel time, reliability, cost…) Transport costs, business revenue, jobs	Modal diversion State economy
Pavement Durability	What changes in pavement wear, etc?	Pavement analysis.	Motor carrier cost responsibility---in general terms.	Pavement wear, replacement agency cost
Bridge Durability	What changes in bridge wear, life, etc?	Bridge fatigue evaluation	Motor carrier cost responsibility (?)	Bridge loadings, fatigue, deck wear, replacement agency cost….
Energy	What effect on energy use?	VMT estimates	Fuel consumption	Energy use, GHG emissions

2.0 Vehicle Effects

2.1 EVALUATION ISSUES

Before and after the one-year pilot period, the truck weight limits on the Vermont Interstate system are limited to 80,000 pounds GVW. The exception is Vermont's grandfather provision in Section 127 of Title 23, United States Code, which allows the State to issue permits for hauling unprocessed milk up to a maximum gross weight of 90,000 pounds on a five-axle tractor-semitrailer combination or truck-trailer combination on its Interstate highways.

Shortly after passage of P.L. 111-117, Vermont passed S.93, which allowed all State truck size and weight limits onto Interstate highways with no commodity limitations. This included three-axle trucks with a gross vehicle weight of 55,000 pounds; four-axle trucks with a gross vehicle weight of 69,000 pounds; five-axle trucks with a gross vehicle weight of 90,000 pounds; and six-axle trucks with a gross vehicle weight of 99,000 pounds.

The following table summarizes the configurations that were allowed on the Interstate system during the pilot, based on observations by the Commercial Vehicle Enforcement Section of the Vermont Department of Motor Vehicles (DMV).

Table 2.1 Vermont Interstate Truck Pilot Configurations

FHWA Vehicle Classification Type	**Name**	**Description**	**Observed Axle Length (First to Last Axle)**	**Registered Weight / Permitted Weight**
Class 6	3-Axle Single-Unit	Three-axle trucks with rear tandem axle. Rear axles are powered and braked. Most common 3-60-SU dump truck.	21’	55,000 lbs. / 60,000 lbs.
	3-Axle Single-Unit Dump Truck	Three-axle trucks with rear tandem axle. Rear axles are powered and braked. With varying axle distances	18’ to 26’	55,000 lbs. / 60,000 lbs.
Class 7	4- Axle Single-Unit	Four-axle trucks with rear tri-axle, at least two of these axles powered and braked. Most common 4-69 SU is a dump truck.	21’ to 24’	60,000 lbs. / 69,000 lbs.
	4- Axle Single-Unit	Four-axle trucks with rear tri-axle, at least two of these axles powered and braked. Log trucks have stake bodies with loader attached at rear. The difference in axle distances between these two 69-4 trucks is primarily caused by the placement of the "tag" or "lift" axle, this axle is typically placed in front of the drive axles on dumps and behind the drive axles on log trucks.	28’	60,000 lbs. / 69,000 lbs.
Class 9	5-Axle Tractor Semi-Trailer	Five-axle tractor/semi-trailer with standard fifth wheel hook up and truck/semi-trailer generally connected with pintle hook.	52’ to 63’ (51’*)	80,000 lbs. / 90,000 lbs.
Class 10	6-Axle Tractor Semi-Trailer	Six-axle tractor/semi-trailer with standard fifth wheel hook up and truck/semi-trailer generally connected with pintle hook.	Generally less than 51’ (43’*)	80,000 lbs. / 90,000 lbs.
	7-Axle Tractor Semi-Trailer	Seven-axle tractor/semi-trailer with standard fifth wheel hook up and truck/semi-trailer generally connected with pintle hook.	Generally less than 51’ (34’*)	80,000 lbs. / 90,000 lbs.
	6-Axle Tractor-Semi-Trailer	Six or more axle tractor/semi-trailer with standard fifth wheel hook up and truck semi-trailer generally connected with pintle hook.	51’ to 62’ (51’*)	80,000 lbs. / 99,000 lbs.

* Minimum axle spacing as per statute. SU = Single-Unit; STT = Single-Trailer Truck as per FHWA Vehicle Types

For reference, Table 5.2 presents the FHWA Vehicle Classifications, which are used for describing the shifts in truck traffic throughout the study. For example, the left column of Table 5.1, above, contains 4 of the FHWA Vehicle Classifications which were the Vermont pilot trucks, and the focus of this study.

Table 2.2 FHWA Vehicle Classifications

FHWA Vehicle Classification	Pilot Truck(s) in Classification	Definition
1		Motorcycles
2		Passenger Cars
3		Other two-axle, four-tire single unit vehicles
4		Buses
5		Two-axle, six-tire, single-unit trucks
6	●	Three-axle single-unit trucks
7	●	Four-or-more-axle single-unit trucks
8		Four-or-fewer-axle single-trailer trucks
9	●	Five-axle single-trailer trucks
10	●	Six-or-more-axle single-trailer trucks
11		Five-axle multi-trailer trucks
12		Six-axle multi-trailer trucks
13		Seven-or-more-axle multi-trailer trucks

2.2 EVALUATION METHOD/S

To identify the changes in the vehicle fleet, the research team analyzed data collected by the Vermont Department of Motor Vehicles and conducted outreach with motor carriers and shippers. From the Vermont DMV the research team obtained Interstate highway use permits issued to the pilot trucks during 2010. The permit data provide some insight into the types of shifts that occurred between truck types.

2.3 KEY FINDINGS

Private Sector

The private motor carriers made modest adjustments to the truck fleet to utilize more productive equipment during the one-year pilot. According to surveys and outreach meetings conducted with carriers and shippers, the trucking industry adjusted the fleet in the following ways:

a) used existing higher-capacity equipment previously limited to the secondary system *on* the Interstate system;

b) more fully utilized the capacity of existing equipment on the Interstate;

c) leased additional higher-capacity equipment;

d) adapted existing equipment;

e) purchased new equipment; or

f) a combination of "a" through "e".

Results vary by industry and carrier specialization. Many carriers did not acquire new or additional equipment but instead loaded existing trailers more fully to take advantage of existing capacity. For example, the petroleum distribution industry was able to more fully load existing tank trailers.

In many cases, carriers obtained additional power units and trailers to haul existing traffic more efficiently. The vehicles were acquired to allow carriers to accommodate the heavier pilot weights.

Very few carriers purchased new equipment for the pilot. Instead, carriers obtained pilot-appropriate equipment through short-term lease agreements to hedge against the temporary nature of the pilot. Carriers with multi-state operations—especially in states with higher weight limits—shifted some equipment meeting the pilot specifications to Vermont during the pilot.

A relatively small number of carriers adapted equipment, including the addition of trailer axles (to form a tridem axle grouping) to meet the specifications for the 99,000-lb. 6-axle configuration.

If the weight limits were permanently lifted, carriers indicated that they would purchase additional and/or more productive equipment within the first few years of the higher weight regime.

Public Sector

The Vermont Department of Motor Vehicles tracked some of the changes to the fleet through its permit system. The permit records show a decrease in the total number of permits issued during the pilot period from about 43,000 total annual permits to approximately 30,000 annual permits. Also, in conjunction with the pilot period, the Vermont DMV tracked the change in permits for 99,000 lb. 6-

axle trucks, which increased from 1,500 in 2009 to over 3,000 in 2010 during the pilot.

Enforcement of pilot trucks is an important public sector issue. Section 7 of this report provides data and insight on the types of enforcement issues of the pilot, including out of service rates. Another major issue relates to the certification and inspection of new or adapted equipment to ensure that the design and loading are legal and compatible. If the pilot were to continue in the future, the State of Vermont and/or the Federal Motor Carrier Safety Administration (FMCSA) may want to collaborate on establishing a means to certify equipment.

3.0 Truck Volume Effects

3.1 EVALUATION ISSUES

The question of how truck traffic changed during the course of the pilot program is a pivotal element of this study. Before the pilot program was initiated, the expectation was that truck traffic would divert from the state highways and local roads of Vermont to the Interstate highway system to take advantage of the higher speeds and more direct routing. In addition, the expectation was that truck tonnage would shift to fewer loads, thereby reducing the total number of trucks utilizing the entire highway system, but increasing average truck weight.

3.2 EVALUATION METHOD/S

In order to measure the change in truck volumes on Vermont's Interstates and local roads, the research team collected available data on truck vehicle-miles-traveled (VMT), data from weigh-in-motion (WIM) stations, traffic counts, permit data, and conducted interviews with carriers and shippers. Using these data sources, the research team estimated the change in truck weights, vehicle types, and volumes on the Interstate highways and local roads of Vermont. The key information sources include:

- **Weigh-in-Motion (WIM)** – Sensors in the roadway detect vehicle axles and weights in a network of 21 stations maintained by the Vermont Agency of Transportation (VTrans). Twelve of the WIM stations are on the Interstate, the remaining 9 are located on the state highway system. The WIM data provide the study with its most reliable data source on truck classifications.
- **Traffic Counts** – Also collected by VTrans, automated traffic count information at approximately 100 locations supplements the WIM data. Because automated counting mechanisms are less sensitive to determine axle configurations, they are not as accurate at distinguishing truck classifications but can provide good information on trends and flows of heavier trucks.
- **Statewide VMT Data** – Vehicle-Miles-Traveled data for trucks is developed by the Vermont Agency of Transportation and submitted to the Federal Highway Administration (FHWA) on an annual basis. These data include VMT for several classes of trucks on different functional classifications of highways.

The one-year pilot was expected to produce two types of changes on the highway system:

1) the weight which various truck classes carry; and

2) the number of trucks by size and the miles that they travel.

To measure the first item (weight), the research team relied on Weigh-in-Motion (WIM) data. The WIM data analysis provides information on how the weight of trucks changed during the pilot, including truck axles.

To measure the second item (truck classifications and VMT), the research team utilized the traffic count data and official 2010 Vermont VMT estimates which the State provides to FHWA by statute. Following the analytical approach presented in section 4, the research team developed "Pilot" estimates of truck VMT observed during 2010. Because the State of Vermont VMT data was provided at an aggregated level—for single unit and combination unit trucks—the research team developed a method to estimate specific truck classes using a sample of vehicle classification counts from Vermont's system of Automated Vehicle Count (AVC) stations.

For comparison purposes, the study subsequently estimated "Control" estimates of truck VMT that *would have occurred* in 2010 without the pilot. The control estimates were developed using VMT data from a multi-year period (2005 to 2009) to provide a more reliable trend than the one-year change from 2009 to 2010, which could have been influenced by a slight recovery from the national recession. Like the 2010 "pilot", the research team used Automated Vehicle Count (AVC) data to break the VMT down by vehicle type.

To validate the findings of the data analysis, the research team conducted focus groups with Vermont carriers, shippers, and railroads. VTrans also conducted a separate shipper survey to inform the study.

3.3 KEY FINDINGS

Table 6.1 summarizes the key findings of the traffic volume analysis. The results are shown for the FHWA truck classifications. The table shows single-unit trucks (SU), Classes 5, 6, and 7 and 6 combination unit (CT) trucks, Classes 8 through 13. The results compare 2010 control results (an estimation of VMT *without* the pilot) to 2010 pilot results (an estimation of VMT *with* the pilot). The results are calculated subtracting the difference between the 2010 pilot and the 2010 control. Percentage change is also shown.

Table 3.1 Summary of Truck Vehicle Miles Traveled (VMT): Control vs. Pilot

FHWA	Control (2010)		Pilot (2010)	
Class	Interstate	Non-Interstate	Interstate	Non-Interstate
5	59,130,998	244,504,975	59,130,998	244,504,975
6	10,764,037	35,019,797	10,764,037	35,019,797
7	506,668	9,152,425	1,998,723	6,421,228
8	31,565,492	49,450,007	29,906,689	50,882,889
9	91,450,272	56,443,643	93,026,429	53,286,115
10	8,992,639	14,579,984	9,235,033	13,225,695
11	2,001,974	661,972	3,309,875	625,042
12	528,811	794,164	1,091,071	349,704
13	297,874	469,740	297,874	469,740
Total	205,238,767	411,076,707	208,760,729	404,785,185

FHWA	Pilot - Control Delta			
Class	Interstate	Pct.	Non-Interstate	Pct.
5	-	0.0%	-	0.0%
6	-	0.0%	-	0.0%
7	1,492,055	294.5%	(2,731,198)	-29.8%
8	(1,658,802)	-5.3%	1,432,882	2.9%
9	1,576,157	1.7%	(3,157,527)	-5.6%
10	242,394	2.7%	(1,354,289)	-9.3%
11	1,307,900	65.3%	(36,930)	-5.6%
12	562,260	106.3%	(444,460)	-56.0%
13	-	0.0%	-	0.0%
Total		1.7%		-1.5%

As shown on the bottom line of the "Pilot-Control Delta" portion of Table 6.1, Interstate truck VMT increased by nearly 2 percent during the pilot period. During that same timeframe, truck VMT on the non-Interstate system decreased by approximately 1.5 percent. While overall changes in VMT were modest (between 1.5 and 1.7 percent), some truck classes experienced significant changes. However, it is important to keep the changes within context. For example, Class 7 truck VMT grew by more than 294 percent on the Interstate system during the pilot, but because the total Class 7 VMT was about 1 percent of the total pilot VMT this estimated change, which might itself only be a statistical aberration resulting from the small numbers involved, had only a modest impact overall.. Figures 6.1 and 6.2 illustrate the relative composition of truck VMT under control and pilot conditions.

Figure 3.1 Summary of Truck Vehicle Miles Traveled: Control (2010)

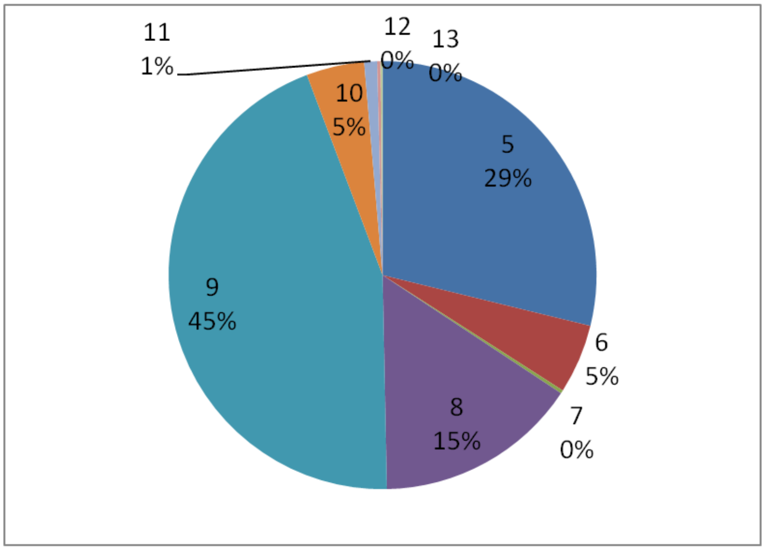
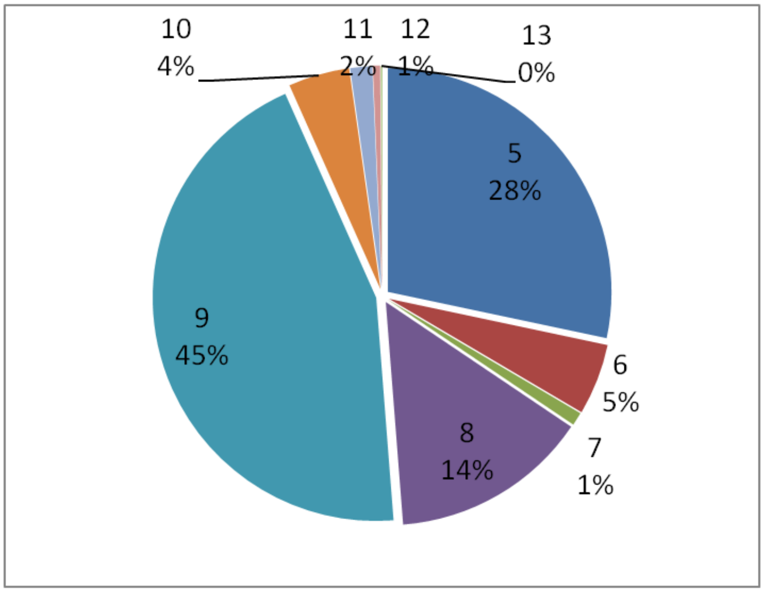


Figure 3.2 Summary of Truck Vehicle Miles Traveled: Pilot (2010)



The truck configurations allowed on the Interstates during the pilot, with the same weights previously allowed on state roads, fall within Classes 6, 7, 9, and 10 (see Table 5.1 for more detail on truck types). The pie charts show that the largest shifts—in terms of total trucks affected—occurred within Classes 7, 8, 10, 11 and 12.

Private Sector

According to outreach activities, carriers and industries maximized their use of the Interstate system and heavier truck configurations to the extent possible during the pilot period. Industries with excess weight allowances (by Vermont statute) on the non-Interstate system shifted as many miles as possible to the Interstate system. For example, carriers said they shifted traffic from secondary routes to parallel or nearby Interstates, including a general shift of traffic from US 5 to I-91; from US 2 to I-89; and from US 7 to I-89. Movements between New York and Maine could transit Vermont during the pilot period, but the effect of these longer-distance trips is unknown.

This information is validated by the VTrans shipper survey, which reports that average truck VMT on the Interstate system was approximately 24 percent before the pilot but increased to an average of 62 percent of total VMT during the pilot (an average increase of 38 percent). At the same time, shippers reported a 32 percent decrease in VMT on non-Interstate highways during the pilot. Thus the Interstate VMT increase and non-Interstate decreases were fairly close in proportion.

Public Sector

The shift of pilot trucks from the non-Interstates to the Interstate system in Vermont provides advantages and disadvantages to the public sector agencies in the State, including VTrans and local municipalities. Because the decrease in VMT on the non-Interstates was relatively small (1.5 percent), the pilot might have provided only limited relief to some communities that complained of heavy trucks using their local thoroughfares, passing close to schools and town centers. Certainly some communities with large shippers might have benefitted from the Interstate diversion more than others. Other towns might not have experienced a discernable difference in truck traffic.

For the State of Vermont, the impact of increased truck VMT on the Interstates is most closely tied to pavement and bridge costs and safety / enforcement operations, all discussed in subsequent sections of this report.

4.0 Highway Safety Effects

4.1 EVALUATION ISSUES

In order to evaluate the vehicle safety impacts the research team examined vehicle safety issues of heavier trucks including commercial vehicles operating under Vermont's special excess weight permits and illegally overweight vehicles over several years leading up to and including the 2010 pilot year. Data was gathered on commercial truck safety related issues from 2007 through 2010, with specific focus on comparisons between 2009 and the pilot year 2010. The research team analyzed crash data, inspection data and overweight violation data to determine if the redistribution of heavy truck traffic from the state highway system to the Interstate system during the pilot had measurable safety impacts. The evaluation also sought to identify highway safety and enforcement issues related to the operation of heavier trucks on the Vermont Interstate System.

4.2 EVALUATION METHOD/S

As part of the evaluation of the crash, fatality, injury and property damage caused by commercial motor vehicle crashes, the research team relied on Vermont's crash database, which is maintained by the VTrans Highway Research Division. This data includes the locations and key attributes (e.g., vehicle configuration, vehicle body type, crash type) of all crashes. VTrans provided the research team with an extract of six years of crash data so that an analysis of the State's commercial vehicle crashes could be conducted. The research team elected to analyze crashes from 2007-2010, in order to be consistent with other elements of the evaluation. Specifically, the following analyses were conducted:

- Changes in the number of fatal commercial-vehicle involved crashes by road type, 2007-2010;
- Changes in the number of injury causing commercial vehicle-involved crashes by road type, 2007-2010; and
- Changes in the number of property damage only commercial vehicle-involved crashes by road type, 2007-2010.

Figures 7.1 through 7.4 in the following section document the results of these analyses.

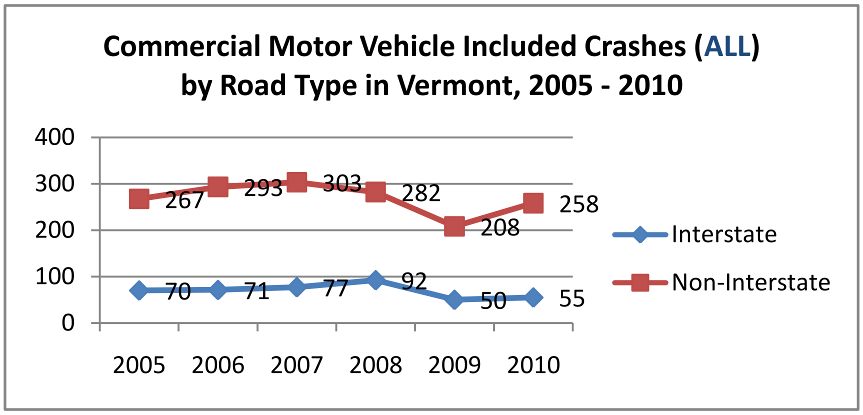
In addition to the crash data analysis, the research team examined commercial motor vehicle overweight permit records and Vermont commercial vehicle enforcement data to identify safety issues and trends during the pilot program.

4.3 KEY FINDINGS

Crash Data Analysis

The following graphs illustrate the findings of the crash data analysis conducted on 2010 pilot year performance and prior years.

Figure 4.1 Number of Commercial Motor Vehicle Included Crashes (ALL) by Road Type in Vermont, 2005 - 2010



As demonstrated in Figure 7.1, commercial motor vehicle crashes on non-Interstate roads increased from 208 in 2009 to 258 in 2010, an increase of 24%, while Interstate crashes increased from 50 crashes in 2009 to 55 crashes in 2010, an increase of 10%. Please note that while the data illustrate multi-year truck crash observations, crash records do not indicate whether trucks involved were pilot configurations.

Figure 4.2 Number of Fatal Crashes in Vermont Involving a Commercial Motor Vehicle Involved by Road Type, 2007 - 2010

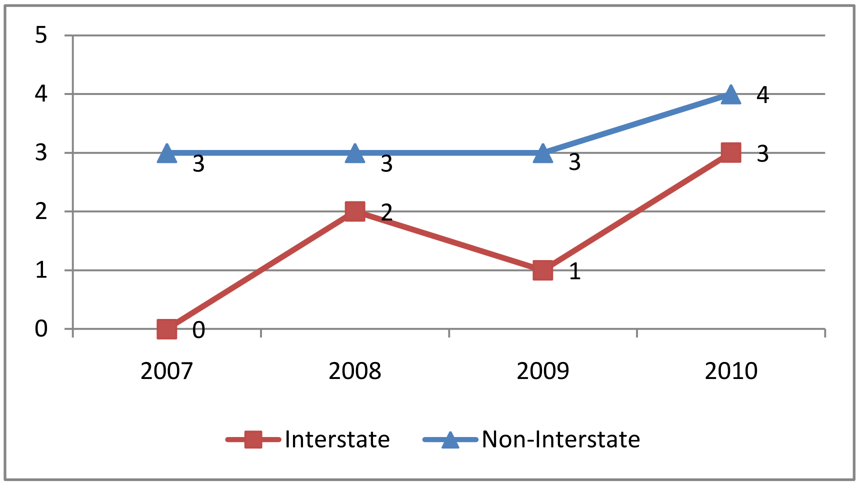


Figure 7.2 shows an increase in the number of fatal crashes from one in 2009 to three in 2010 for commercial trucks traveling on the Vermont Interstate highway system, an increase of 200%. While crash data do not differentiate between pilot trucks or other trucks, the increase in crashes had important ramifications, including costs to society. For example, the estimated costs to society for each fatality is $7.24 million per fatality, so the total cost of in fatal crashes for 2010 the pilot year was $50.7 million.

Figure 4.3 Number of Injury Crashes in Vermont Involving a Commercial Motor Vehicle Involved by Road Type, 2007 - 2010

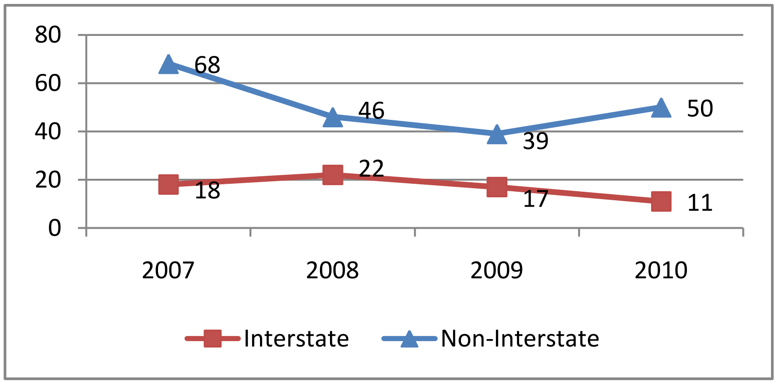
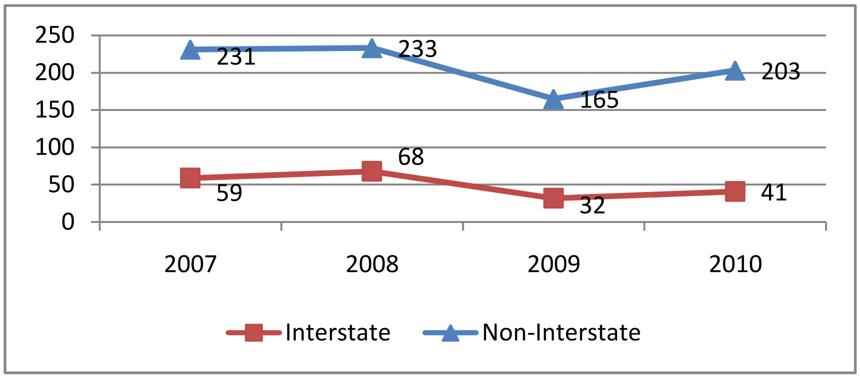


Figure 7.3 shows an increase in the number of injury crashes from 39 in 2009 to 50 in 2010 for commercial trucks traveling on the Vermont non-Interstate highway system, an increase of 28%. The estimated cost to society for each injury crash is $321,000 per injury; the total value of the injury crashes for 2010 is $3.53 million. The number of Interstate injury crashes reduced from 17 in 2009 to 11 in 2010, a reduction of 35%.

Figure 4.4 Number of Property Damage Crashes in Vermont Involving a Commercial Motor Vehicle Involved by Road Type, 2007 - 2010



As shown in Figure 7.4, the number of non-Interstate property damage crashes increased from 165 to 203 between 2009 and 2010, a one-year increase of 21%. At an estimated cost to society of $13,000 per crash, the total cost in 2010 was $494,000. The Interstate crashes increased from 2009 to 2010 from 32 crashes to 41 crashes, an increase of 27%, at an estimated cost to society of $104,000.

Safety and Enforcement Issues

In addition to the quantitative analysis of crashes, FMCSA and FHWA research team members identified a series of operational safety issues that they recommend be considered should additional pilot tests of larger commercial vehicles be considered.

The first issue related to overweight axles is braking. Figures 7.5 and 7.6 show the average load distribution on single and tandem axles, respectively. Figure 7.5 illustrates a relatively low rate of violation above the 20,000 lb. single axle weight limit (about 3%), Figure 7.6 shows a higher violation rate of 13%above the 36,000 lb. tandem axle weight limit allowed during the pilot period.

Figure 7.5 Single Axle Load Distribution (Vermont 2010 Average)

Percent of axle loads (in thousands of pounds)

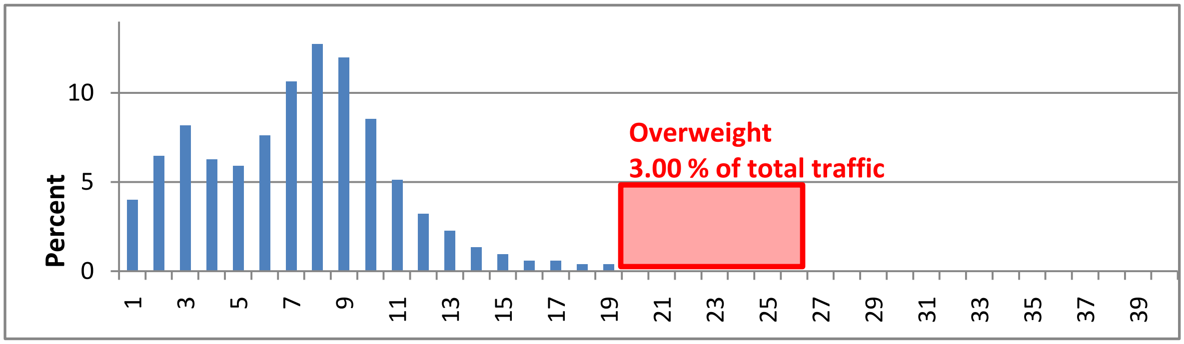
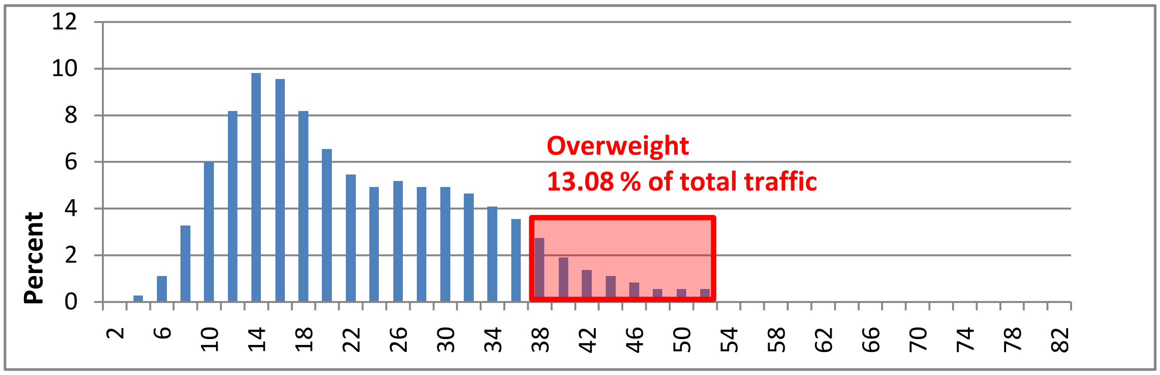


Figure 7.6 Tandem Axle Load Distribution (Vermont 2010 Average)

Percent of axle loads (in thousands of pounds)



The research team analyzed permit data with crash data to determine whether pilot trucks were involved in crashes. The Vermont DMV permit records identify that 89 carriers obtained special excess weight permits in 2010. These permits include all vehicle special excess permit categories: 60K, 69K, 90K, and 99K and could be used by carriers for multiple trucks. While these records were not designed to capture the data needed to draw definitive conclusions, the research team analyzed them to identify potential trends. By cross-referencing the names of the carriers from the permit data with crash records, the research team determined that 44 special excess permit carriers had commercial vehicles that were involved in crashes, i.e., approximately half of the "pilot" carriers had vehicles involved in crashes in Vermont during the 2010 pilot. It should be noted that crash records are not sufficiently detailed to identify whether pilot trucks were involved in the crashes. For example, special permit holders may have many trucks in a fleet, many of which may not be "pilot" trucks.

Using information on permits, vehicle weight enforcement, citations, inspections, and out of service (OOS) rates, the research team also sought to identify important safety and enforcement trends. Table 7.1 summarizes this research.

Table 7.1 Vermont Permits and Enforcement Trends 2007 to 2010

Year	Permits	Vehicles Weighed	Weight Citations	Vermont Truck Roadside Inspections	Vermont Truck OOS Rate
2007	44,179	19,174	437	9,195	19.85 %
2008	41,879	9,866	521	8,082	21.36 %
2009	30,568	11,075	406	6,293	23.07 %
2010	20,474	TBD	TBD	4,608	7.90 %

As demonstrated in Table 7.1, the total number of commercial motor vehicles weighed by law enforcement personnel on platform scales, portable or semi-portable scales has decreased significantly from a high of over 19,174 in 2007 to 11,075 in 2009. The number of cited violations decreased from just over 437 in 2007 to 406 in 2009, with permits decreasing from 44,179 in 2007 to 41,879 in 2008, to 30,568 in 2009, and 20,474 in 2010 (less than half of the permits issued in 2007). The number of roadside inspections declined during the pilot period and consequently the out of service rate experienced a double-digit decline to less than 10 percent of inspected vehicles.

Table 7.2 Comparison of Roadside Inspection Out-of-Service Rates 2007 to 2010

Year	U.S. Truck OOS Rate	Vermont Truck OOS Rate	New Hampshire Truck OOS Rate	Massachusetts Truck OOS Rate	New York Truck OOS Rate
2007	23.1 %	19.85 %	18.2 %	30.1 %	23.1 %
2008	23.1 %	21.36 %	19.4 %	28.9 %	24.6 %
2009	21.7 %	23.07 %	19.9 %	30.7 %	22.9 %
2010	20.3 %	7.90 %	18.7 %	31.8 %	17.4 %

In 2010, over 2.3 million commercial motor vehicles were inspected in the U.S., and 20.3% of those vehicles inspected were placed out of service until safety repairs were made. In 2010, Vermont conducted 4,608 truck inspections, and of those 7.90% were placed out of service. The Vermont Truck OOS rate dropped from 23.07 percent in 2009 to 7.90% in 2010. In reviewing the Vermont Commercial Vehicle Safety Plan for 2010, it was noted that 6 rest areas were closed in late 2009, which had been used for CMV inspection, and the loss of "2 DMV inspectors, 1 municipal officer, and a number of VSP troopers", could have contributed to the significant reduction in both inspections and the low vehicle out of service rate. The states surrounding Vermont (New Hampshire, Massachusetts, and New York) all showed a consistent roadside truck out-of-service rate from 2007 through 2010 although Vermont's dropped considerably in 2010.

Table 7.3 Vermont Roadside Truck Inspections 2007 to 2010

Calendar Year	Vermont Interstate Carrier Truck Inspections	Vermont Intrastate Carrier Truck Inspections	Vermont Intrastate Carrier Inspection %	U.S. Intrastate Carrier Inspection %
2007	12,029	542	4.31 %	18.05 %
2008	10,881	472	4.16 %	16.14 %
2009	8,418	344	3.93 %	16.00 %
2010	6,445	358	5.26 %	15.51 %

As demonstrated in Table 7.3, the number of intrastate commercial motor vehicles inspected during the 2010 pilot was 358 truck/combination vehicles which were only 5.26% of the total number (6,719) of Interstate plus intrastate truck/combination vehicles inspected. The nationwide intrastate carrier inspection rate was 15.51% for 2010 which is 3 times the rate of intrastate vehicles inspected in Vermont during the 2010 pilot period.

Additional analysis reveals that the vehicle out of service rate was more than twice the normal truck inspection OOS rate. For those trucks with vehicle weight violations placed OOS, the truck was placed out of service for brake violations between 54.2% and 66.2% of the time. It is important to note during calendar year 2010 (the pilot study year) that the number of weight violations went down significantly.

Vermont Commercial Motor Vehicle Annual Inspection Issues

Federal Motor Carrier Safety Regulation (FMCSR) 396.17 *Periodic Inspection,* requires that every commercial motor vehicle must be inspected annually. Vermont has a mandatory state inspection requirement that FMCSA has identified as a method to satisfy the Federal requirements. Vermont's mandatory state inspection requirement is authorized under Vermont Statute Title 23 Section 1222, *Inspection of Registered Vehicles*. However, Vermont does not mandate that commercial motor vehicles which apply for overweight permits are required to undergo any additional or more frequent inspection to determine the suitability and safety of that commercial motor vehicle to transport the higher permitted weight. Furthermore, Vermont then absolves itself of any responsibility as identified in Section J. Responsibility of Vermont's Special Excess Weight Permit (TA-VX-01 LV (d)) which reads:

> J. RESPONSIBILITY: The applicant shall assume all responsibility for injury to persons or damage to public or private property caused directly or indirectly by the transportation of vehicle or loads under the permit. Furthermore, the applicant agrees to hold the State of Vermont, Agency of Transportation, and the Department of Motor Vehicles harmless from all suits, claims, damages or proceedings of any kind as a direct or indirect result of the transportation of the vehicle and/or load.

It is important to note that Vermont's Special Excess Weight Permit (TA-VX-01 LV (d)) specifies under the section entitled "General Regulations Governing this Permit" 3(b) identifies that 4 axle trucks with a single steering axle and rear tri-axle unit (two axles of the tri-axle powered and braked) which gave a maximum gross weight of not more than 69,000 lbs., is in violation of Federal Motor Carrier Safety Regulation 49 CFR 393.42 *Brakes Required on all Wheels,* which would require that all 3 axles of the rear tri-axle of the truck have brakes rather than just two of the three axles.

Another vehicle safety concerns revolves around the 99,000 lb permitted 6 axle combination vehicles, this combination vehicle uses a 3-axle tractor configured as a single-axle steering axle and tandem drive axles, the semi-trailer is either a trailer manufacturer designed and certified to DOT Federal Motor Vehicle Safety Standards (FMVSS) tri-axle configuration or a modified tandem axle configuration with a non-OEM third axle added. The safety concern is that a trailer designed by the original trailer manufacturer with a tandem rear axle may not be structurally sufficient to withstand the added stresses placed on the trailer by the addition of a third axle and be able to withstand the added weight on the frame and body of the trailer. For a trailer originally manufactured as a tandem axle trailer, the original trailer gross vehicle weight rating may be as much as 80,000 lb. this takes into account that the maximum gross axle weight rating (GAWR) of each axle in the tandem is rated at 20,000 lb. (40,000 lb. tandem) , and counts the tandem drive axles on the tractor which support the front of the trailer as an additional 40,000 lb. For a trailer which is permitted to 99,000 lbs for a six axle combination, that is 19,000 lbs (25%) above the original manufacturer certified GVWR of 80,000 lbs, assuming that an additional axle is added to the trailer's rear tandem axle configuration. This is without any engineering consideration of the stresses the additional third axle contributes to the trailer when turning or braking.

Summary of Findings

Based on the results of the evaluation, the research team identified the following key findings: made:

- Interstate crashes increased 10% from 2009 to 2010, rising from 50 incidents in 2009 to 55 incidents in 2010. During the same period there was a 200% increase in the number of fatal crashes from one in 2009 to 3 in 2010 for commercial trucks traveling on the Vermont Interstate highway system. Similarly, an analysis of crash rates shows that the fatal crash rate increased from .49 fatal crashes per 100 million miles traveled in 2009 to 1.44 fatal crashes per 100 million miles traveled in 2010. Because there are relatively few fatal crashes involving trucks on the Vermont Interstates, an increase of two fatal crashes between 2009 and 2010 drove this dramatic increase in the crash rate. Further, it must be noted that detailed information about these crashes is not available and therefore it is not possible to determine whether pilot vehicles were involved in these fatal crashes. With the increase in fatal crashes, the costs to society increased by $7.24 million per fatality, for a total of $14.48 million. (Note: crash records are being reviewed to determine pilot vehicle involvement-Information on this will be included in final draft)
- It was expected that during the 2010 pilot that motor carriers would shift their operations from the secondary roads to the Interstate highways and that the number of accidents on secondary roads would fall. However in this case there was a significant increase in the number of crashes on non-

Interstate roads, increasing from 208 in 2009 to 258 in 2010, a 24% increase. Because VMT decreased on non-Interstate highways in 2010, this increase also signals a higher accident rate.

- Forty-four of 89 carriers with special excess weight permits, including all categories (i.e., 60,000, 69,000, 90,000, and 99,000) were involved in a crash in 2010. Please note, while the permit carriers were involved in crashes, there are no direct data to link specific pilot trucks to crashes and there is no data to differentiate whether permit carrier-involved crashed occurred on or off the Interstates.
- FMCSA detailed a number of operational safety issues that they recommend be considered with the implementation of excess weight special permits. These concerns include:

  Safety of modified trailers-- Semi-trailers in the 99,000-lb permitted 6 axle configuration use a three axle tractor and either a trailer designed and certified to DOT Federal Motor Vehicle Safety Standards (FMVSS) tri-axle configuration or a modified tandem axle configuration with a non-OEM[1] third axle added. The safety concern is that a trailer designed by the original trailer manufacturer with a tandem rear axle may not be structurally sufficient to withstand the added stresses placed on the trailer by the addition of a third axle. Further, the trailer may not be able to withstand the added weight on the frame and body of the trailer. For a trailer originally manufactured as a tandem axle trailer, this increased weight may be as much as 25% (19,000 pounds) greater than the trailers original maximum gross vehicle weight rating (GVWR).

  Verification of Gross Vehicle Weight Rating (GVWR) and Registered Weights—Most states currently do not verify a commercial vehicle's gross vehicle weight rating (GVWR) or registered weight prior to issuing a special excess weight permit. As such, they rely on the integrity of the permit applicant to honestly and accurately report the amount of weight that can be safely and legally hauled by a commercial motor vehicle. Information systems are developing, however, that allow states to electronically verify a commercial vehicle's registered weight prior to issuing a permit. Adoption of these technologies would provide an additional level of verification that could improve commercial vehicle safety.

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[1] Original Equipment Manufacturer

5.0 Pavement Durability Effects

5.1 EVALUATION ISSUES

The rate at which pavements deteriorate depends largely on the number and weight of the vehicle axle loads that they carry. Deterioration caused by automobile traffic is negligible in comparison to that caused by heavy trucks. For this study, the key research question is whether the heavier truck fleet during the pilot program accelerated pavement damage on the Vermont Interstate highway system. Except in extreme cases, techniques for measuring pavement damage "on the ground" are not sensitive enough to accurately assess the amount of damage that accumulates over a single year. Therefore, this study leveraged the results of past modeling efforts to estimate pavement damage in terms of its effect on the life-cycle costs of pavements, or the degree to which the pilot reduced the life of the pavements. Drawing on a significant body of research, the study team sought to quantify the relative impact of the heavier truck axles during the one-year pilot versus the control case in which the heavier trucks were not allowed on the Vermont Interstate system.

5.2 EVALUATION METHOD/S

The pavement evaluation relies on the Weigh-in-Motion (WIM) data and truck vehicle-miles-traveled (VMT) estimates presented in section 7 to determine the effect of the pilot trucks on pavement life-cycle costs. The study team calculated the difference in pavement damage caused by the truck fleet under the pilot and the control scenario. To identify the impacts of the heavier trucks on pavement life, the study team followed these four steps:

1. Assess Shifts in Traffic and Axle Loads

During the pilot, some heavier trucks shifted from state routes to the Interstate system while other trucks on the Interstate system started using heavier axles of the same type, or added both an axle and heavier loads. Also, some trucks that had been partly on the Interstate system increased their loads on both the Interstate and state road portions of their travels.

The research team analyzed weigh-in-motion (WIM) data collected from 2007 through 2010 to estimate the net changes in truck gross weights and axle weights by truck type on Interstate and non-Interstate highways in Vermont. The research team combined these weight changes with the truck volume estimates described in Section 7 of this report to derive overall changes in axle weights using each type of highway.

The research team determined that 2008 data would provide a more reliable control year for comparisons than 2009 in some cases because, in some cases, the 2009 data showed significant increases in vehicle weights. These unexpected increases could be attributable to anticipation of the pilot period or some other reason.

2. Calculate Overall Measures of Relative Pavement Damage

The weight carried by a vehicle axle is among the most important factors in determining how much damage it induces in the pavement, with heavier loads being many times more damaging than lighter loads. This study made use of models developed for the National Pavement Cost Model (NAPCOM) to estimate the relative damage caused by different axle weights and configurations (single, tandem, tridem) as compared to the damage caused by a 34-kip tandem axle load, for several different types of distress (i.e., manifestations of damage, including rutting, cracking and roughness).

3. Evaluate Distress Levels On Vermont Highways

VTrans collects pavement distress information biannually on Interstate, state and Class 1 Town highways. Using the most recent compilation of this distress information, the research team estimated the relative importance of each type of distress on Interstate and non-Interstate highways.

4. Estimate Pavement Cost Impacts

With the information developed in steps 1 through 3, the research team weighted the relative damage estimated for each distress type by the relative impact of each distress on pavement costs in Vermont to derive an overall assessment of overall changes in pavement damage on each type of highway. Finally, the research team estimated the annual overall pavement costs incurred by Vermont and factored in the estimated load-related share of these expenditures to derive an estimate of overall annual changes in pavement costs, as well as cost-per-LEF for each highway type.

5.3 KEY FINDINGS

More trucks and heavier trucks used the Interstate system during the pilot study, resulting in increased pavement wear. Although the overall truck traffic volumes decreased slightly on non-Interstate highways during the pilot period, operating weights of several types of trucks increased enough to nearly offset the lower volumes, so pavement damage remained virtually unchanged on these roads.

During the pilot period (2010), the Vermont Interstate system experienced an increase in vehicle operating weights for several vehicle classes. Because heavier loads are many times more damaging than lighter loads, the estimated pavement damage on the interstate increased during the pilot. Table 9.1 summarizes the change in pavement damage potential of the various vehicle classes affected by the pilot study, as well as other trucks.

Table 5.1 Summary of Changes in Pavement Damage Potential

FHWA Vehicle Class	Interstate Pavement Changes (Pilot Versus Control) 2010	Non-Interstate Pavement Changes (Pilot Versus Control) 2010
7	686.2%	-15.0%
8	-5.1%	2.7%
9	1.7%	-5.7%
10	63.9%	18.4%
11	65.5%	9.1%
12	144.0%	-25.9%
Other	0.0%	0.0%
All Trucks	11.4%	-0.4%

According to these estimates, load-related pavement damage increased by about 12% on the Interstate system and decreased by less than half of one percent on non-Interstate highways. This translates into significant increases in both the pavement maintenance and repair costs in Vermont born by the public sector agency and highway user costs due to more frequent work zones and/or deteriorated pavement conditions.

Another way of looking at the impact of the pilot study is to look at how the average damage induced by a vehicle in each class compares to the damage induced by a single 34-kip tandem axle. This table illustrates which trucks caused the greatest incremental damage during the pilot.

Table 5.2 Summary of Changes in Pavement Damage Factors per Vehicle

	Interstate			Non-Interstate		
Class	**Control**	**Pilot**	**Change**	**Control**	**Pilot**	**Change**
7	1.0	2.0	97.6%	2.3	2.98	19.6%
8	0.3	0.3	0.0%	0.4	0.4	0.0%
9	0.98	0.9	0.0%	0.9	0.9	0.0%
10	1.3	2.0	59.1%	2.1	2.7	30.1%
11	0.7	0.7	0.0%	0.5	0.5	0.0%
12	0.8	1.0	25.0%	1.8	2.7	50.1%
Other	0.1	0.1	0.0%	0.2	0.2	0.0%
All Trucks	0.6	0.61	9.6%	0.4	0.5	1.1%

Table 9.2 shows that on average, a single Class 10 truck, 1.27 times as much damage as a single 34-kip axle under the control loading conditions, and about twice as much damage as a 34-kip axle under the Pilot conditions. So, the pilot loading results in a 59 percent increase in damage due to Class 10 trucks. Interstate damage from single-unit 4 axle vehicles (FHWA Class 7) increased by 97%; damage from 6+-axle single trailer combination units (FHWA Class 10) increased by 59%; and damage from 6 axle multiple trailer combination units FHWA Class 12 increased by 25%.

Private Sector

If the Federal government allows the heavier trucks to operate in the future the private sector—individual highway users, motor carriers and shippers—will experience higher operating costs due to delays caused by more frequent work zones for pavement maintenance and repair and/or increased wear and tear on vehicles caused by deteriorated pavements.

Public Sector

Although the study lacks sufficient Vermont expenditure information to derive a precise assessment of the pavement-related costs of truck travel in Vermont, the research team used national averages and the results of detailed analyses in other states to develop estimates. Using Vermont truck weight data applied to these national average costs, a fully loaded, 80,000-lb 5-axle combination truck incurs 21.5 cents of pavement costs per-mile on the Interstate system and 32.9 cents per mile on other highways. A typical 99,000-lb 6-axle pilot vehicle requires pavement expenditures of 34.5 cents per mile of travel on the Interstate system and about 53.6 cents per mile of travel off the Interstate system—about 63% more per vehicle mile and about 32% more per ton-mile than a fully loaded 5-axle vehicle.

The findings of this analysis warrant greater examination of the potential funding gaps in pavement programs if the Federal government permanently lifted the Interstate weight limits. For example, Vermont might not be able to reorient its current Interstate pavement program to keep pace with the accelerated deterioration of the system caused by the heavier trucks.

6.0 Bridge Durability Effects

6.1 EVALUATION ISSUES

The focus of this portion of the study is on impacts to bridge durability from the pilot study trucks. This is different from the 6-month report, which focused on impacts to bridge safety. The general approach is to identify any bridges that do not provide sufficient strength, and to predict and quantify any loss in service life expected in bridges, if the pilot program of heavy trucks were to continue indefinitely on the interstate system in the state of Vermont. These impacts are monetized based on average bridge construction cost and assumed baseline performance. It is noted that this study is based on field measurements of truck weight and classification, but is purely theoretical in terms of assessment of bridge stresses and predicted performance. A one year study is not sufficient time to observe physical changes in bridge condition that could be used to quantify impacts.

6.2 EVALUATION METHOD/S

The focus of the bridge study is bridge superstructures excluding the bridge deck. Although it is probable that decks may suffer reduced performance when subjected to heavier loads, the bridge-deck deterioration models currently available deal with deterioration from de-icing agents not wheel loads. Thus, a definitive analytical study assessment of bridge deck durability as a function of increased wheel or truck loads is not possible. Similarly, bridge substructures or foundations are not included as these bridge components are typically not rated for load-carrying capacity. Therefore, the bridge study concentrates on the superstructure components supporting the deck and as we will see, typically steel girders.

Although impacts to bridge decks are not addressed directly, impacts to the deck wearing surfaces are considered. It is the practice in Vermont to provide a membrane plus asphaltic wearing surface on all bridge decks. It is surmised that because the wearing surface is made from similar materials and has similar mechanisms of failure to typical roadway pavement, that the impacts to performance will also be similar.

The analysis approach is done by performing detailed structural analysis on the interstate bridges to quantify changes in the stresses under the pilot loads, and then checking these stresses against the code-specified limits for various limit-states. Limit states are conditions under which the bridge would cease to satisfy the provisions for acceptability as per national standards. Where limit states are violated, the bridge would require posting, strengthening, or replacement for it to carry the pilot truck loading indefinitely.

The set of bridge-design criteria relating to loss of load-carrying capacity, the strength limit states, were used to understand the safety of the bridges with respect to an increase in gross vehicle weight (GVW). Based upon limited resources, the bridges were rated only at the design-load level for the HL-93 notional live-load model of the AASHTO LRFD Bridge Design Specifications and at the legal-load level for the controlling Vermont legal load in accord with the load and resistance factor rating (LRFR) provisions of the AASHTO Manual for Bridge Evaluation (MBE). (A rating factor equal to or greater than one indicates that the bridge can safely carry the load. A rating factor less than one indicates that the bridge should be posted or strengthened some action is necessary.) The ratings for the Vermont interstate bridges as currently reported in the National Bridge inventory (NBI) were developed using the load factor rating (LFR) provisions of the MBE. These LFR provisions were not used for this study as studies have shown that these provisions do not produce consistent ratings. In other words, the LFR ratings show little or no correlation to anticipated probabilities of failure. Thus, this study uses the ratings based upon the newer LRFR provisions for which the ratings show strong correlation to probabilities of failure.

The LRFR HL-93 design-load level ratings are values that could be reported in the NBI and may inform other bridge owners of the impact of overweight vehicles on the safety of their bridges.

The set of bridge-design criteria relating to durability, the service limit states of the LRFD Specifications and the MBE, are not calibrated. In other words, these design criteria may not correlate well with anticipated probabilities of failure performance. Further, these uncalibrated service limit states when exceeded (such when prestressed-concrete beams crack) do not provide a measure of loss of service life.

Another set of design criteria for steel bridges, the fatigue limit states, while not strictly calibrated are based upon probabilities of failure on the resistance side of the limit-state function (The load side is considered to be determinant.) and by estimating remaining fatigue life can provide a measure of the loss of fatigue or service life. However, the vast majority of the Vermont interstate highway bridges are steel bridges and the fatigue limit states can be used to estimate the effects of increased GVM on service life.

The fatigue lives of the steel bridges on the Vermont interstate highway system were estimated for a baseline control loading period representing the year 2010 if the pilot was not initiated and for the actual pilot loading during the year 2010. To standardize the fatigue estimates, a category C detail, one of the most common fatigue details on modern steel highway bridges, was assumed to occur at the point of maximum stress. The category C fatigue criteria were used because it is a detail type that is frequently found on most steel bridges (stiffeners and shear studs), and would provide the most meaningful measure of the impact to the bridge inventory in a broad sense. The fatigue lives for the two loading period’s conditions were estimated for a hypothetical category C detail at this critical location.

Loads

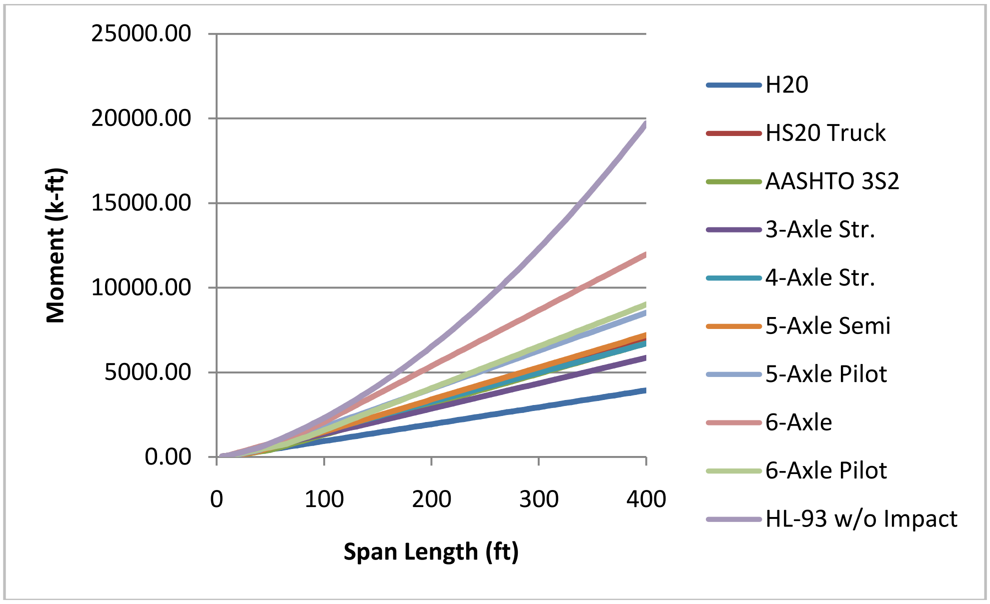
The loads under consideration are tabulated below in Table 1, including the pilot trucks as allowed by legislation, Vermont rating vehicles and traditional design and rating vehicles. What is particularly unique about these pilot truck configurations is that they have short total lengths, and are not compliant with Federal Bridge Formula B.

Table 6.1 Vermont Truck Pilot Study Rating Trucks
W = wheel load (kips), S = axle spacing (feet), SU = single unit

Truck	GVW (kips)	Length (ft)	W	S	W	S	W	S	W	S	W	S	W
H20	40	14	4	14	16								
HS20	72	28	4	14	16	14	16						
3S2	72	41	4	11	8	4	8	22	8	4	8		
3-axle SU	60	19	4	15	13	4	13						
4-axle SU	69	23	4	15	10.17	4	10.17	4	10.17				
5-axle semi	76	35	4	11	8.5	4	8.5	16	8.5	4	8.5		
5-axle 90-kip pilot	90	51	4	11	10.25	4	10.25	32	10.25	4	10.25		
6-axle 90-kip pilot	90	43	4	11	8.2	4	8.2	20	8.2	4	8.2	4	
6-axle	132	54	4	11	12.4	4	12.4	31	12.4	4	12.4	4	12.4
6-axle 99-kip pilot	99	51	4	11	9.1	4	9.1	28	9.1	4	9.1	4	9.1

The effects of the trucks included in the study were assessed by comparing moments and shears on simple-span and two-span continuous bridges of prismatic cross section for span lengths up to 400 feet. A sample plot of simple-span moments for the various trucks is given in Figure 1. It should be noted that the moments from the 99 kip 6-Axle Pilot truck is less than the HL-93 and the 6-Axle for the full range of span lengths. The 6-Axle truck is a rating vehicle that is used in the state of Vermont, as per their bridge design manual.

Figure 6.2 Vermont Truck Pilot Study Rating Trucks
W = wheel load (kips), S = axle spacing (feet)

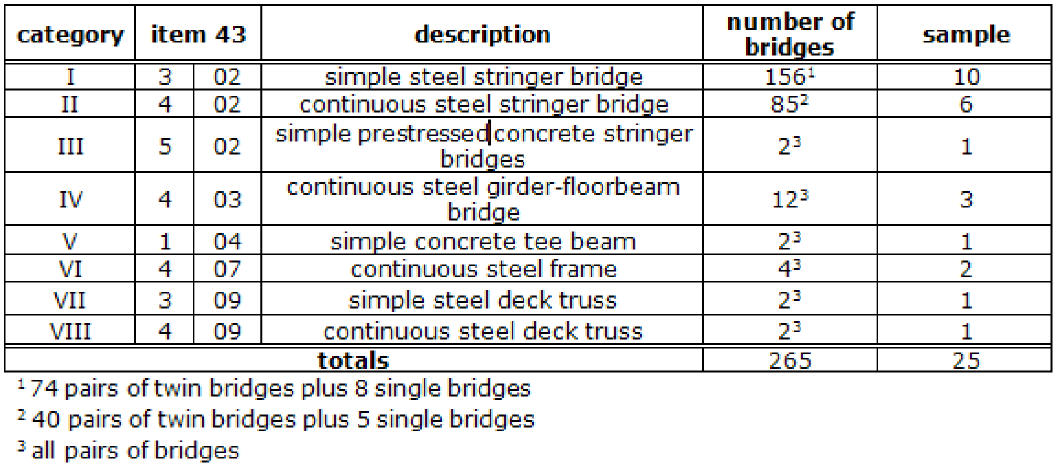


From plots of these moments and shears, the research team selected the critical truck for each bridge component being rated for strength. The critical trucks for all of the components of the 25 bridges being rated were the four-axle single unit, the 6-axle 90-kip truck or the 6-axle 99-kip truck. None of the other pilot trucks shown in Table 1 governed any components.

Bridge Sampling

A representative sample of bridges that reflects the types of bridges found on the interstate network in Vermont was used to perform detailed analysis. The results of these analyses were then used to extrapolate and quantify total impacts to the overall interstate inventory. The Vermont interstate bridge system consists of 265 bridges as tabulated below.

Table 6.2 Vermont Interstate Bridges by Type



category	item 43		description	number of bridges	sample
I	3	02	simple steel stringer bridge	156[1]	10
II	4	02	continuous steel stringer bridge	85[2]	6
III	5	02	simple prestressed concrete stringer bridges	2[3]	1
IV	4	03	continuous steel girder-floorbeam bridge	12[3]	3
V	1	04	simple concrete tee beam	2[3]	1
VI	4	07	continuous steel frame	4[3]	2
VII	3	09	simple steel deck truss	2[3]	1
VIII	4	09	continuous steel deck truss	2[3]	1
totals				265	25

[1] 74 pairs of twin bridges plus 8 single bridges

[2] 40 pairs of twin bridges plus 5 single bridges

[3] all pairs of bridges

Recognizing that the majority of the bridges are twin bridges reduces the number of bridges to about 139 unique bridges.

The following basic strategy was adopted to select a sample from these bridges:

1. Select one of each of the twin bridges in categories III and V through VIII. (No choices are necessary.)
2. Hand select three bridges from category IV to capture a good distribution of age and ADTT.
3. Select one of the bridges in category I built prior to 1985 (see the table below), hand select 2 of the 15 bridges built between 1976 and 1985 (one with ADTT <1000, the other with ADTT>1000), finally hand select 6 of the 139 bridges built prior to 1975 (three with ADTT < 1000, three with ADTT > 1000).
4. Hand select 2 of the 8 bridges in category II built between 1976 and 1985 (see the table below), one with ADTT <1000, the other with ADTT>1000; finally hand select 4 of the 77 bridges built prior to 1976 (two with ADTT < 1000, two with ADTT > 1000).
5. In general, With regard to span length, a reasonable distribution of span length should be chosen where possible.

Table 6.3 Simple Steel Stringer Bridges by Year Built

Year Built	1975 or Earlier	1976 through 1985	After 1985
Number of bridges	139	15	2
Sample	6	2	1

Table 6.4 Category II – Continuous Steel Stringer Bridges by Year Built

Year Built	1975 or Earlier	1976 through 1985	After 1985
Number of bridges	77	8	0
Sample	4	2	0

Based upon this basic strategy, VTrans the study team selected a preliminary sample of 25 bridges which is 18% of the interstate inventory considering twins. At a meeting of VTrans and the bridge study team, the sample was refined based upon VTrans's specific knowledge of the bridges and the location of heavily-traveled truck routes and finalized.

The final sample includes:

10 simple-span steel girder bridges,
6 continuous steel girder bridges,
1 simple-span prestressed-concrete girder bridge,
3 continuous steel girder-floorbeam bridges,
1 simple-span concrete tee-beam bridge,
2 continuous steel frames,
1 simple-span steel through truss, and
1 continuous steel deck truss.

6.3 KEY FINDINGS

Strength Limit States

The research team rated all of the sample bridges for the strength limit states at the design-load and legal-load levels using the LRFR provisions of the MBE. The design load is the HL-93 notional live-load model of the LRFD Specifications. The design-load level rating informs us of the bridges' load-carrying capacity relative to today's national design and rating standard. (The majority of existing Vermont interstate bridges were not designed using this newer design standard, but the design load used for the Vermont interstate bridges is not consistent with the LRFR provisions which are the only consistent rating provisions.) The legal load is the controlling pilot-truck configuration for each bridge and load effect (moment or shear). The legal-load level rating informs us of the ability of the bridges to safely carry the pilot trucks.

The live-load load factors used for both the design-load and the legal-load levels are taken directly from the MBE. The legal-load level load factors are a function of the values of the average daily truck traffic (ADTT) for each bridge which were taken from VTrans' 2010 Automatic Vehicle Classification Report.

All but two of the sample bridges rated adequately at the legal-load level for the Vermont pilot trucks. In other words, 23 of the 25 bridges of the sample can carry the pilot trucks with the minimum level of safety specified by the MBE. The two bridges which did not rate at this level were two of the three continuous steel girder-floorbeam bridges. The ratings of both of these bridges were governed by the floorbeams with rating factors of 0.85 and 0.90. For these two bridges, the bridges would need to be posted or the floorbeams strengthened to provide the safety specified in the MBE. The other superstructure components of these bridges, the girders and stringers, rated adequately for the pilot trucks at the legal-load level. Thus, the costs associated with bridge strengthening to carry pilot loads would be very small.

Fatigue Limit States

The research team also evaluated the fatigue lives of the 23 steel bridges in the sample. Fatigue life is characterized by two sets of design criteria, or limit states, in the LRFD Specifications and the MBE: the fatigue I limit state and the fatigue II limit state. These two limit states represent two distinct regimes of fatigue behavior. The fatigue I limit state represents infinite fatigue life performance in the high-cycle regime. In other words, if this limit state is satisfied the bridge will not experience significant cracking during its 75-year design life no matter how many stress cycles are applied. This is typically referred to “infinite life.” The fatigue II limit state represents finite fatigue life performance in the lower-cycle regime. In other words, if the fatigue I limit state is not satisfied and cracking is expected, the fatigue II limit state can estimate the fatigue life as a function of applied stress cycles. The fatigue limit states, fatigue I and fatigue II, inform us of the effect of the pilot trucks on the fatigue lives of the Vermont Interstate highway bridges.

Fatigue load factors are multipliers that are applied to a standard design truck (HS20) to provide adequate safety against fatigue cracking for the design life of the bridge. Instead of applying the fatigue load factors of the LRFD Specifications and the MBE which represent national values, Vermont Interstate system-specific load factors were derived. The values as specified in the AASHTO documents are given in the table below.

Table 6.5 AASHTO-Specified Fatigue Load Factors

Limit State	Load Factors
Fatigue I	1.50
Fatigue II	0.75

The AASHTO fatigue-design load when factored by the fatigue I load factor represents the maximum load for considering fatigue effects. Similarly, the AASHTO fatigue-design load when factored by the fatigue II load factor represents the effective load for considering fatigue effects. In other words, the effective load is a load that yields equal fatigue damage as the actual distribution of trucks. These factors are derived based on analysis of truck weight spectra and the moments that are generated as these are passed over bridges of varying span length.

Vermont Interstate highway system-specific fatigue load factors were derived using limited weigh-in-motion (WIM) data by vehicle class factored by percentage of each class according to the vehicle miles traveled (VMT) for the control and the pilot. The process of applying WIM data in conjunction with the VMT has been previously discussed in the section, Pavement Durability Effects. Applying these Vermont Interstate highway system-specific fatigue loads factors, The research team determined the fatigue lives of the 23 steel bridges in the sample.

The Vermont Interstate highway system-specific fatigue load factors derived as discussed above are given in the table below.

The Vermont Interstate highway system-specific fatigue load factors derived as discussed above are given in the table below.

Table 6 -- Vermont Interstate Highway System-specific Fatigue Load Factors

Limit State	Load Factors	
	Control	Pilot
Fatigue I	2.07	2.07
Fatigue II	0.74	0.76

A comparison of these load factors suggests that introduction of the pilot trucks onto the Vermont Interstate highway system will have little or no effect on the fatigue lives of these bridges as the load-factor values do not significantly change from the control to the pilot.

Of the 23 steel bridges rated for fatigue, 19 bridges were deemed to result in infinite fatigue life when the control and the pilot distributions are considered. The remaining four steel bridges estimated to have fatigue lives both during the control and the pilot equal to or greater than the 75 years , currently required by AASHTO sought during original design. The results for the control and the pilot are essentially the same since the fatigue load factors for both as shown in the table above are essentially the same. In other words, the difference in a fatigue II load factor of 0.74 and 0.76 is not significant as the error in the fatigue-life calculations is much greater than this difference.

Deck Wearing Surfaces

The impacts to bridge deck wearing surfaces are assumed to similar to roadway pavement since the materials and failure mechanisms are also similar. The pavement study team found that the pilot trucks will cause a loss of pavement service life of approximately 11%. VTrans experience indicates that bridge wearing surfaces typically last 5 years and cost $2/SF to mill and replace. Thus, the annualized additional cost for this impact is calculated to be $100,000 per year to maintain all interstate bridges (2.67M SF deck area), based on 4% real discount rate. This is very small increase in cost as compared to the overall interstate bridge program in Vermont, approximately 0.3%.

Discussion

In summary, the bridge study results indicate that the change to the truck size and weight law as considered in this pilot program would have a negligible impact to the interstate bridges in the state of Vermont. All of the bridges analyzed provide adequate load rating to safely support the pilot loads, and service life appears to be unaffected based on the fatigue limit state in the bridge girders. It was only secondary members (floorbeams) of two existing bridges that indicate any need for strengthening. This would require investment for a small, one-time upgrade. Future designs that meet LRFD will have no problem supporting the pilot loading. There is the potential for minor impacts to the deck wearing surfaces, but these costs are likely to be very small in comparison to the overall bridge program. There may be impacts to other bridge components such as decks, joints, bearings, piers, abutments, etc. but these impacts are impossible to quantify with currently available analytical tools.

It is not surprising that the Vermont interstate highway bridges for the most part adequately rate for the pilot trucks. In other words, the rating yields a rating factor equal to or greater than one, and the Vermont interstate bridges can safely carry the pilot trucks in the vast majority of cases. Historically before the LRFD Specifications and their HL-93 live-load model were mandated for federally-funded bridges, Vermont has designed their interstate bridges to carry a 28-foot long, three-axle 90-kip, called the HS25 truck. This was in excess of the live load mandated by AASHTO by 25% at the time and exceeds bridge formula B. Further, Vermont makes certain that new bridges can safely carry their 54-foot long, 6-axle 132-kip rating truck as a legal load to allow them to permit these vehicles to operate on their highways.

Fatigue is the steady accumulation of damage due to repetitive loads. In highway bridges, it's not the really heavy loads which contribute the most to fatigue but the vast majority of typical loads. During the pilot, the WIM plus VMT data suggests that the increase in heavy trucks has little or no effect on the accumulating damage as these trucks are over shadowed by the vast majority of trucks which have not changed. We characterize fatigue damage by an effective stress which is the cube root of the sum of the cube of stresses due to all of the trucks crossing the bridge. This effective stress virtually remains unchanged during the pilot and even as projected into the future. The data suggests that the pilot trucks only represent 3% of the total truck fleet. There are just not enough pilot trucks to make a difference in fatigue damage during the pilot. Obviously, if the pilot was extended or made permanent and the distribution of traffic changed as the pilot trucks became the norm, fatigue damage would increase.

It must be noted that these conclusions are based on the unique parameters that exist in this study and the conditions that exist in Vermont. The conclusions should not be taken as applicable to other states.