Truck Platooning Impacts on Bridges: Phase I – Structural Safety

Final Report

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FOREWORD

Connected and Autonomous Vehicle (CAV) technology is advancing rapidly and has potential to significantly improve the safety and efficiency of highway transportation. However, it is also recognized that the technology can create challenges for the operation, management and preservation of current transportation infrastructure and impact the design of new bridges.

CAV technology connecting trucks into "platoons" (truck platooning) for long distance travel will create higher demands on bridge structures in comparison with non-platooned trucks or connected passenger cars and light vehicles. Specifically, truck platoons may produce stresses in a bridge to a higher level than it currently experiences under typical truck loading. To be prepared for deployment of truck platooning technology, there is a need to investigate and document the potential impacts of the technology on highway bridges. These include potential impacts on structural safety (Strength Limit States), serviceability (Service and Fatigue Limit States), and durability (long-term performance).

This report documents Phase I of the research investigation of those potential impacts. This phase focused on immediate, short-term structural safety impacts of truck platooning on bridges for the Strength Limit State. This study identified probable truck platooning scenarios, assessed the magnitude of impacts from scenario analysis, developed load rating models for safe load carrying capacity evaluation of bridges for truck platoons, and identified potential design specifications modifications for new design.

I would like to express my sincere appreciation for the work of the technical advisory panel for the Phase I research, as well as staff engineers and subject matter experts from their agencies. The advice, counsel and contributions from the technical advisory panel during the course of the research and the development of this report were greatly valued.

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Connected and Autonomous Vehicle (CAV) technology is advancing rapidly in the United States and abroad. The technology allows two or more vehicles equipped with state-of-the-art driving support systems to travel closely, one following the other, forming a platoon with the vehicles driven by Intelligent Transportation Systems (ITS) technology, and mutually communicating along a certain distance. Platooning is applicable to all types of motor vehicles, including cars, buses, and trucks. Any of the Federal Highway Administration (FHWA) vehicle classes can potentially become a part of a "platoon." Potential benefits of CAV technology applied to truck platooning include cleaner operation, improved safety, and greater efficiency. Because of its potential benefits, several states and FHWA performed truck platoon demonstrations that confirmed the validity and benefit of the technology.

Available literature mostly discusses the software and hardware used in the technology and field demonstrations. Very little information is available on the effect of truck platoons on bridges. This research studied these effects at the strength limit state. Several scenarios involving different configurations of trucks and the number and spacing of trucks in the platoons were investigated to determine the effective truck platoon configurations that may be allowed without having detrimental effects to existing bridges. The number of bridges expected to be affected by each platoon configurations per State was determined and tabulated.</td></tr>
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Connected and Autonomous Vehicle (CAV) technology is advancing in the United States and abroad. The technology allows two or more vehicles equipped with state-of-the-art driving support systems to travel closely forming a platoon with the vehicles driven by Intelligent Transportation Systems (ITS) technology, and mutually communicating along a certain distance. Any of the Federal Highway Administration (FHWA) vehicle classes can potentially become a part of a "platoon". Potential benefits of CAV technology applied to truck platooning include cleaner operation, improved safety, and greater efficiency. Because of its potential benefits, several states and FHWA performed truck platoon demonstrations.

The technology also creates challenges to the management and preservation of current transportation infrastructure assets. Travel over bridges in platoons of trucks and buses may produce greater load effects than those produced by individual vehicles. Very limited information on the effects of truck platoons on bridges exists in the literature. Work under this study investigated truck platooning impacts on bridges, primarily focusing on the strength limit state. In addition, the focus was on bridges on the Interstate System (IS), the National Highway System (NHS), and the National Network for Trucks (NN).

The work in this project included the review of weigh-in-motion (WIM) data to determine the most common truck configurations and to select a representative truck configuration that was used in the study. In addition, the study also included two American Association of State Highway and Transportation Officials (AASHTO) trucks, the Type 3-3 and the 3S2 trucks. Two-, three-, and four-truck platoons with truck spacing of 30, 50, and 70 feet were included in the study. The bridge span lengths considered ranged from 30- to 300-foot simple and continuous spans.

Considering that truck platoons will be treated as legal loads and the load rating is performed for the operating level, the results of the study indicate that:

- Existing bridges currently having an inventory rating for HL-93 ≥ 1.0 using the Load and Resistance Factor Rating (LRFR) method are expected to safely support all truck platoons considered.
- Existing bridges having an operating rating for HL-93 ≥ 1.0 using the LRFR rating method are expected to safely support all truck platoons considered except for three- and four-truck platoons with 30-foot truck spacing when applied to spans longer than 200 feet.
- Existing bridges currently having an inventory rating for HS 20 ≥ 1.0 using the LFR rating method are expected to safely support all truck platoons considered.
- Existing bridges currently having load capacity to safely support AASHTO special hauling vehicles (SHVs) (generally, bridges currently having operating rating factor >1.2 for HS 20 design load operating rating using the Load Factor Rating (LFR) method) are expected to safely support all truck platoons except for three- and four-truck platoons with 30-foot truck spacing and limited cases of the end shear of simple spans of 160 feet under two-truck platoons with 30-foot truck spacing.
- Existing bridges currently having an operating rating >1.0 for HS 20 design load operating rating using the LFR rating method are expected to be impacted by two-, three- and four truck platoons with truck spacing of 30 ft. for spans longer than 100 ft. and three- and four- truck platoons with truck spacing of 50 ft. for spans longer than 130 ft.

Based on this study, allowing two-truck platoons with truck spacing as short as about 40 feet is expected to result in a small number of existing bridges needing strengthening to support this load at the strength limit state. Allowing three- and four-truck platoons may be considered in the future, but it would result in more bridges needing strengthening to safely support these loads.

Three highway systems were considered in this study: the interstate system, the national highway system and the national network for trucks (IS, NHS, and NN). Tables showing the number of bridges that are expected to need strengthening to support different platoon configurations are included in this report. The total number of bridges for the entire country is shown in Table I through Table III for the most demanding among the three different trucks used in the study.:

- Table I shows the number of bridges with platoon operating rating factor <1.00 excluding bridges currently having an operating rating factor <1.00 for the HL-93 design load using the LRFR rating method and an operating rating factor <1.2 for the HS 20 design load rating using the LFR rating method. These bridges are considered to have current load capacity adequate to support the AASHTO specialized hauling vehicles (SHVs) without restrictions.
- Table II shows the number of bridges with platoon operating rating factor <1.00 excluding bridges currently having an operating rating factor <1.00 for the HL-93 design load using the LRFR rating method and an operating rating factor <1.02 for the HS 20 design load rating using the LFR rating method..
- Table III shows the number of bridges with platoon operating rating factor <1.00 including bridges currently having a design load operating rating factor

The total number of bridges on the highway systems considered is as follows:

The interstate system (IS): 57,640 bridges
The national highway system (NHS): 145,190 bridges
The national network for trucks (NN): 102,707 bridges
The total number of bridges on the three systems combined: 163,292 bridges

Notice that the combined total number of bridges for the three highway systems is smaller than the sum of the numbers for the three individual systems because some highways are designated under more than one highway system (e.g., most IS are also part of the NHS). This also applies to the of bridges in Tables I, II and III.

Table I - Total Number of Bridges with Platoon Operating Rating Factor <1.00 on IS, NHS and NN Highways for the Entire Country Excluding Bridges Currently Having an Operating Rating Factor <1.00 for the HL-93 Design Load Using the LRFR Rating Method or an Operating Rating Factor <1.2 for the HS 20 Design Load Rating Using the LFR Rating Method.

Loading	IS	NHS	NN	Total for the three systems
Single truck	0	0	0	0
2-trucks @ 30 ft. Spacing	14	71	46	84
2-trucks @ 50 ft. Spacing	0	0	0	0
2-trucks @ 70 ft. Spacing	0	0	0	0
3-trucks @ 30 ft. Spacing	266	600	405	660
3-trucks @ 50 ft. Spacing	2	2	2	2
3-trucks @ 70 ft. Spacing	0	0	0	0
4-trucks @ 30 ft. Spacing	382	859	565	934
4-trucks @ 50 ft. Spacing	5	6	5	6
4-trucks @ 70 ft. Spacing	0	0	0	0

Table II - Total Number of Bridges with Platoon Operating Rating Factor <1.00 on IS, NHS and NN Highways for the Entire Country Excluding Bridges Currently Having an Operating Rating Factor <1.00 for the HL-93 Design Load Using the LRFR Rating Method or an Operating Rating Factor <1.0 for the HS 20 Design Load Rating Using the LFR Rating Method.

Loading	IS	NHS	NN	Total for the three systems
Single truck	0	0	0	0
2-trucks @ 30 ft. Spacing	378	1239	853	1468
2-trucks @ 50 ft. Spacing	141	420	278	497
2-trucks @ 70 ft. Spacing	30	64	43	70
3-trucks @ 30 ft. Spacing	701	2006	1382	2309
3-trucks @ 50 ft. Spacing	190	562	377	652
3-trucks @ 70 ft. Spacing	37	80	54	85
4-trucks @ 30 ft. Spacing	817	2265	1542	2583
4-trucks @ 50 ft. Spacing	196	575	383	665
4-trucks @ 70 ft. Spacing	40	84	57	89

Table III - Total Number of Bridges with Platoon Operating Rating Factor <1.00 on IS, NHS and NN Highways for the Entire Country Including Bridges Currently Having a Design Load Operating Rating Factor <1.00

Loading	IS	NHS	NN	Total for the three systems
Single truck	287	980	1478	1949
2-trucks @ 30 ft. Spacing	844	2663	2614	3878
2-trucks @ 50 ft. Spacing	500	1599	1855	2631
2-trucks @ 70 ft. Spacing	369	1190	1625	2186
3-trucks @ 30 ft. Spacing	1195	3484	3181	4777
3-trucks @ 50 ft. Spacing	571	1784	1980	2830
3-trucks @ 70 ft. Spacing	387	1229	1653	2225
4-trucks @ 30 ft. Spacing	1315	3748	3344	5075
4-trucks @ 50 ft. Spacing	581	1801	1991	2848
4-trucks @ 70 ft. Spacing	426	1284	1697	2283

1.0 INTRODUCTION

Connected and Autonomous Vehicle (CAV) technology is advancing in the United States and abroad. The technology allows two or more vehicles equipped with state-of-the-art driving support systems to travel closely forming a platoon with the vehicles driven by Intelligent Transportation Systems (ITS) technology, and mutually communicating along a certain distance. Any of the Federal Highway Administration (FHWA) vehicle classes can potentially become a part of a "platoon." Travel over bridges in platoons of trucks and buses may produce greater load effects than those produced by individual vehicles.

In current practice and research, connectivity and automation offer many approaches to enable the advanced functionality for platooning. Potential benefits of CAV technology applied to truck platooning include:

Cleaner Operation

- Truck platooning lowers fuel consumption and CO_2 emissions. A recent study by European Road Transport Telematics Implementation Coordination Organization for Intelligent Transportation Systems in Europe (Ertico ITS Europe) (Winder 2016) shows that two-truck platoons can achieve a reduction of CO_2 emissions up to 16 percent from the trailing vehicles and up to 8 percent from the lead vehicle.

Improved Safety

- Braking of the trailing trucks is automatic and immediate with reaction time shorter than the human reaction time.
- Truck platooning is expected to reduce driving workload and driver fatigue.

Greater Efficiency

- The short distance between vehicles can reduce air drag and improves fuel economy.
- Platooning means less space taken up on the road, thus allowing more trucks to use the highway without creating slow-downs and traffic jams.
- Platooning can contribute to the optimization of transportation systems, using roads more effectively and delivering goods faster. The driving range of trucks can also be extended in certain situations.

Because of its potential benefits, several States have tested truck platooning and have passed legislation to take advantage of the ITS technology it uses. The FHWA performed truck platoon demonstrations using the Cooperative Adaptive Cruise Control (CACC) System technology in September 2017 (Guo and Jenn 2017).

The technology also creates challenges to the management and preservation of current transportation infrastructure assets. Work under this study investigated truck platooning impacts on bridges, primarily focusing on the strength limit state.

The research team reviewed existing literature. Most information was related to the hardware and software used to allow the formation of truck platoons and on demonstrations of different systems. Very limited information existed on the effects of truck platoons on bridges.

The team reviewed weigh-in-motion (WIM) data to determine the most common truck configurations and to select truck configurations for this study. In addition, the study included two American Association of State Highway and Transportation Officials (AASHTO) trucks, the Type 3-3 and the 3S2 trucks.

The load effects from the three trucks were applied as single trucks and in platoons of two, three, and four trucks. The load effects were determined and compared to the load effects from the design loads used in AASHTO LRFD Bridge Design Specifications (AASHTO LRFD), 8th Edition, 2017, (23 CFR 625) and AASHTO Standard Specifications for Highway Bridges, 17th Edition, 2002 (23 CFR 625). The AASHTO LRFD (2017) is currently used for the design of new bridges while the AASHTO Standard Specifications were used in the design of most bridges constructed before the first decade of this century. The two specifications are used by all jurisdictions in the United States; however, each jurisdiction may revise them to fit its need. Truck spacings, defined as the distance between the rear axle of a truck in a platoon and the steering axle of the following truck, of 30, 50, and 70 feet were included in the study, which resulted in 30 load configurations in addition to the design loads from the two design specifications. The research team analyzed simple, two-span continuous and three-span continuous beams under each of the load configurations and considered span lengths of 30, 50, 70, 100, 130, 160, 200, 250, and 300 feet. The results were compared to those from the design loads to identify truck platoons with the highest potential for negatively affecting existing bridges. For this research, a bridge is considered to be negatively affected by a platoon when this platoon produces an operating rating factor less than 1.0 while current rating loads produce an operating rating factor equal to or greater than 1.0.

The team also screened the National Bridge Inventory (NBI) database to determine the bridges that could be negatively affected by each load configurations for the Interstate System (IS), the National Highway System (NHS), and the National Network for Trucks (NN). The number of bridges was tabulated by States for each load configuration and each highway system.

A group of 97 girder lines in existing bridges was selected from an existing bridge database provided by FHWA. The research team analyzed these bridges, which were of different common bridge types and configurations, under different platoon and design load scenarios. The results were compared to the results of the screening of the NBI database and confirmed the validity of the screening results.

The team then analyzed a group of 2,941 girder lines in existing bridges to further confirm the screening results. The percentage of bridges that could be affected by the platoon loadings was greater than the percentage of bridges in the screening of the NBI database. The research team concluded that the difference is that the bridges on the three highway systems included in the screening of the NBI database (SI, NHS, and NN) tend, on average, to be in better shape than the bridges on other smaller highways. The bridges represented by the 2,941 girder lines were meant to represent a cross-section of all bridges and include many older bridges (designed to HS 20 and lower loads) that tend to have lower load capacity and thus could be more affected by the platoon loadings.

The results of the study were used to identify the articles of the design and rating specifications that should be revised to account for platoon loadings.

2.0 LITERATURE REVIEW

A comprehensive literature search was performed. Although many publications could be located, none presented work specifically performed to determine the effect of truck platoons on bridges. Most past work focused on the development of the platooning technologies, safety issues, and level of fuel economy. Conclusions from the literature search are summarized as follows:

- Most available literature considers development of the technology (hardware and software), investigation of safety issues, and fuel savings. No studies of the effect of platoons on bridges could be located.

- Truck clear spacings as small as 20 feet (measured from leading truck rear bumper to following truck front bumper) have been used in field testing of truck platoons.

- A variety of systems for platooning have been developed worldwide. These systems differ in the number of vehicles included in a platoon, the direction of control (lateral and/or longitudinal), degree/level of human control (fully autonomous/partially operated by the driver), etc. However, these platooning systems use hardware and software that is not used in existing trucks. Such trucks will need to be upgraded with assistive systems (adaptive cruise control, automatic emergency braking, lane keeping assistant, etc.).

- The most common configuration of vehicles to form the platoon could be FHWA Class 7 (4- or more axle single unit), Class 8 (3- or 4-axle single trailer), and Class 9 (5-axle, single trailer) trucks since these vehicle types are commonly found in operation based on WIM data.

- The fuel efficiency of jointly operating vehicles mostly depends on the spacing between trucks, the number of vehicles in the platoon, vehicle configuration, speed, and the time vehicles are in the platoon as a percentage of the total travel time.

- The maximum fuel consumption reduction for a two-truck platoon corresponds to the spacing between vehicles (gross vehicle weight [GVW] of 60-80 kips and speed of 65 mph) equal to 30-50 feet. Peak fuel savings for the lead vehicle occurs at a 30-foot spacing (4-6 percent), while the trailing vehicle demonstrates the highest savings (10-15 percent) at 50-foot spacing and maintains it for the longer spacing (100-150 feet).

- The optimum (the most efficient) truck platoon configurations, however, do not satisfy many State regulations that specify the allowed minimum between truck spacing.

The literature search is included as Appendix A.

3.0 STUDY OF WEIGH-IN-MOTION DATA TO DETERMINE MOST COMMON TRUCK CONFIGURATIONS

3.1 WIM DATA INCLUDED IN THE STUDY

WIM data collection provides a powerful tool for estimating the effective traffic load. The research team used the following sources of WIM data to determine the most common truck configurations (axle-load distribution and axle-spacing configuration):

- WIM data obtained for NCHRP Project 12-76 (Sivakumar et al. 2008) – 13 WIM sites covering 3 States for 2005-2008 (Table 1).

- WIM data obtained from FHWA for SHRP 2 Research Reports (SHRP 2 Research Reports 2015) – 18 WIM sites covering 15 States for 2005-2006 (Table 1).

- WIM data obtained from FHWA Long-Term Pavement Performance program – 18 WIM sites covering 17 States for 2005-2011 (Table 2).

- WIM data obtained from Alabama Department of Transportation (ALDOT) – 12 WIM sites for 2006-2017 (Table 3).

- The first three sets of WIM data were previously used for several studies and their use provided consistency of the data across studies. The last set of data was more recent data to incorporate any recent changes in truck configurations. The "Lane ADTT" in Table 1 through Table 3 is that for the lane used to record the data, typically the right lane of multi-lane highways.

Table 1. WIM States and Number of Records (NCHRP 12-76, FHWA Data Used for SHRP 2) 2005-2008

#	State	Total Number of Truck Records, N	Period of taking records	# of WIM Sites	Lane ADTT
1	MS	5,914,950	2006	5	2,967
2	CA	13,458,818	2006-2007	6	8,366
3	FL	4,143,162	2005-2006	3	2,558
4	AR	1,675,349	2008	2	3,919
5	AZ	1,466,033	2008	1	4590
6	CO	343,603	2008	1	941
7	DE	201,677	2008	1	553
8	IL	854,075	2008	1	2340
9	IN	185,267	2008	1	508
10	LA	477,922	2008	1	1309
11	MD	328,778	2008	1	235
12	ME	183,576	2008	1	503
13	MN	55,572	2008	2	450
14	NM	725,382	2008	1	1,667
15	PA	1,495,741	2008	1	4098
16	TN	1,622,320	2008	1	4445
17	VA	259,190	2008	1	710
18	WI	226,943	2008	1	622

Table 2. WIM States FHWA Long-Term Pavement Performance Program – 2005-2011

#	State	Total Number of Truck Records, N	Period of taking records	Lane ADTT
1	AZ	5,796,376	2007-2011	209
2	AR	17,402,870	2007-2011	4,536
3	CA	19,092,412	2008-2011	3,709
4	CO	8,592,990	2006-2011	920
5	DE	9,357,123	2007-2011	449
6	IL	18,656,899	2005-2011	2,339
7	IN	6,473,806	2008-2011	953
8	KS	12,835,262	2006-2011	1,238
9	LA	6,199,867	2008-2011	215
10	ME	5,817,763	2007-2011	469
11	MD	17,595,476	2006-2011	342
12	MN	4,219,742	2006-2011	134
13	NM	3,866,110	2008-2011	434
14		6,015,923	2008-2011	2,518
15	PA	14,455,909	2007-2011	3,976
16	TN	17,864,184	2007-2011	4,523
17	VA	7,097,734	2007-2011	625
18	WI	6,175,858	2007-2011	568

Table 3. Number of Vehicles in the ALDOT WIM Database for Years 2006-2017.

Station code	Period of taking records	Total Number of Truck Records, N	Lane ADTT
911	2006-2008, 2013-2017	2,354,130	704*
915	2006-2008, 2010-2017	2,415,890	478*
931	2006-2011, 2014	12,839,543	2,518*
933	2006-2011, 2013-2017	6,040,557	1,168*
934	2006-2008, 2013-2017	3,703,494	1,348*
942	2006-2008, 2013-2017	5,263,320	1,475*
960	2006-2008, 2013-2017	2,229,743	656*
961	2006-2008, 2013-2017	7,060,813	2,499*
964	2006-2011, 2013-2017	4,947,173	813*
965	2006-2008, 2013-2017	11,322,124	3,492*

* ALDOT WIM data is for multilane cases, lane with maximum average daily truck traffic (ADTT) is listed

3.2 WIM DATA FILTERING

A correctly installed and maintained WIM system produces the high quality traffic data that bridge and transportation engineers can use for analysis (Pigman et al. 2012; Quinley 2010). However, because WIM data collection inevitably involves recording some errors (random or systematic), these data should be "filtered" to remove erroneous records by applying a set of quality control (QC) criteria developed based on a comprehensive literature review and permit data analysis. Filtering also removes lightweight vehicles that are insignificant. Table 4 shows the filtering criteria used to eliminate what are likely to be erroneous records.

Table 4. Quality Control Criteria (Criteria Applied Instantly During the Recording Process)

No.	Filtering Criteria	Description
1	FIPs State code	(Ramachandran et al. 2011)
2	Station ID	In range (Ramachandran et al. 2011)
3	Direction of Travel code	In range (Ramachandran et al. 2011)
4	Lane of Travel	In range (Ramachandran et al. 2011)
5	Year of data	In range (Ramachandran et al. 2011)
6	Month of data	In range (1 to 12) (Ramachandran et al. 2011), (*Traffic Monitoring Guide* 2016)
7	Day of data	In range (1 to 30) (Ramachandran et al. 2011), ("Traffic Monitoring Guide" 2016)
8	Hour of data	In range (0 to 23) (Ramachandran et al. 2011), ("Traffic Monitoring Guide" 2016)
9	Vehicle class	1 to 13 ("Traffic Monitoring Guide" 2016)
10	Zero GVW	Hour without any weight records (Ramachandran et al. 2011), (Pelphrey et al. 2008)
11	Any field with a null value	Field Value = Null (Ramachandran et al. 2011)
12	Number of Axle	Range (from 2 to 12) (ALDOT recording limits); • N_{axle}> 25 (Ramachandran et al. 2011); • N_{axle}> 22 (ALDOT permit database);
13	Axle loads	Axle load is out of range: • 1 kip <W_{axle} (Qu, Lee, and Huang 1997) • W_{axle}< 70 kips (Sivakumar et al. 2011)
14	Axle spacing	Axle spacing is out of acceptable range: • 3.2<L_{axle}<70 ft (Pelphrey et al. 2008)
15	Number of Axles = Number of Axle Spaces + 1	(Ramachandran et al. 2011)
16	Number of Axles = Number of Axle loads	(Ramachandran et al. 2011)
17	Sum of Axle loads ≠ GVW	The practical limit is being set to incorporate error in weight sensors: • Limit is ±10% ((Pelphrey et al. 2008), (Sivakumar et al. 2011)
18	Minimum First Axle Space	Record in which the first axle spacing is: ▪ L_{axle1} < 6 ft (Pelphrey et al. 2008);

No.	Filtering Criteria	Description
19	Minimum length of the vehicle	Record in which the sum of the axle spacing lengths is less than 7 ft (Pelphrey et al. 2008)
20	Maximum length of the vehicle	Record in which the sum of the axle spacing lengths is ▪ L_{total} > 215.19ft (ALDOT permit database);
21	Records with misplaced characters	Such as a letter where a number should be or a number where a letter should be (Ramachandran et al. 2011);
22	Records with identical records (rows)	(Pelphrey et al. 2008);

3.3 MOST COMMON VEHICLE TYPES THAT COULD FORM A PLATOON

One or a few types of vehicles can control the live load model. The distribution of GVW and live load effects for each WIM site depends on traffic mix, in particular the dominating vehicle types. The FHWA specifies the configurations of vehicle classes as shown in Figure 1.

While less common than Class 9, Class 11 twin trailers are commonly used by less-than truckload carriers for hub to hub movements along certain routes. Because of the frequency of shipment between these hubs, there could be potential for platooning these types of trucks. The average weight of less-than truckload carrier trucks tends to be less than truckload carriers. In addition, the twin trailer configuration of Class 11 trucks typically results a larger total length of the truck than the tractor-semitrailer configurations of Class 9. Therefore, Class 11 trucks used by less-than truckload carriers are not expected to produce higher load effects than those from Class 9 trucks.

Vehicle classification is primarily based on axle spacing configuration. Typically, WIM systems installed in most locations process input data based on Scheme F (Cambridge Systematics, Inc. 2007; *Traffic Monitoring Guide* 2001). The main principle is a comparison of measured axial spacing with corresponding values for individual vehicle classes. Vehicle class then is verified based on the expected GVW and reclassified if needed.

The research team considered the proportion of each FHWA vehicle class, as well as the distribution of GVW and truck wheelbase, for all States in the United States. GVW for Classes 1 through 6 is relatively low and, therefore, were not considered in determining the possible truck configurations for the platoons. Five-axle, tractor-trailer trucks classified by FHWA as Class 9 vehicles was the dominating class for all considered States. The most common type of truck on the U.S. roads is a Class 9 (tractor-semitrailer, 5-axle trucks) (Figure 2). Of the 10 States considered in Figure 1 and Table 5, the only other heavy truck classification that has a significant presence is Class 10 (6- or more axle single trailer trucks) in Maine (19.47 percent). Other heavy truck classes (Class 8, 11, 12, and 13) do not represent a significant percentage of trucks in any State:

- Class 8 representing 7.84 percent of trucks in Maryland, and less than 5.44 percent elsewhere
- Class 11 representing 5.63 percent in Arkansas

- Class 12 representing 2.04 percent in Arkansas
- Class 13 representing 0.18 percent in Maryland

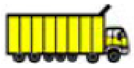
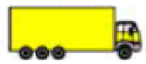
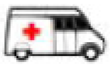
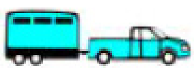
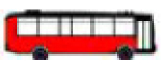
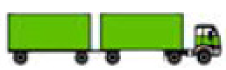
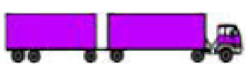
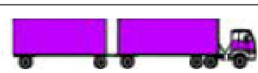
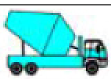
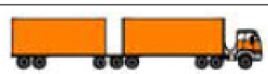
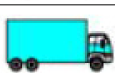
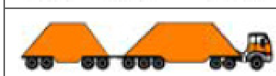
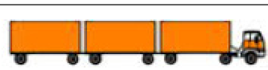
Vehicle Class	Example	Vehicle Class	Example
Class 1 Motorcycles		Class 7 Four or more axle, single unit	
Class 2 Passenger Cars			
			
		Class 8 Four or less axle, single trailer	
			
Class 3 Four tire, single unit			
		Class 9 Five axle tractor semitrailer	
			
Class 4 Busses		Class 10 Six or more axle, single trailer	
			
		Class 11 Five or less axle, multi trailer	
Class 5 Two axle, six tire, single unit		Class 12 Six axle, multi trailer	
			
		Class 13 Seven or more axle, multi trailer	
Class 6 Three axle, single unit			
			
			

Figure 1. The FHWA Vehicle Classification (FHWA, 2014)

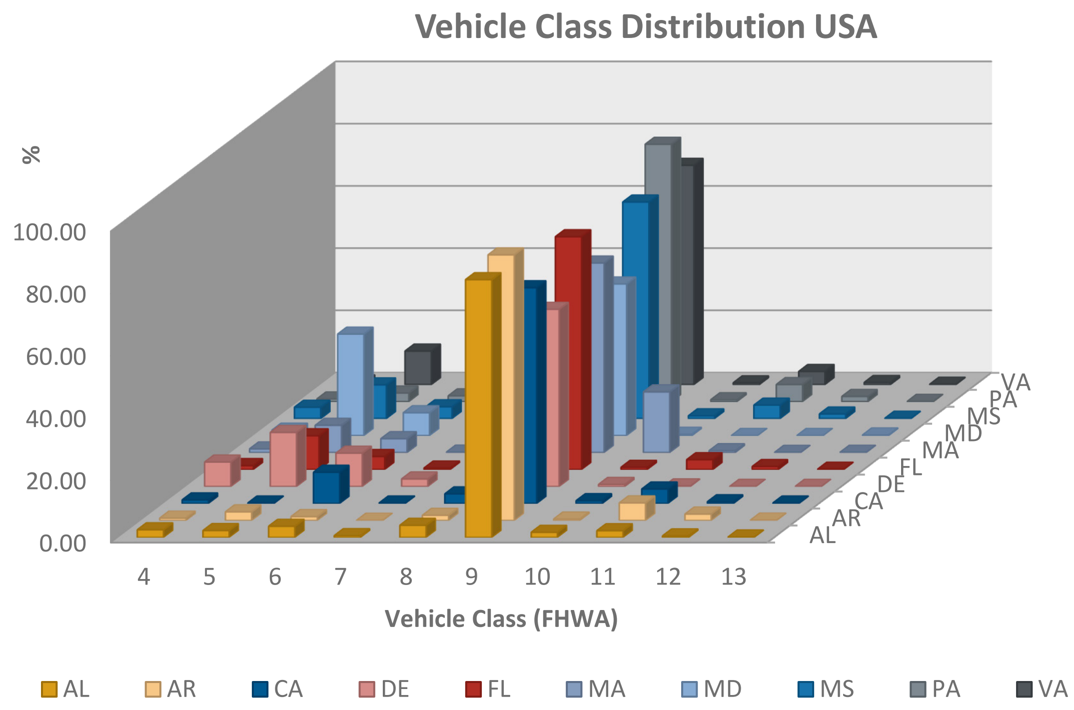


Figure 2. Percentage of Each Vehicle Class in the United States

Table 5. Percentage of Vehicles (GVW ≥20 kips) in Each Class Based on Scheme F Classification

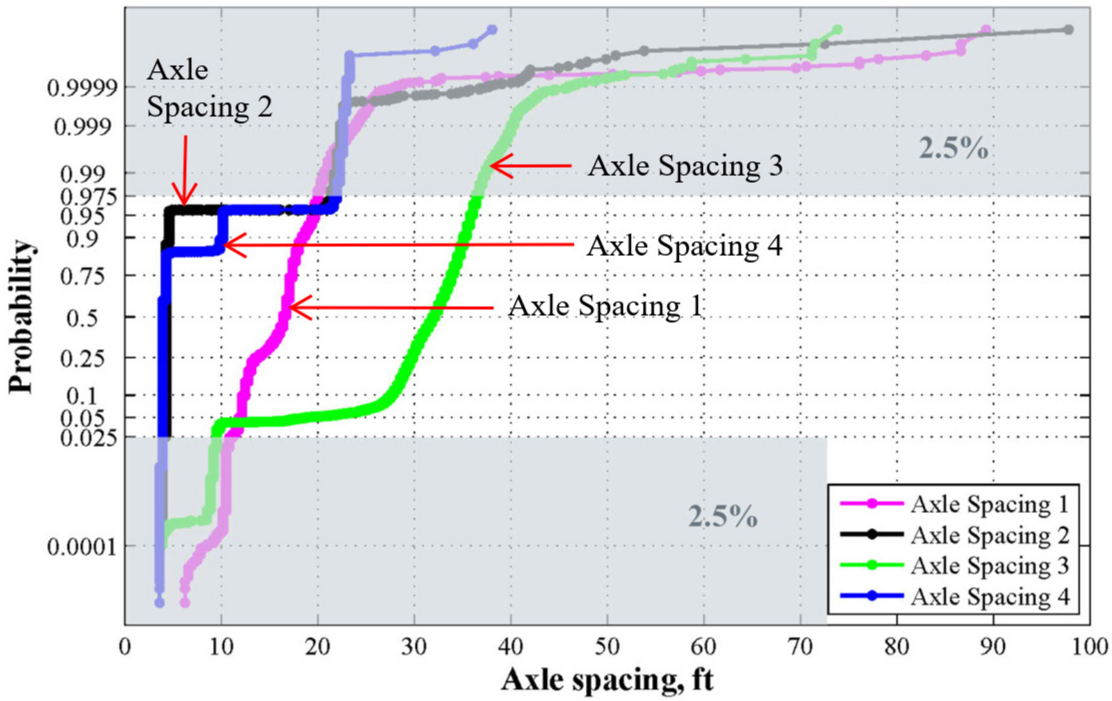
FHWA Class	AL 2006-2014	AR 2008	CA 2008	DE 2008	FL 2005	ME 2008	MD 2008-2009	PA 2008	MS 2008	VA 2008
4	2.46	0.75	1.15	7.85	1.25	1.16	1.74	0.83	3.62	0.86
5	2.20	2.76	0.15	17.36	10.84	8.72	32.56	2.73	10.81	10.75
6	3.59	1.23	10.04	10.71	4.17	4.43	7.33	1.83	3.78	6.65
7	0.58	0.07	0.17	2.42	0.47	0.14	1.28	2.72	0.04	0.37
8	3.91	1.65	3.08	3.83	3.58	4.53	7.84	1.46	5.44	5.36
9	82.80	85.29	69.29	56.88	74.77	60.87	48.67	82.68	69.56	70.45
10	1.65	0.45	0.89	0.66	0.71	19.47	0.38	0.59	0.88	0.56
11	2.15	5.63	4.64	0.19	3.15	0.58	0.01	5.46	4.30	4.21
12	0.51	2.04	0.56	0.04	0.95	0.04	0.01	1.63	1.47	0.68
13	0.15	0.12	0.15	0.05	0.12	0.08	0.18	0.07	0.09	0.10

The distribution of axle spacing, total wheelbase, GVW, and axle load distribution were considered separately for each vehicle class. For example, using the available WIM database for WIM site AL911 located at US 280 Coosa County, the cumulative distribution functions (CDFs) of the axle spacing configuration, as well as axle load distribution for Class 9, are shown in Figure 3 and Figure 4, respectively. The upper tails of CDF curves of axle spacings show the maximum spacing varies from 60 to 100 feet (part "a" of Figure 3). However, such cases are extreme and, therefore, not appropriate for typical configuration analysis. To select the most common axle spacing, the top and bottom 2.5 percent of values for each spacing were eliminated (part “b” of Figure 3). Although the selection of the percentage (2.5 percent) was arbitrary, it appeared to have eliminated the extreme values.

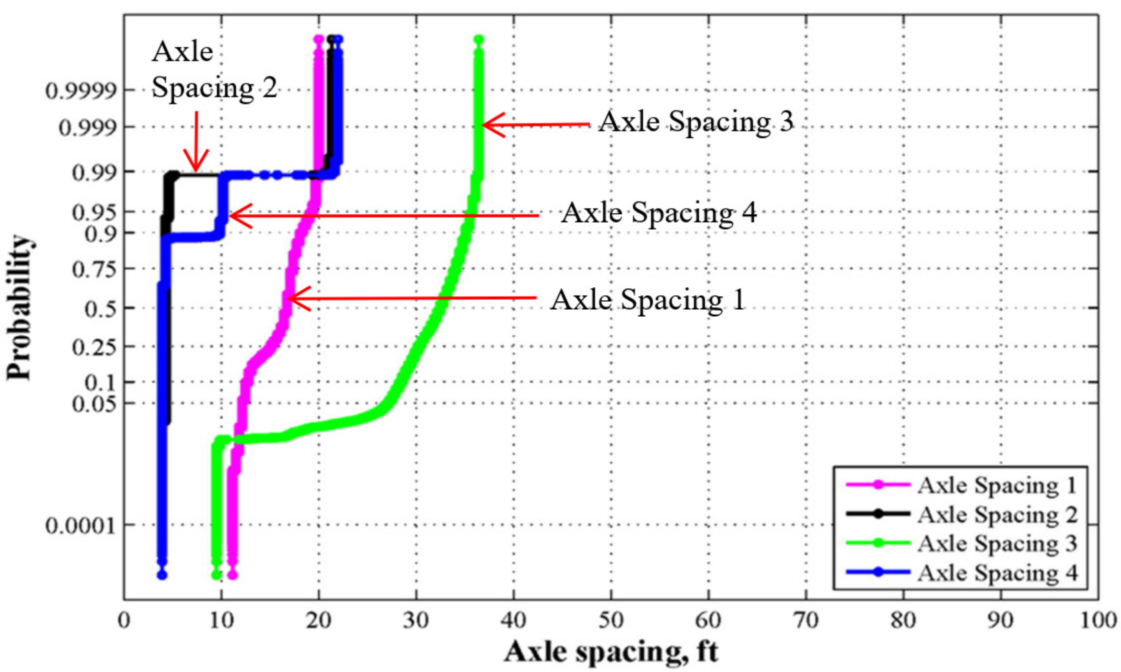
The database collected at this WIM site consists of 1,104,895 records in 2014, 886,156 in 2015, and 1,338,865 in 2016. Application of the QC filtering procedure eliminated 60-70 percent of records as light weight vehicles (<20 kip) and errors or unrealistic vehicles. Class 9 includes 278,353 vehicles (77 percent of 2014 data remained after filtering), 274,903 vehicles (78 percent of 2015 data remained after filtering), and 278,353 vehicles (77 percent of 2016 data remained after filtering).

Figure 4 shows both the CDFs of the axle load distribution for the entire data and after the removal of the top and bottom 2.5 percent.

The parameters of the 5-axle truck are distributed as shown in Table 6 through Table 11. Class 9 has two different configurations as shown in Figure 1. One configuration shows the two rear axles tightly spaced, and the other shows the two axles spread apart. The distribution of the spacing between the rear axles shown in Table 8 indicates that the great majority of Class 9 trucks have the rear axles tightly spaced, and only about 8.2 percent of the trucks in the class have the two axles widely spaced.

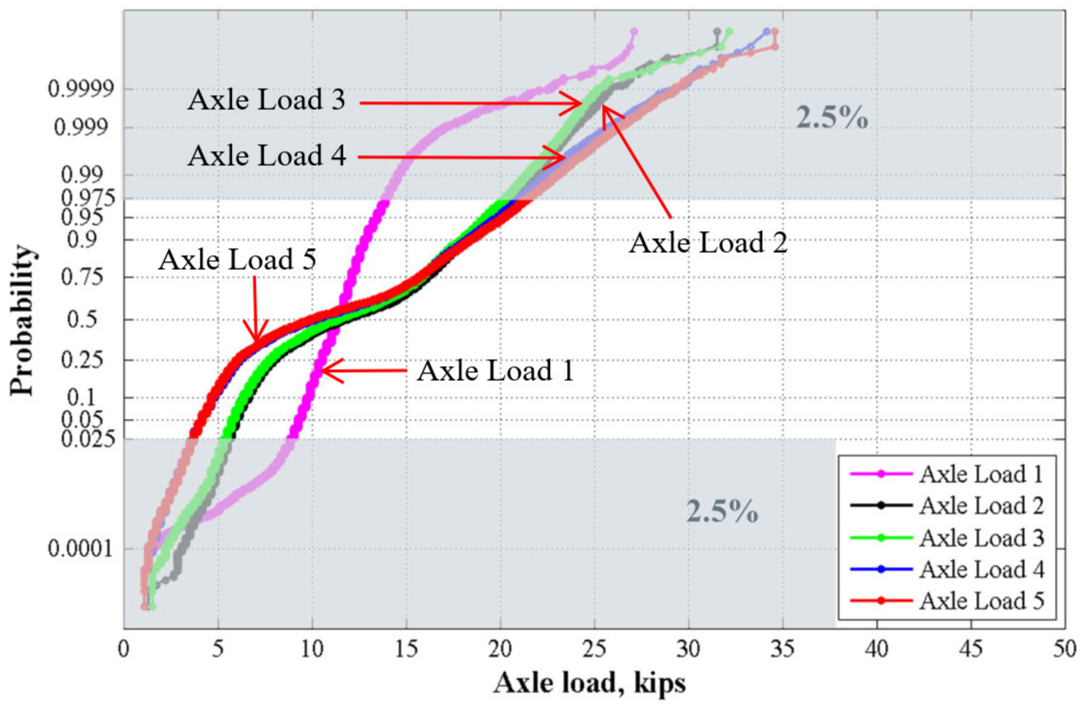


a)

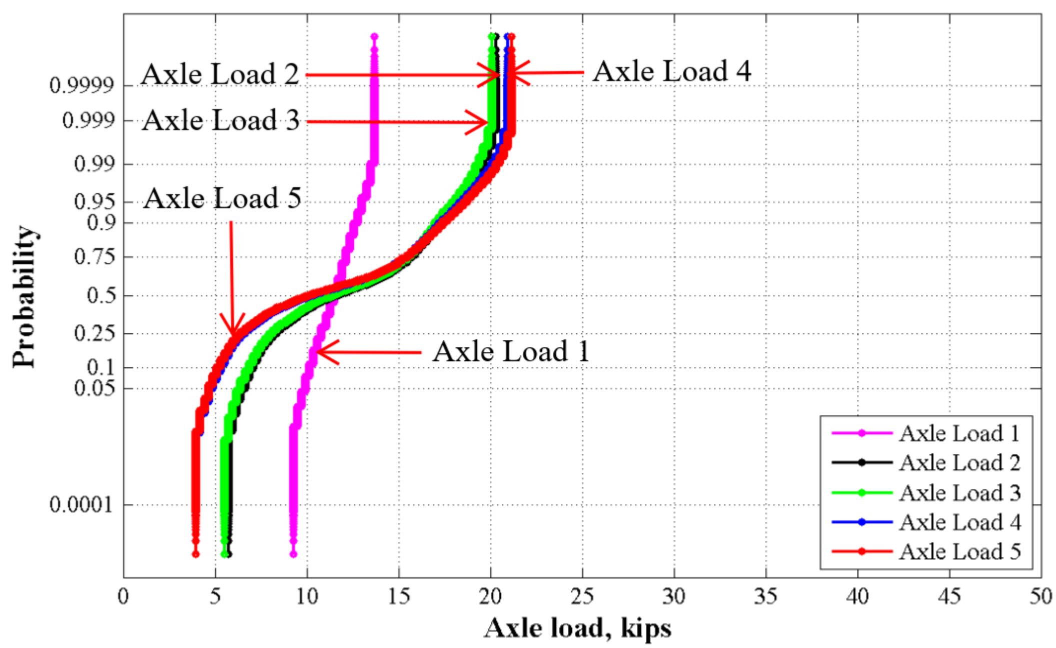


b)

Figure 3. CDFs Axle Spacing for WIM Site 911 (US 280 Coosa County, AL) in 2016



a)



b)

Figure 4. CDFs Axle Load for WIM Site 911 (US 280 Coosa County, AL) in 2016

The CDFs for axle spacing and axle loads for 6-axle trucks recorded at WIM site AL911 located at US 280 Coosa County are shown in Figure 5 and Figure 6, respectively. The database of 6-axle vehicles collected at this WIM site consists of 7,733 (2.1 percent) records in 2014, 7,484 (2.1 percent) in 2015, and 6,403 (1.7 percent) in 2016 after filtering. These vehicles are most often classified as FHWA Class 7 (4- or more axle, single trailer trucks), Class 10 (6- or more axle, single trailer trucks), and 12 (6-axle, multi-trailer trucks) that are not dominating classes in the truck traffic stream.

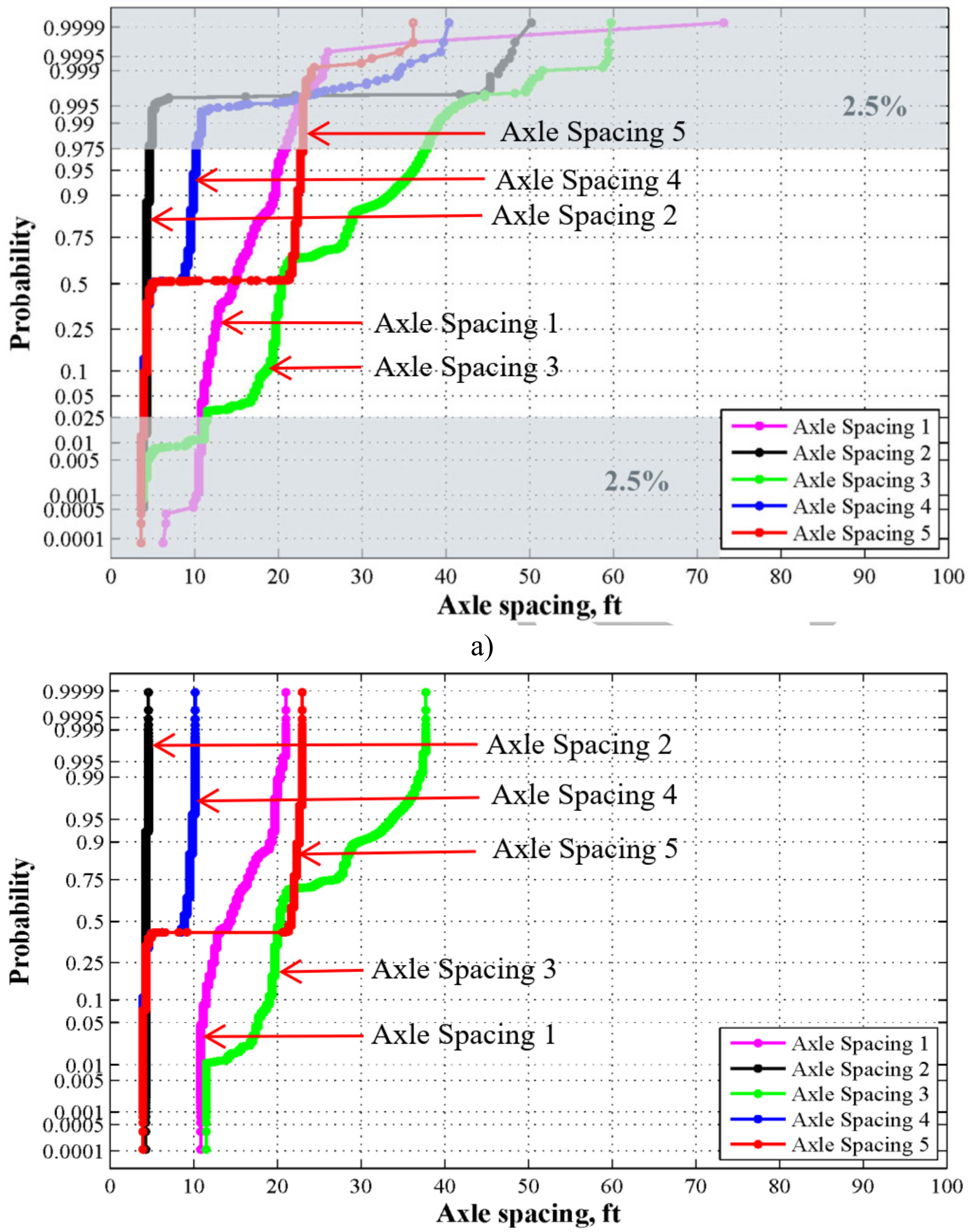
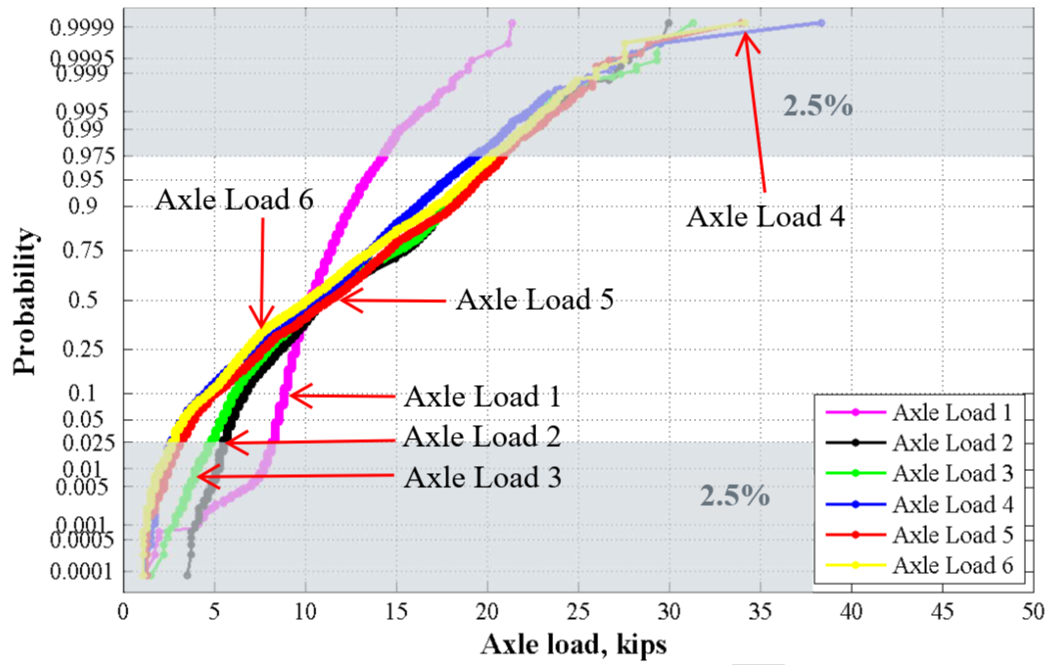
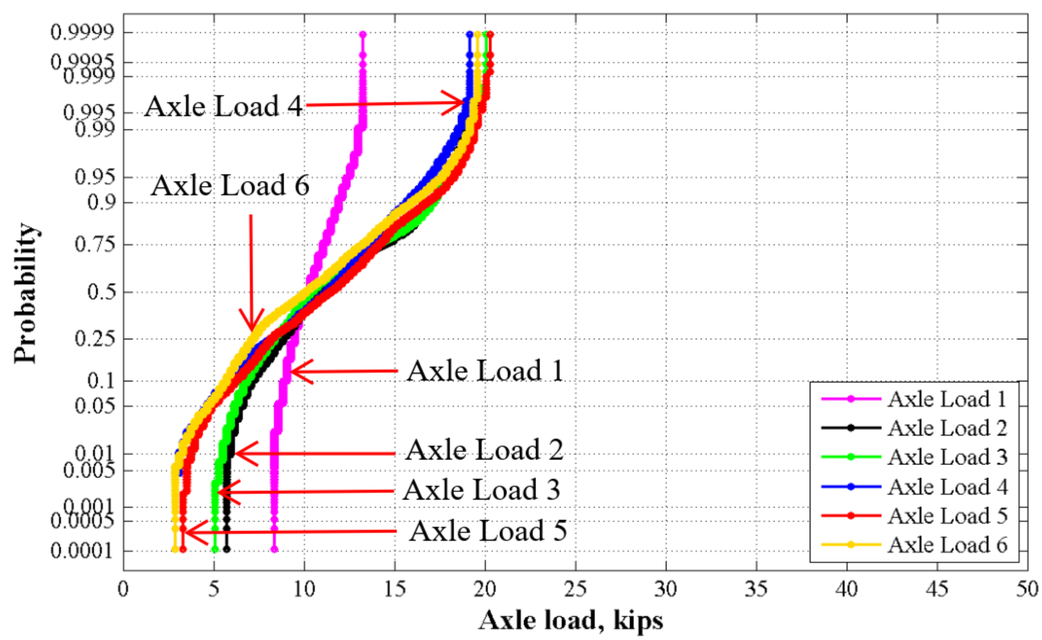


Figure 5. CDFs of Axle Spacing for 6-Axle Vehicles at WIM Site 911 (US 280 Coosa County, AL) in 2016



a)



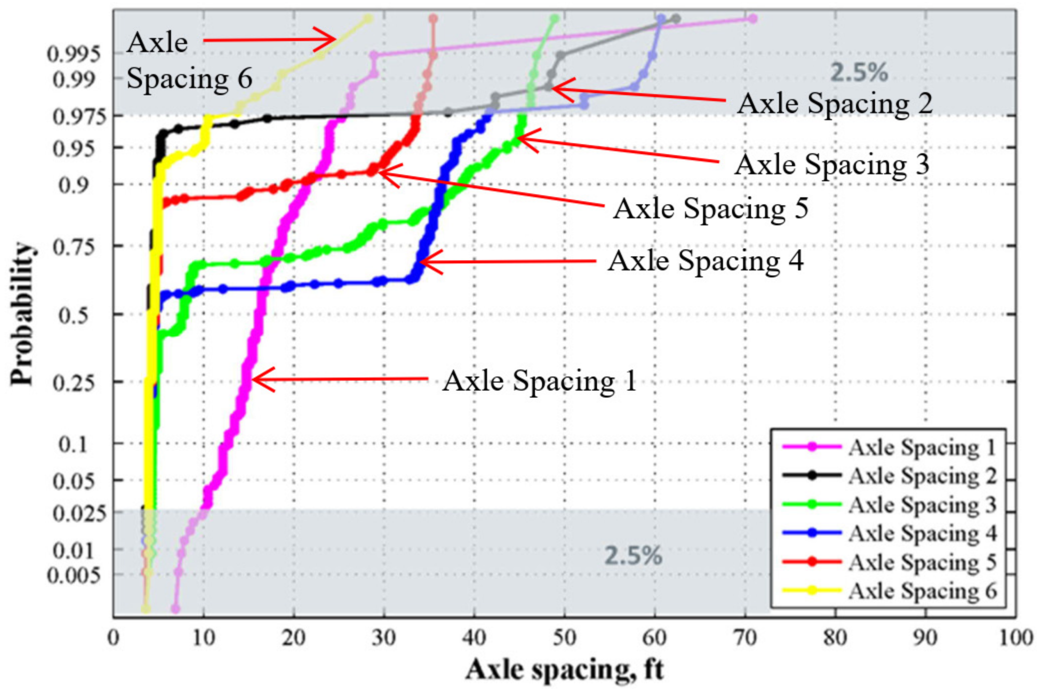
b)

Figure 6. CDFs of Axle Load for 6-Axle Vehicles at WIM Site 911 (US 280 Coosa County, AL) in 2016

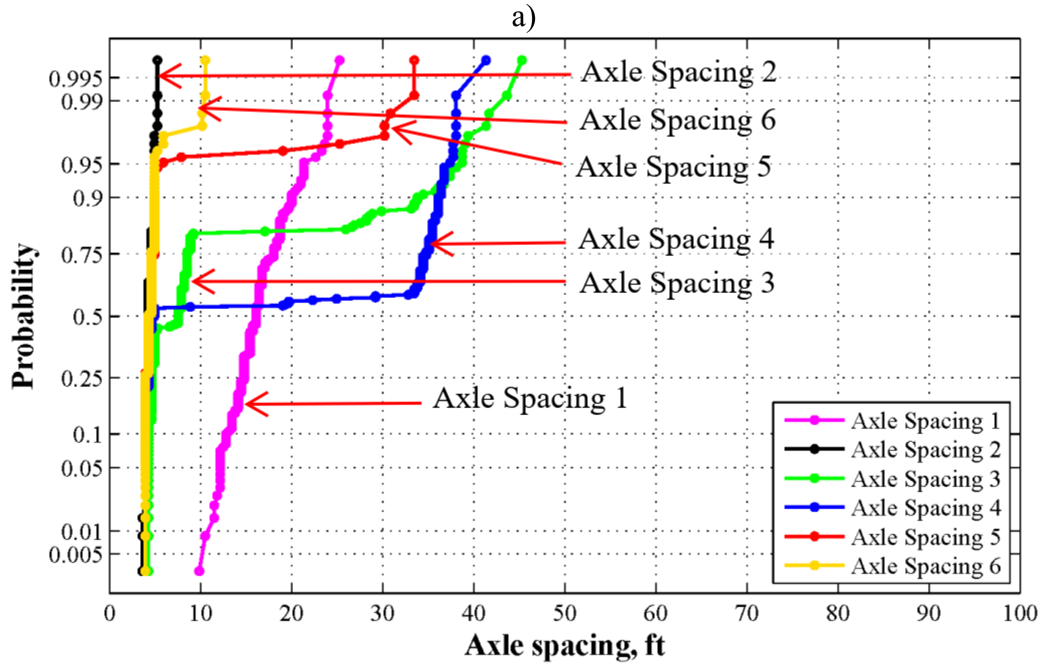
The parameters of the 6-axle trucks are distributed as shown in Table 12 through Table 17. Notice that these truck configurations are mostly overweight trucks, however, and therefore are not expected to be a high percentage of the trucks in typical traffic.

The CDFs for axle spacing and axle loads for 7-axle trucks recorded at WIM site AL911 located at US 280 Coosa County are shown in Figure 7 and Figure 8, respectively. The database of

7-axle vehicles collected at this WIM site consists of 532 (0.15 percent) records in 2014, 428 (0.12 percent) in 2015, and 280 (0.08 percent) in 2016 after filtering. These vehicles are most often classified as FHWA Class 13 (7- or more-axle, multi-trailer trucks) that are not dominating classes in the truck traffic stream.



a)



b)

Figure 7. CDFs of Axle Spacing for 7-Axle Vehicles at WIM Site 911 (US 280 Coosa County, AL) in 2016

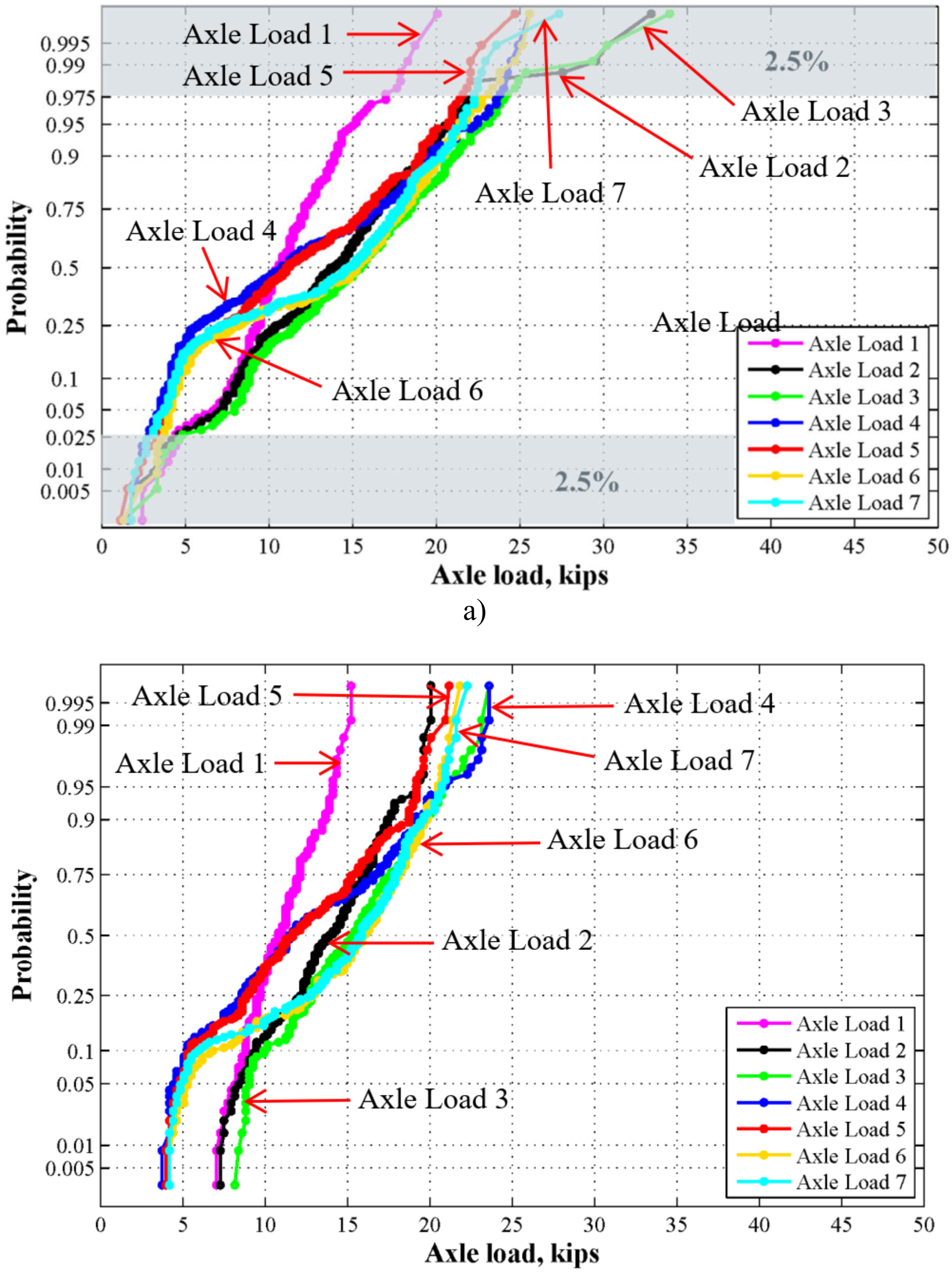


Figure 8. CDFs of Axle Load for 7-Axle Vehicles at WIM Site 911 (US 280 Coosa County, AL) in 2016

The parameters of the 7-axle trucks are distributed as shown in Table 18 through Table 23. Notice that these truck configurations are mostly overweight trucks and, therefore, are not expected to be a high percentage of the trucks in typical traffic.

The CDFs for axle spacing and axle loads for 4-axle trucks recorded at WIM site AL911 located at US 280 Coosa County are shown in Figure 9 and Figure 10, respectively. The database of 4-axle vehicles collected at this WIM site consists of 15,848 (4.43 percent) records in 2014, 14,491

(4.13 percent) in 2015, and 16,383 (4.53 percent) in 2016 after filtering. These vehicles are most often classified as FHWA Class 7 and 8 (4- or less-axle, single trailer trucks) that are not dominating classes in the truck traffic stream.

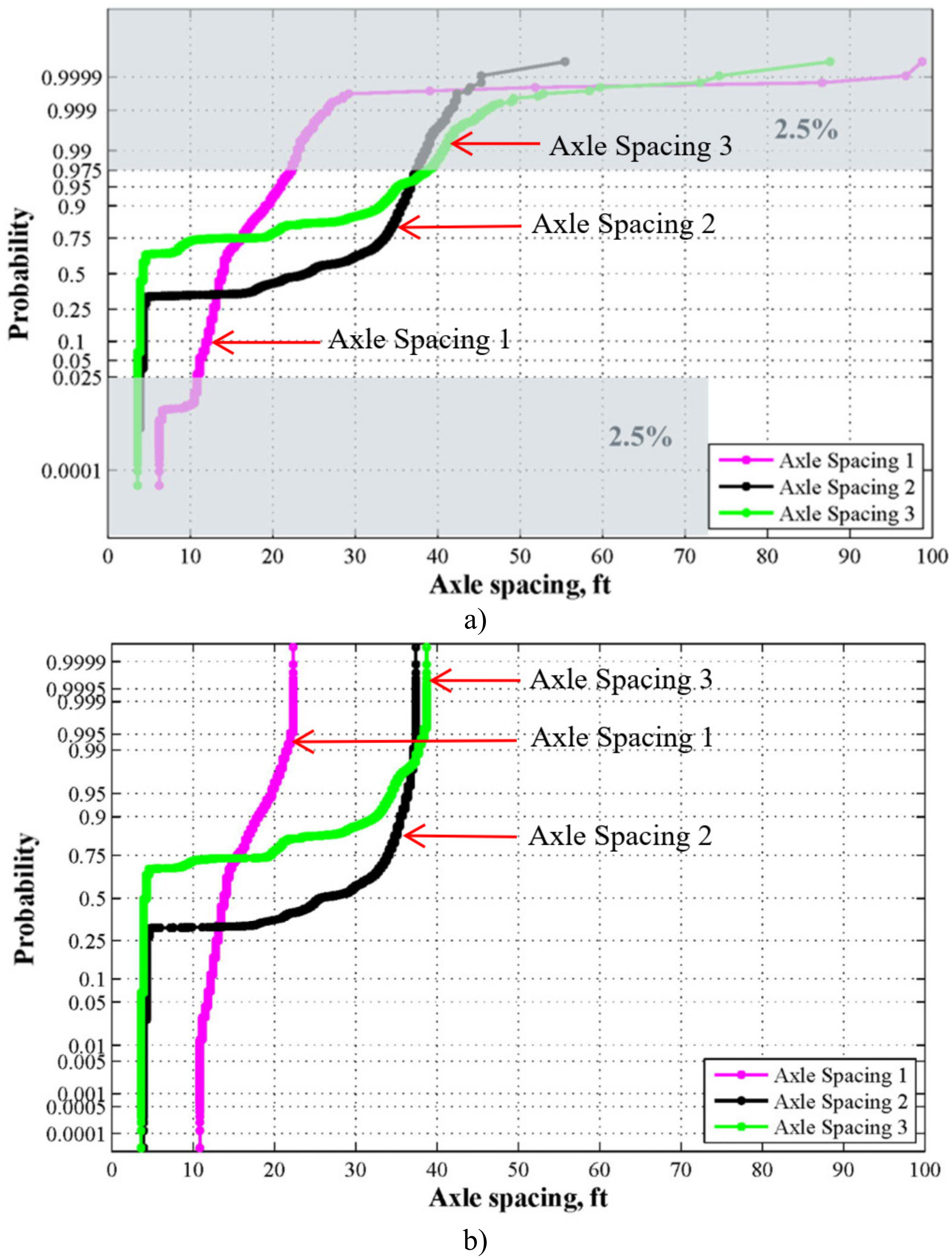
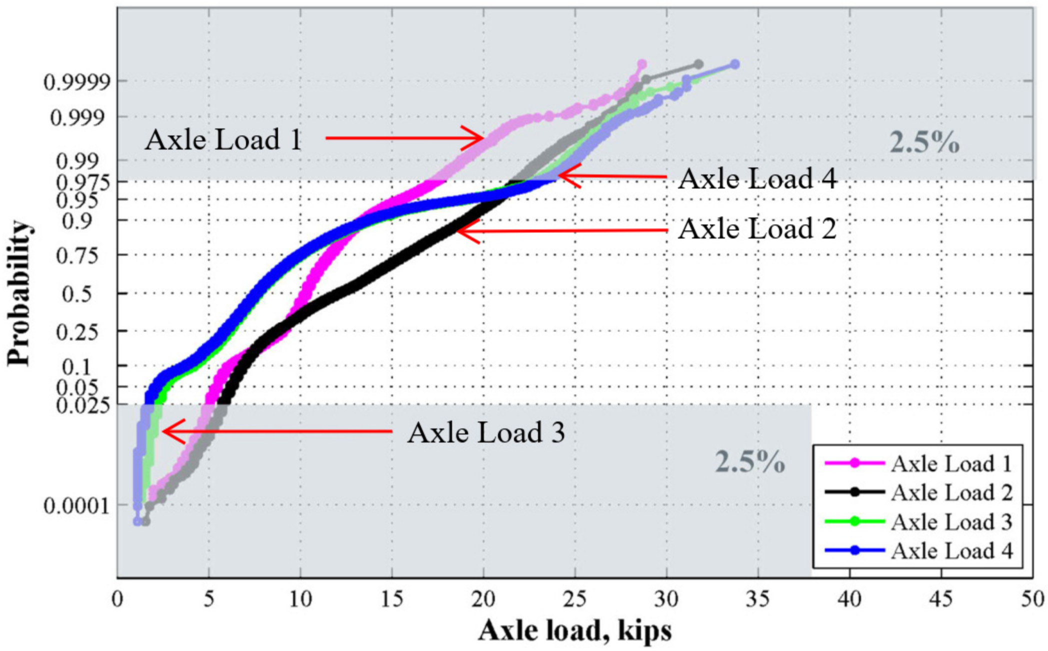
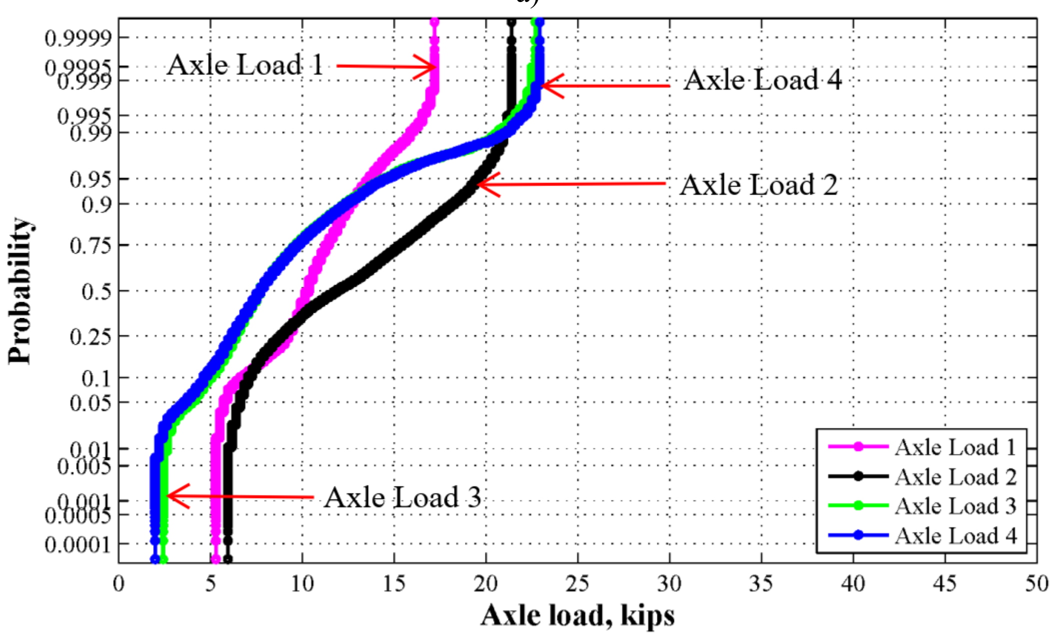


Figure 9. CDFs of Axle Spacing for 4-Axle Vehicles at WIM Site 911 (US 280 Coosa County, AL) in 2016



a)



b)

Figure 10. CDFs of Axle Load for 4-Axle Vehicles at WIM Site 911 (US 280 Coosa County, AL) in 2016

The parameters of the 4-axle trucks are distributed as shown in Table 24 through Table 29.

Table 6. Minimum and Maximum Values of the Axle Spacing for Vehicles of FHWA Class 9.

Axle spacing No.	Min. (ft)	Max. (ft)	Average. (ft)
1	11.2	20.0	16.1
2	3.9	21.3	4.5
3	9.5	36.4	31.8
4	3.9	22.0	4.9
Total Wheelbase (TWB)	31.8	69.9	57.2

Table 7. Percentile of Spacing Range of the Axle Spacing for Vehicles of FHWA Class 9.

Axle spacing No.	0-10%	10%-20%	20%-30%	30%-40%	40%-50%	50%-60%	60%-70%	70%-80%	80%-90%	90%-100%
1	11.2-12.1	12.1-12.9	12.9-13.8	13.8-14.7	14.7-15.6	15.6-16.5	16.5-17.4	17.4-18.2	18.2-19.1	19.1-20.0
2	3.9-5.7	5.7-7.4	7.4-9.2	9.2-10.9	10.9-12.6	12.6-14.4	14.4-16.1	16.1-17.9	17.9-19.6	19.6-21.3
3	9.5-12.2	12.2-14.9	14.9-17.6	17.6-20.3	20.3-22.9	22.9-25.7	25.7-28.4	28.4-31.0	31.0-33.7	33.7-36.4
4	3.9-5.7	5.7-7.6	7.6-9.4	9.4-11.2	11.2-12.9	12.9-14.7	14.7-16.6	16.6-18.4	18.4-20.2	20.2-22.0
TWB	31.8-35.6	35.6-39.4	39.4-43.2	43.2-47.1	47.1-50.8	50.8-54.7	54.7-58.5	58.5-62.3	62.3-66.1	66.1-69.9

* Axle spacings in ft.

Table 8. Distribution of the Axle Spacing Range for Vehicles of FHWA Class 9.

Axle spacing No	Min to 0.1 of spacing range	From 0.1 to 0.2 of spacing range	From 0.2 to 0.3 of spacing range	From 0.3 to 0.4 of spacing range	From 0.4 to 0.5 of spacing range	From 0.5 to 0.6 of spacing range	From 0.6 to 0.7 of spacing range	From 0.7 to 0.8 of spacing range	From 0.8 to 0.9 of spacing range	From 0.9 to Max of spacing range
1	2.0%	11.4%	5.5%	2.9%	7.2%	17.4%	27.1%	16.6%	4.7%	5.4%
2	98.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.2%
3	1.2%	0.1%	0.4%	0.4%	0.4%	1.0%	6.3%	22.2%	36.3%	31.8%
4	88.5%	0.0%	0.3%	10.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.2%
TWB	0.0%	0.2%	0.6%	0.6%	5.3%	15.8%	37.7%	33.2%	6.3%	0.3%

Table 9. Minimum and Maximum Values of the Axle Load for Vehicles of FHWA Class 9.

Axle No.	Min. (kip)	Max. (kip)	Average. (kip)
1	9.3	13.7	11.5
2	5.7	20.3	12.0
3	5.5	20.1	11.8
4	4.0	20.9	11.0
5	4.0	21.2	10.9
Gross Vehicle Weight (GVW)	28.9	95.2	57.2

Table 10. Percentile of Axle Load Range for Vehicles of FHWA Class 9.

Axle No.	0-10%	10%-20%	20%-30%	30%-40%	40%-50%	50%-60%	60%-70%	70%-80%	80%-90%	90%-100%
1	9.3-9.7	9.7-10.1	10.1-10.6	10.6-11.0	11.0-11.5	11.5-11.9	11.9-12.4	12.4-12.8	12.8-13.2	13.2-13.7
2	5.7-7.2	7.2-8.6	8.6-10.1	10.1-11.5	11.5-13.0	13.0-14.5	14.5-15.9	15.9-17.4	17.4-18.8	18.8-20.3
3	5.5-6.9	6.9-8.4	8.4-9.9	9.9-11.3	11.3-12.8	12.8-14.2	14.2-15.7	15.7-17.2	17.2-18.6	18.6-20.1
4	4.0-5.7	5.7-7.4	7.4-9.1	9.1-10.8	10.8-12.5	12.5-14.2	14.2-15.9	15.9-17.6	17.6-19.3	19.3-20.9
5	4.0-5.7	5.7-7.4	7.4-9.1	9.1-10.9	10.9-12.6	12.6-14.3	14.3-16.0	16.0-17.7	17.7-19.4	19.4-21.2
GVW	28.8-35.5	35.5-42.2	42.2-48.8	48.8-55.4	55.4-62.1	62.1-68.7	68.7-75.3	75.3-81.9	81.9-88.6	88.6-95.2

* Axle load in kips

Table 11. Distribution of Axle Load Range for Vehicles of FHWA Class 9.

Axle No.	Min to 0.1 of axle load range	From 0.1 to 0.2 of axle load range	From 0.2 to 0.3 of axle load range	From 0.3 to 0.4 of axle load range	From 0.4 to 0.5 of axle load range	From 0.5 to 0.6 of axle load range	From 0.6 to 0.7 of axle load range	From 0.7 to 0.8 of axle load range	From 0.8 to 0.9 of axle load range	From 0.9 to Max of axle load range
1	2.5%	5.1%	14.6%	14.4%	8.0%	17.8%	16.7%	10.8%	6.0%	4.1%
2	12.4%	16.9%	11.1%	9.4%	6.5%	8.6%	14.1%	11.6%	6.9%	2.6%
3	11.7%	17.4%	11.2%	9.6%	6.4%	8.6%	12.9%	12.5%	7.1%	2.7%
4	14.1%	18.4%	11.9%	7.5%	7.0%	8.3%	11.1%	13.0%	6.3%	2.5%
5	15.6%	17.9%	11.6%	8.2%	5.8%	7.9%	12.9%	11.7%	5.9%	2.5%
GVW	9.0%	18.8%	13.0%	9.6%	7.4%	7.8%	14.5%	13.7%	5.0%	1.3%

Table 12. Minimum and Maximum Values of the Axle Spacing for 6-Axle Vehicles.

Axle spacing No.	Min. (ft)	Max. (ft)	Average. (ft)
1	10.8	21.0	14.5
2	4.3	4.6	4.3
3	11.5	37.7	22.6
4	3.9	10.2	7.2
5	3.9	23.0	14.4
Total Wheelbase (TWB)	38.4	76.8	63.0

Table 13. Percentile of Spacing Range of the Axle Spacing for Vehicles of 6-Axle Vehicles.

Axle Spacing No.	0-10%	10%-20%	20%-30%	30%-40%	40%-50%	50%-60%	60%-70%	70%-80%	80%-90%	90%-100%
1	10.8-11.9	11.9-12.9	12.9-13.9	13.9-14.9	14.9-15.9	15.9-16.9	16.9-18.0	18.0-18.9	18.9-20.0	20.0-21.00
2	4.3-4.3	4.3-4.3	4.3-4.4	4.4-4.4	4.4-4.4	4.4-4.5	4.5-4.5	4.5-4.5	4.5-4.5	4.5-4.6
3	11.5-14.1	14.1-16.7	16.7-19.4	19.4-22.0	22.0-24.6	24.6-27.2	27.2-29.9	29.9-32.5	32.5-35.1	35.1-37.7
4	3.9-4.6	4.6-5.2	5.2-5.8	5.8-6.4	6.4-7.1	7.1-7.7	7.7-8.3	8.3-8.9	8.9-9.6	9.6-10.2
5	3.9-5.8	5.8-7.7	7.7-9.7	9.7-11.6	11.6-13.5	13.5-15.5	15.5-17.3	17.3-19.2	19.2-21.1	21.1-23.0
TWB	38.4-42.2	42.2-46.1	46.1-49.9	49.9-53.7	53.7-57.6	57.6-61.4	61.4-65.3	65.3-69.1	69.1-72.9	72.9-76.8

* Axle spacings in ft.

Table 14. Distribution of the Axle Spacing Range for Vehicles of 6-Axle Vehicles.

Axle spacing No.	Min to 0.1 of spacing range	From 0.1 to 0.2 of spacing range	From 0.2 to 0.3 of spacing range	From 0.3 to 0.4 of spacing range	From 0.4 to 0.5 of spacing range	From 0.5 to 0.6 of spacing range	From 0.6 to 0.7 of spacing range	From 0.7 to 0.8 of spacing range	From 0.8 to 0.9 of spacing range	From 0.9 to Max of spacing range
1	18.6%	23.6%	4.3%	13.1%	10.9%	8.8%	6.6%	1.9%	9.9%	2.3%
2	92.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.4%
3	1.5%	0.7%	9.0%	59.1%	1.7%	3.3%	14.7%	3.2%	3.4%	3.5%
4	32.8%	9.9%	0.4%	0.1%	0.0%	0.0%	0.0%	11.2%	31.9%	13.8%
5	43.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	56.5%
TWB	1.2%	4.5%	5.9%	4.4%	16.7%	3.0%	2.8%	39.7%	12.1%	9.7%

Table 15. Minimum and Maximum Values of the Axle Load for 6-Axle Vehicles.

Axle No.	Min. (kip)	Max. (kip)	Average. (kip)
1	8.4	13.2	10.3
2	5.7	20.1	11.6
3	5.1	20.1	11.3
4	2.9	19.2	10.9
5	3.3	20.3	11.4
6	2.9	19.6	10.4
Gross Vehicle Weight (GVW)	30.0	105.6	65.9

Table 16. Percentile of Axle Load Range for Vehicles 6-Axle Vehicles.

Axle No.	0-10%	10%-20%	20%-30%	30%-40%	40%-50%	50%-60%	60%-70%	70%-80%	80%-90%	90%-100%
1	8.4-8.9	8.9-9.3	9.3-9.8	9.8-10.3	10.3-10.8	10.8-11.3	11.3-11.8	11.8-12.3	12.3-12.8	12.8-13.2
2	5.7-7.2	7.2-8.6	8.6-10.0	10.0-11.5	11.5-12.9	12.9-14.3	14.3-15.8	15.8-17.2	17.2-18.6	18.6-20.1
3	5.1-6.6	6.6-8.1	8.1-9.6	9.6-11.1	11.1-12.6	12.6-14.1	14.1-15.6	15.6-17.1	17.1-18.6	18.6-20.1
4	2.9-4.5	4.5-6.1	6.1-7.8	7.8-9.4	9.4-11.0	11.0-12.7	12.7-14.3	14.3-15.9	15.9-17.5	17.5-19.2
5	3.3-5.0	5.0-6.7	6.7-8.4	8.4-10.1	10.1-11.8	11.8-13.5	13.5-15.2	15.2-16.9	16.9-18.6	18.6-20.3
6	2.9-4.5	4.5-6.2	6.2-7.9	7.9-9.6	9.6-11.2	11.2-12.9	12.9-14.6	14.6-16.3	16.3-17.9	17.9-19.6
GVW	30.0-37.5	37.5-45.1	45.1-52.7	52.7-60.2	60.2-67.8	67.8-75.3	75.3-82.9	82.9-90.5	90.5-98.0	98.0-105.6

* Axle load in kips

Table 17. Distribution of Axle Load Range for Vehicles of 6-Axle Vehicles.

Axle No.	Min to 0.1 of axle load range	From 0.1 to 0.2 of axle load range	From 0.2 to 0.3 of axle load range	From 0.3 to 0.4 of axle load range	From 0.4 to 0.5 of axle load range	From 0.5 to 0.6 of axle load range	From 0.6 to 0.7 of axle load range	From 0.7 to 0.8 of axle load range	From 0.8 to 0.9 of axle load range	From 0.9 to Max of axle load range
1	10.0%	13.0%	13.3%	13.8%	13.5%	16.8%	7.7%	5.4%	3.1%	3.5%
2	10.2%	10.9%	18.3%	18.0%	11.0%	6.0%	7.1%	10.2%	6.3%	2.0%
3	7.3%	14.3%	17.8%	17.5%	10.7%	7.4%	6.5%	8.5%	7.5%	2.7%
4	4.5%	7.3%	11.1%	10.4%	13.5%	18.5%	15.7%	10.7%	5.4%	3.0%
5	5.3%	7.5%	14.4%	10.7%	14.6%	17.3%	13.0%	7.4%	6.4%	3.5%
6	4.4%	11.1%	16.6%	13.6%	12.2%	15.1%	11.4%	6.6%	5.4%	3.7%
GVW	2.9%	8.4%	12.5%	15.4%	15.0%	13.8%	13.3%	13.7%	4.6%	0.6%

Table 18. Minimum and Maximum Values of the Axle Spacing for 7-Axle Vehicles.

Axle spacing No.	Min. (ft)	Max. (ft)	Average. (ft)
1	9.8	25.3	16.3
2	3.6	5.3	4.4
3	4.3	45.3	11.3
4	3.9	41.3	17.9
5	3.9	33.5	5.4
6	3.9	10.5	4.6
Total Wheelbase (TWB)	36.1	101.1	60.0

Table 19. Percentile of Spacing Range of the Axle Spacing for Vehicles of 7-Axle Vehicles.

Axle Spacing No.	0-10%	10%-20%	20%-30%	30%-40%	40%-50%	50%-60%	60%-70%	70%-80%	80%-90%	90%-100%
1	9.8-11.4	11.4-12.9	12.9-14.5	14.5-16.0	16.0-17.6	17.6-19.1	19.1-20.6	20.6-22.2	22.2-23.7	23.7-25.3
2	3.6-3.8	3.8-3.9	3.9-4.1	4.1-4.3	4.3-4.4	4.4-4.6	4.6-4.8	4.8-4.9	4.9-5.1	5.1-5.3
3	4.3-8.4	8.4-12.5	12.5-16.6	16.6-20.7	20.7-24.8	24.8-28.9	28.9-33.0	33.0-37.1	37.1-41.2	41.2-45.3
4	3.9-7.7	7.7-11.4	11.4-15.2	15.2-18.9	18.9-22.6	22.6-26.4	26.4-30.1	30.1-33.9	33.9-37.6	37.6-41.3
5	3.9-6.7	6.7-9.8	9.8-12.8	12.8-15.8	15.8-18.7	18.7-21.7	21.7-24.6	24.6-27.6	27.6-30.5	30.5-33.5
6	3.9-4.6	4.6-5.3	5.3-5.9	5.9-6.6	6.6-7.2	7.2-7.9	7.9-8.5	8.5-9.2	9.2-9.8	9.8-10.5
TWB	36.1-42.6	42.6-49.1	49.1-55.6	55.6-62.1	62.1-68.6	68.6-75.1	75.1-81.6	81.6-88.1	88.1-94.6	94.6-101.1

* Axle spacings in ft.

Table 20. Distribution of the Axle Spacing Range for Vehicles of 7-Axle Vehicles.

Axle spacing No.	Min to 0.1 of spacing range	From 0.1 to 0.2 of spacing range	From 0.2 to 0.3 of spacing range	From 0.3 to 0.4 of spacing range	From 0.4 to 0.5 of spacing range	From 0.5 to 0.6 of spacing range	From 0.6 to 0.7 of spacing range	From 0.7 to 0.8 of spacing range	From 0.8 to 0.9 of spacing range	From 0.9 to Max of spacing range
1	1.1%	9.1%	13.7%	22.3%	26.9%	13.7%	4.6%	4.0%	1.7%	2.9%
2	1.7%	0.0%	7.4%	0.0%	55.4%	0.0%	17.7%	0.0%	15.4%	2.3%
3	67.4%	14.3%	0.0%	0.6%	0.0%	4.0%	1.1%	5.7%	4.6%	2.3%
4	53.7%	0.6%	0.0%	0.0%	2.9%	0.6%	1.1%	5.1%	31.4%	4.6%
5	95.4%	0.6%	0.0%	0.0%	0.0%	0.6%	0.0%	0.6%	1.1%	1.7%
6	50.9%	45.1%	0.6%	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%	2.3%
TWB	29.7%	6.3%	2.3%	2.3%	14.9%	33.1%	6.9%	1.1%	1.1%	2.3%

Table 21. Minimum and Maximum Values of the Axle Load for 7-Axle Vehicles.

Axle load No.	Min. (kip)	Max. (kip)	Average. (kip)
1	7.1	15.2	10.9
2	7.3	20.1	13.8
3	8.2	23.6	15.2
4	3.8	23.6	12.4
5	4.0	21.2	12.0
6	4.2	21.8	14.9
7	4.2	22.3	14.7
Gross Vehicle Weight (GVW)	44.5	133.8	93.9

Table 22. Percentile of Axle Load Range for Vehicles 7-Axle Vehicles.

Axle No.	0-10%	10%-20%	20%-30%	30%-40%	40%-50%	50%-60%	60%-70%	70%-80%	80%-90%	90%-100%
1	7.1-7.9	7.9-8.7	8.7-9.5	9.5-10.3	10.3-11.1	11.1-12.0	12.0-12.8	12.8-13.6	13.6-14.4	14.4-15.2
2	7.3-8.6	8.6-9.8	9.8-11.1	11.1-12.4	12.4-13.7	13.7-14.9	14.9-16.2	16.2-17.5	17.5-18.8	18.8-20.1
3	8.2-9.7	9.7-11.2	11.2-12.8	12.8-14.3	14.3-15.9	15.9-17.4	17.4-19.0	19.0-20.5	20.5-22.1	22.1-23.6
4	3.8-5.7	5.7-7.7	7.7-9.7	9.7-11.7	11.7-13.7	13.7-15.7	15.7-17.6	17.6-19.6	19.6-21.6	21.6-23.6
5	4.0-5.7	5.7-7.4	7.4-9.1	9.1-10.9	10.9-12.6	12.6-14.3	14.3-16.0	16.0-17.8	17.8-19.4	19.4-21.2
6	4.2-6.0	6.0-7.7	7.7-9.5	9.5-11.2	11.2-13.0	13.0-14.8	14.8-16.5	16.5-18.3	18.3-20.1	20.1-21.8
7	4.2-6.0	6.0-7.8	7.8-9.6	9.6-11.4	11.4-13.2	13.2-15.0	15.0-16.8	16.8-18.7	18.7-20.5	20.5-22.3
GVW	44.5-53.5	53.5-62.4	62.4-71.3	71.3-80.3	80.3-89.2	89.2-98.1	98.1-107.0	107.0-116.0	116.0-125.0	125.0-133.8

* Axle load in kips

Table 23. Distribution of Axle Load Range for Vehicles of 7-Axle Vehicles.

Axle No.	Min to 0.1 of axle load range	From 0.1 to 0.2 of axle load range	From 0.2 to 0.3 of axle load range	From 0.3 to 0.4 of axle load range	From 0.4 to 0.5 of axle load range	From 0.5 to 0.6 of axle load range	From 0.6 to 0.7 of axle load range	From 0.7 to 0.8 of axle load range	From 0.8 to 0.9 of axle load range	From 0.9 to Max of axle load range
1	3.4%	5.7%	14.9%	16.6%	13.7%	19.4%	9.1%	6.9%	8.0%	2.3%
2	5.1%	6.9%	6.9%	11.4%	16.6%	14.3%	16.0%	13.1%	3.4%	6.3%
3	9.1%	2.9%	10.9%	17.7%	14.9%	17.7%	13.1%	6.3%	4.0%	3.4%
4	12.0%	7.4%	13.1%	17.7%	11.4%	6.9%	12.0%	10.3%	5.1%	4.0%
5	11.4%	5.1%	10.3%	15.4%	13.1%	10.9%	13.1%	8.6%	8.6%	3.4%
6	7.4%	3.4%	4.0%	3.4%	6.9%	9.1%	20.6%	21.1%	16.6%	7.4%
7	10.3%	2.9%	2.3%	5.7%	5.7%	14.9%	19.4%	24.0%	8.0%	6.9%
GVW	5.1%	4.0%	2.9%	6.3%	13.1%	29.7%	14.9%	12.6%	8.0%	3.4%

Table 24. Minimum and Maximum Values of the Axle Spacing for vehicles of 4-Axle Vehicles.

Axle spacing No.	Min. (ft)	Max. (ft)	Average. (ft)
1	10.8	22.3	14.5
2	3.9	37.4	22.0
3	3.6	38.7	10.7
Total Wheelbase (TWB)	18.7	68.2	47.2

Table 25. Percentile of Spacing Range of the Axle Spacing for Vehicles of 4-Axle Vehicles.

Axle Spacing No.	0-10%	10%-20%	20%-30%	30%-40%	40%-50%	50%-60%	60%-70%	70%-80%	80%-90%	90%-100%
1	10.8-12.0	12.0-13.1	13.1-14.3	14.3-15.4	15.4-16.6	16.6-17.7	17.7-18.9	18.9-20.0	20.0-21.2	21.2-22.3
2	3.9-7.3	7.3-10.6	10.6-14.0	14.0-17.3	17.3-20.7	20.7-24.0	24.0-27.4	27.4-30.7	30.7-34.1	34.1-37.4
3	3.6-7.1	7.1-10.6	10.6-14.1	14.1-17.7	17.7-21.2	21.2-24.7	24.7-28.2	28.2-31.7	31.7-35.2	35.2-38.7
TWB	18.7-23.7	23.7-28.6	28.6-33.6	33.6-38.5	38.5-43.5	43.5-48.4	48.4-53.4	53.4-58.3	58.3-63.3	63.3-68.2

* Axle spacings in ft.

Table 26. Distribution of the Axle Spacing Range for Vehicles of 4-Axle Vehicles.

Axle spacing No	Min to 0.1 of spacing range	From 0.1 to 0.2 of spacing range	From 0.2 to 0.3 of spacing range	From 0.3 to 0.4 of spacing range	From 0.4 to 0.5 of spacing range	From 0.5 to 0.6 of spacing range	From 0.6 to 0.7 of spacing range	From 0.7 to 0.8 of spacing range	From 0.8 to 0.9 of spacing range	From 0.9 to Max of spacing range
1	6.9%	17.9%	37.9%	10.1%	9.4%	5.9%	4.7%	3.0%	2.8%	1.4%
2	31.7%	0.2%	0.4%	0.7%	4.0%	7.0%	7.8%	7.4%	15.8%	25.1%
3	68.3%	4.5%	0.8%	0.1%	7.6%	2.3%	1.0%	4.2%	8.2%	2.9%
TWB	4.5%	0.9%	0.2%	7.1%	15.9%	14.1%	37.8%	16.4%	3.0%	0.2%

Table 27. Minimum and Maximum Values of the Axle Load for 4-Axle Vehicles.

Axle No.	Min. (kip)	Max. (kip)	Average. (kip)
1	5.3	17.2	10.2
2	6.0	21.4	12.3
3	2.4	22.7	8.4
4	2.0	22.9	8.3
Gross Vehicle Weight (GVW)	20.1	82.2	39.1

Table 28. Percentile of Axle Load Range for Vehicles 4-Axle Vehicles.

Axle No.	0-10%	10%-20%	20%-30%	30%-40%	40%-50%	50%-60%	60%-70%	70%-80%	80%-90%	90%-100%
1	5.3-6.5	6.5-7.7	7.7-8.9	8.9-10.1	10.1-11.2	11.2-12.4	12.4-13.6	13.6-14.8	14.8-16.0	16.0-17.2
2	6.0-7.5	7.5-9.0	9.0-10.6	10.6-12.1	12.1-13.7	13.7-15.2	15.2-16.8	16.8-18.3	18.3-19.8	19.8-21.4
3	2.4-4.5	4.5-6.5	6.5-8.5	8.5-10.5	10.5-12.6	12.6-14.6	14.6-16.6	16.6-18.7	18.7-20.7	20.7-22.7
4	2.0-4.1	4.1-6.2	6.2-8.3	8.3-10.4	10.4-12.5	12.5-14.6	14.6-16.6	16.6-18.7	18.7-20.8	20.8-22.9
GVW	20.1-26.3	26.3-32.5	32.5-38.7	38.7-44.9	44.9-51.2	51.2-57.4	57.4-63.6	63.6-69.8	69.8-76.0	76.0-82.2

* Axle load in kips

Table 29. Distribution of Axle Load Range for Vehicles of 4-Axle Vehicles.

Axle No.	Min to 0.1 of axle load range	From 0.1 to 0.2 of axle load range	From 0.2 to 0.3 of axle load range	From 0.3 to 0.4 of axle load range	From 0.4 to 0.5 of axle load range	From 0.5 to 0.6 of axle load range	From 0.6 to 0.7 of axle load range	From 0.7 to 0.8 of axle load range	From 0.8 to 0.9 of axle load range	From 0.9 to Max of axle load range
1	9.2%	4.4%	7.6%	22.3%	28.0%	16.9%	6.3%	3.2%	1.2%	1.0%
2	12.2%	13.4%	14.3%	11.0%	10.5%	11.7%	9.6%	7.1%	5.9%	4.3%
3	7.2%	20.2%	34.4%	19.0%	9.4%	4.9%	1.9%	0.9%	1.0%	1.1%
4	6.5%	16.9%	35.2%	20.3%	11.2%	4.7%	2.2%	1.0%	0.9%	1.1%
GVW	6.6%	18.2%	29.6%	22.3%	12.6%	6.3%	2.3%	1.1%	0.9%	0.3%

3.4 SELECTION OF "TYPICAL" TRUCK CONFIGURATIONS

Figure 2 and Table 5 show that the most common truck class is Class 9. A number of sites include up to 10.84 percent and 10.71 percent of total traffic in Class 5 and Class 6 trucks, respectively. However, vehicles in these two classes are 2- and 3-axle vehicles. Because these are not as heavy as the 5-axle trucks of Class 9, they do not produce the controlling load effects. Only one State (Maine) included a relatively high percentage of Class 10 trucks (19.47 percent). For the next highest State, Class 10 trucks represented only 1.65 percent of total truck traffic.

All trucks in Class 9 are 5-axle tractor-trailer trucks (steering axle, dual axle at the rear of the tractor, and another dual axle at the rear of the trailer). Two different configurations are considered Class 9 (see Figure 1). The two configurations differ only in the spacing between the two axles in the rear tandem. Based on the information in Figure 3 and Table 6 through Table 8, the two axles are closely spaced in the first configurations (between 3.94 and 5.74 feet spacing), and they are spaced between 9.35 to 11.15 feet in the second configurations). As Table 8 shows, most of the trucks in Class 9 (88.48 percent) are of the first configuration, and the second configuration comprises 8.98 percent of this class.

After review of Class 9 truck axle spacing and truck axle loads statistics (Table 6 through Table 11) and considering that a legal truck using the interstate system must satisfy the federal bridge formula to conform to the Code of Federal Regulations (CFR 23 §658.17(e)), the truck shown in Figure 11 stands as a representative of the most common vehicles on the road. This is especially true for long-haul commercial truck traffic on the Interstate System (IS), the National Highway System (NHS) and the National Network for Trucks (NN).

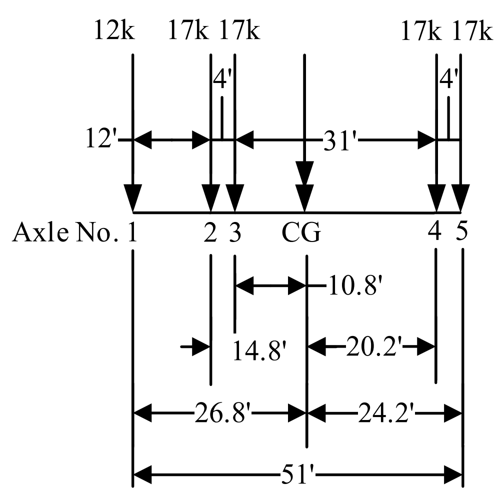


Figure 11. "Typical" Truck Configurations (5-Axle, 40 ton truck)

4.0 TRUCK PLATOON CONFIGURATIONS

The study investigated the effects of single trucks and the effects of two-, three- and four-truck platoons. The study of the WIM data determined that the truck in Figure 11 can be considered as a representative of the most common trucks on the road, in other words as a "typical truck.". The preliminary analysis utilized the Type 3-3 (Figure 12), Type 3S2 (Figure 13), and the typical truck (Figure 11).

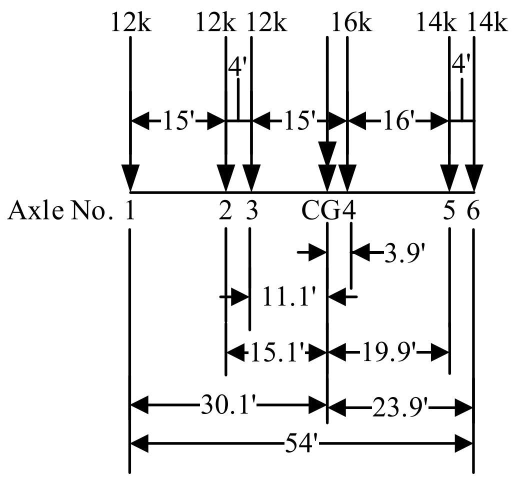


Figure 12. Type 3-3 Truck Weight = 80 kips (40 tons)

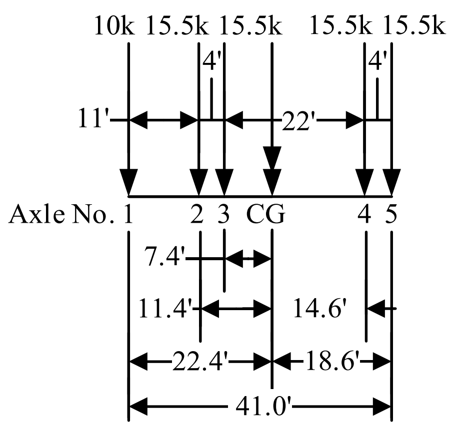


Figure 13. Type 3S2 Truck Weight = 72 kips (36 tons)

The literature review indicated that past truck platoon experiments used bumper-to-bumper spacings as small as about 10 feet. For preliminary analysis, the bumper-to-bumper spacings used was: 25, 45, and 65 feet. For analysis purposes, the spacing between the rear axle in a truck to the leading axle of the following truck was taken as the bumper-to-bumper spacing plus 5 feet, resulting in spacing between the rear axle of a truck and the steering axle of the following truck of 30, 50, and 70 feet. These distances are referred to as “the truck spacing” for trucks in platoons throughout the report.

The truck platoons in Figure 14 through Figure 16 are designated as: XX-Y-ZZ

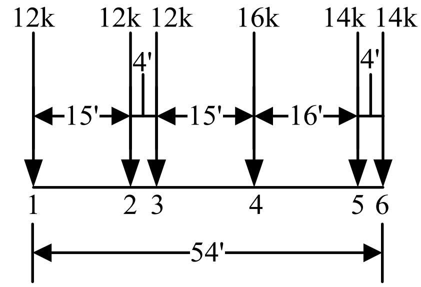
Where:

XX = 3S2, 33 and T for Type 3S2, Type 3-3 and the “typical trucks”, respectively
Y = 1, 2, 3 and 4 for single truck, two-, three- and four-truck platoons, respectively
ZZ = the spacing between the rear axle of a truck in a platoon and the steering axle of the following truck (30, 50, and 70 feet will be used). If ZZ is shown as “00,” it refers to the single truck used as a benchmark.

For example:

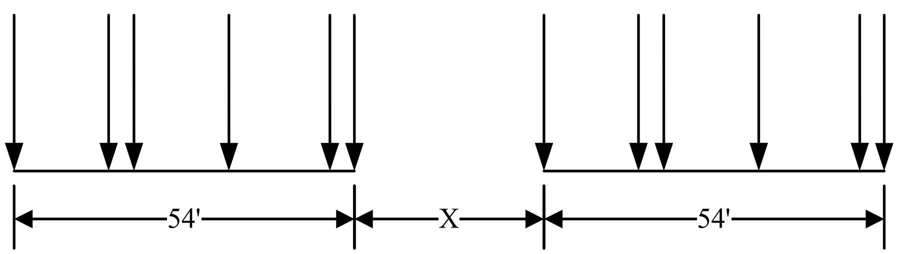
- platoon designation 3S2-3-50 indicates a three-truck platoon consisting of 3S2 trucks with 50-foot spacing between the rear axle of a truck and the front axle of the following truck in the platoon.
- platoon designation 3S2-1-00 indicates a single 3S2 truck.

In total, 30 different platoon configurations were considered in the analyses. Figure 14, Figure 15, and Figure 16 show graphical representations of the investigated 3-3, 3S2 and “T” truck platoon configurations.



Single Type 3-3 Truck

Platoon Configuration 33-1-00



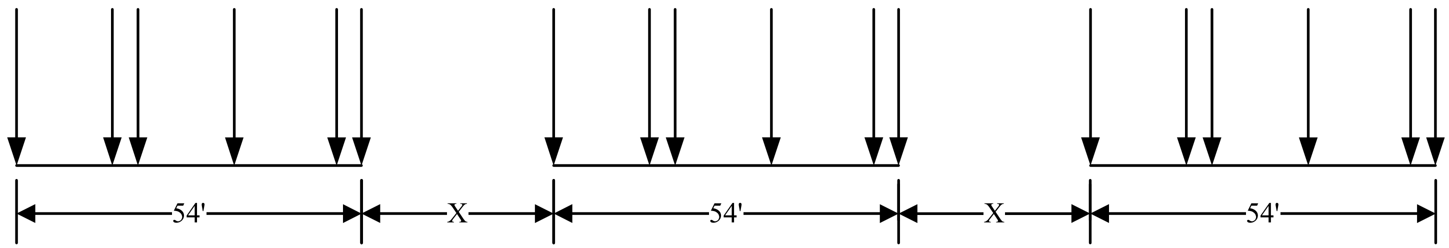
Two Type 3-3 Truck Platoons

X=30 ft.: Platoon configuration 33-2-30

X=50 ft.: Platoon configuration 33-2-50

X=70 ft.: Platoon configuration 33-2-70

Figure 14. Type 3-3 Truck Platoons Configurations

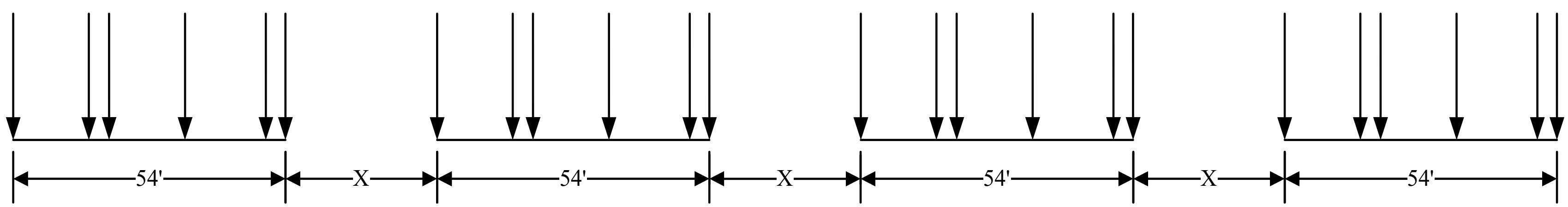


Three Type 3-3 Truck Platoons

X=30 ft.: Platoon configuration 33-3-30

X=50 ft.: Platoon configuration 33-3-50

X=70 ft.: Platoon configuration 33-3-70



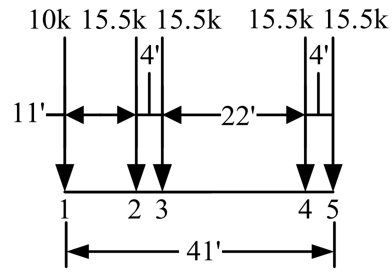
Four Type 3-3 Truck Platoons

X=30 ft.: Platoon configuration 33-4-30

X=50 ft.: Platoon configuration 33-4-50

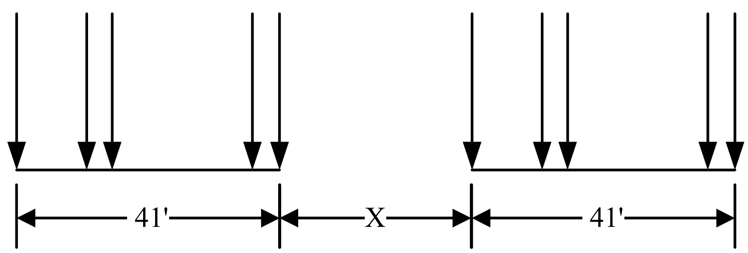
X=70 ft.: Platoon configuration 33-4-70

Figure 14. Type 3-3 Truck Platoons Configurations (cont’d)



Single Type 3S2 Truck

Platoon Configuration 3S2-1-00



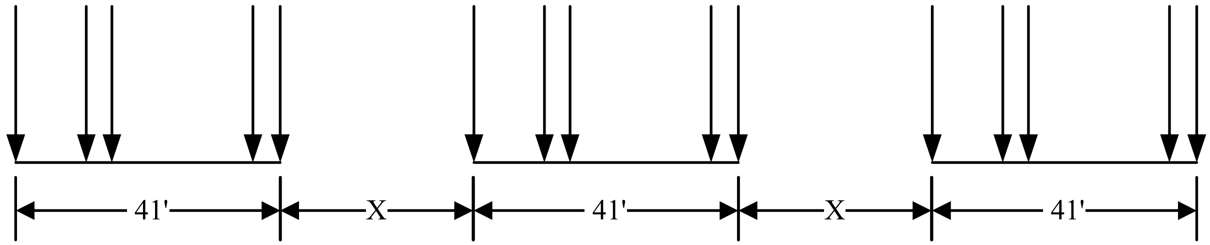
Two Type 3S2 Truck Platoons

X=30 ft.: Platoon configuration 3S2-2-30

X=50 ft.: Platoon configuration 3S2-2-50

X=70 ft.: Platoon configuration 3S2-2-70

Figure 15. Type 3S2 Truck Platoons Configurations

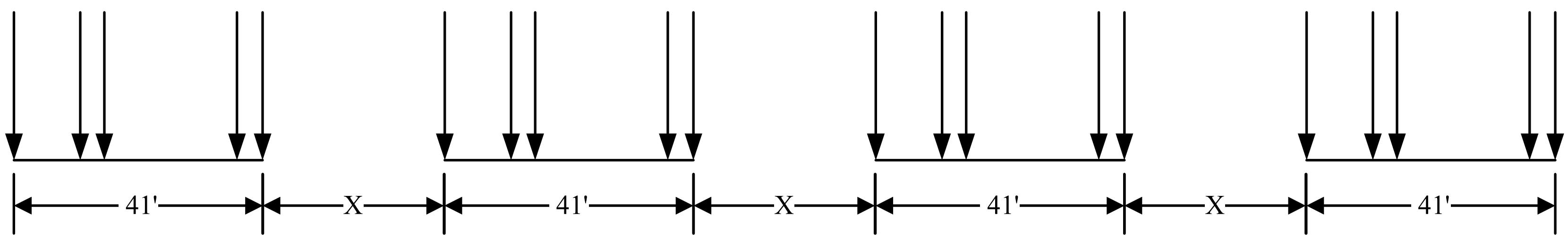


Three Type 3S2 Truck Platoons

X=30 ft.: Platoon configuration 3S2-3-30

X=50 ft.: Platoon configuration 3S2-3-50

X=70 ft.: Platoon configuration 3S2-3-70



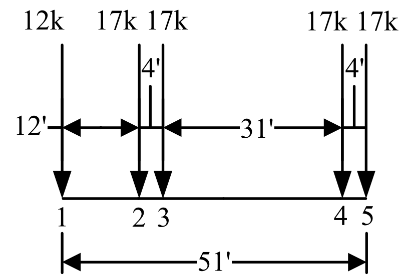
Four Type 3S2 Truck Platoons

X=30 ft.: Platoon configuration 3S2-4-30

X=50 ft.: Platoon configuration 3S2-4-50

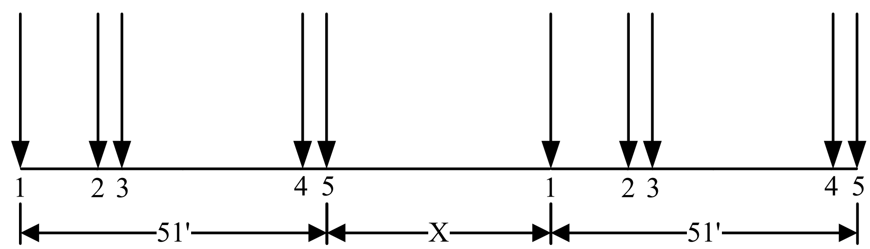
X=70 ft.: Platoon configuration 3S2-4-70

Figure 15. Type 3S2 Truck Platoons Configurations (cont'd)



Single Typical Truck

Platoon Configuration T-1-00



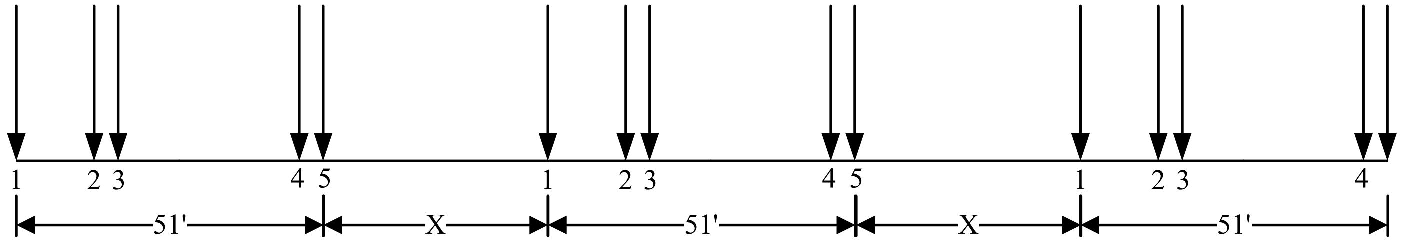
Two Typical Truck Platoons

X=30 ft.: Platoon configuration T-2-30

X=50 ft.: Platoon configuration T-2-50

X=70 ft.: Platoon configuration T-2-70

Figure 16. Typical Truck Platoons Configurations

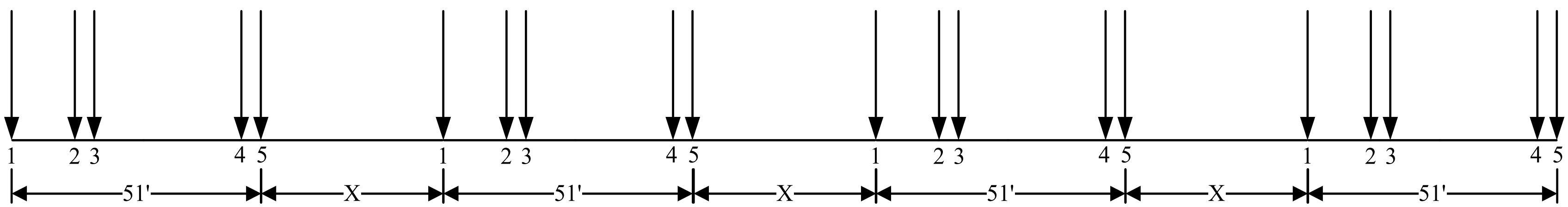


Three Typical Truck Platoons

X=30 ft.: Platoon configuration T-3-30

X=50 ft.: Platoon configuration T-3-50

X=70 ft.: Platoon configuration T-3-70



Four Typical Truck Platoons

X=30 ft.: Platoon configuration T-4-30

X=50 ft.: Platoon configuration T-4-50

X=70 ft.: Platoon configuration T-4-70

Figure 16. Typical Truck Platoons Configurations (cont’d)

5.0 MAXIMUM LOAD EFFECTS FROM PLATOONS

5.1 LIVE LOAD EFFECTS FROM THE PLATOON CONFIGURATIONS FOR DIFFERENT INVESTIGATED BRIDGE SPAN LENGTHS

Several representative span lengths were selected to determine the load effects from different platoon configurations and for both the HL-93 and the HS 20 design loads. The span lengths selected were 30, 50, 70, 100, 130, 160, 200, 250, and 300 feet. The load effects were determined for simple spans, two equal continuous spans, and three equal continuous spans.

The research team used AASHTOWare Bridge Rating (BrR) to determine load effects. Each platoon configuration was introduced as a special vehicle, and load effects from different loads were determined at the 10^{th} points. Maximum load effects for the HS 20, HL-93, and the investigated truck platoon configurations were tabulated for different span lengths investigated. The trucks for the HS 20 and HL-93 loadings were introduced as "notional trucks," which means that, in line with design specifications provisions, axles that do not maximize the load effect are ignored. The special trucks representing the platoons were considered "actual trucks." This means that all axles were considered regardless of them increasing or decreasing the load effect being maximized. Historically, the provision to exclude axles that does not add to the load effects being maximized came about when it was noticed that for very short spans, typically culverts, the load effects from an H truck was sometimes larger than those from the corresponding HS truck. Such short spans are not a concern for platoons because the single notional truck case will still be included in the design and will cover the case of needing to eliminate some axles.

Load effects tabulated are:

- Simple spans
  - Maximum positive moment in the span
  - Maximum end shear
- Two equal continuous spans
  - Maximum positive moment in Span 1 (Span 2 is similar from symmetry)
  - Maximum negative moment at the intermediate support
  - Maximum end shear
  - Maximum shear on one side of the intermediate support (the other side is similar from symmetry)
- Three equal continuous spans
  - Maximum positive moment in Span 1 (Span 3 is similar from symmetry)
  - Maximum positive moment in Span 2
  - Maximum negative moment at first interior support (second interior support is similar from symmetry)

- Maximum end shear in Span 1 (end shear in Span 3 is similar from symmetry)
- Maximum shear left of the first interior support (right of the second interior support is similar from symmetry)
- Maximum shear right of the first interior support (left of the second interior support is similar from symmetry)

Table 30 shows a sample of the tabulated values for 100-foot spans. The tabulated values do not include the dynamic load allowance (IM). The tabulated values for all spans investigated are included in Appendix B.

Table 30. Maximum Unfactored Load Effects for 100 ft. Long Spans

Loading	Simple Span		Two-Span Continuous			
	M mid span (ft.k)	End shear (kips)	Pos. M span 1 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear left of int. support (kips)
HL-93 Truck	1520	65	1234	-661	64	-68
HL-93 Tandem	1200	49	988	-478	49	-49
HL-93 Lane	800	32	610	-792	28	-40
HL-93 Truck Pair	-	-	-	-1320	-	-
HS 20 Tandem	1152	47	949	-459	47	-47
HS 20 Truck	1520	65	1234	-661	64	-68
HS 20 Lane	1250	58	981	-1138	54	-66
33-1-00	1340	61	1048	-646	57	-66
33-2-30	1340	65	1048	-1277	57	-71
33-2-50	1340	61	1048	-1261	57	-69
33-2-70	1340	61	1048	-1129	57	-67
33-3-30	1340	65	1048	-1295	57	-76
33-3-50	1340	61	1048	-1261	57	-69
33-3-70	1340	61	1048	-1129	57	-67
33-4-30	1340	65	1048	-1295	57	-76
33-4-50	1340	61	1048	-1261	57	-69
33-4-70	1340	61	1048	-1129	57	-67
3S2-1-00	1322	59	1064	-617	56	-62
3S2-2-30	1389	67	1064	-1184	61	-74
3S2-2-50	1322	61	1064	-1234	56	-67
3S2-2-70	1322	59	1064	-1166	56	-64
3S2-3-30	1389	67	1064	-1282	61	-79
3S2-3-50	1322	61	1064	-1234	56	-69
3S2-3-70	1322	59	1064	-1166	56	-64
3S2-4-30	1389	67	1064	-1326	61	-79
3S2-4-50	1322	61	1064	-1234	56	-69
3S2-4-70	1322	59	1064	-1166	56	-64
T-1-00	1315	61	1064	-636	57	-65
T-2-30	1367	67	1064	-1248	61	-76
T-2-50	1315	61	1064	-1254	57	-69
T-2-70	1315	61	1064	-1141	57	-67
T-3-30	1367	67	1064	-1280	61	-79
T-3-50	1315	61	1064	-1254	57	-69
T-3-70	1315	61	1064	-1141	57	-67
T-4-30	1367	67	1064	-1280	61	-79
T-4-50	1315	61	1064	-1254	57	-69
T-4-70	1315	61	1064	-1141	57	-67

Table 30 (cont'd.) Maximum Unfactored Load Effects for 100 ft. Long Spans

Loading	Three-Span Continuous					
	Pos. M span 1 (ft.k)	Pos. M span 2 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear left of 1st int. support (kips)	Shear right of 1st int. support (kips)
HL-93 Truck	1217	1006	-705	64	-68	66
HL-93 Tandem	977	828	-510	49	-49	49
HL-93 Lane	642	483	-739	29	-39	37
HL-93 Truck Pair	-	-	-1253	-	-	-
HS 20 Tandem	938	795	-489	47	-47	47
HS 20 Truck	1217	1006	-705	64	-68	66
HS 20 Lane	1009	798	-1068	55	-65	63
33-1-00	1032	833	-689	57	-66	62
33-2-30	1032	651	-1207	57	-71	70
33-2-50	1032	617	-1174	57	-68	67
33-2-70	1032	678	-1042	57	-66	64
33-3-30	1032	625	-1219	57	-75	70
33-3-50	1032	617	-1174	57	-68	67
33-3-70	1032	678	-1042	57	-66	64
33-4-30	1032	625	-1219	57	-75	70
33-4-50	1032	617	-1174	57	-68	67
33-4-70	1032	678	-1042	57	-66	64
3S2-1-00	1048	847	-659	55	-63	60
3S2-2-30	1048	765	-1129	61	-74	68
3S2-2-50	1048	654	-1160	55	-66	65
3S2-2-70	1048	666	-1079	55	-64	62
3S2-3-30	1048	660	-1218	61	-79	75
3S2-3-50	1048	654	-1160	55	-69	65
3S2-3-70	1048	666	-1079	55	-64	62
3S2-4-30	1048	660	-1218	61	-79	75
3S2-4-50	1048	654	-1160	55	-69	65
3S2-4-70	1048	666	-1079	55	-64	62
T-1-00	1047	834	-678	56	-66	61
T-2-30	1047	704	-1177	61	-76	71
T-2-50	1047	647	-1170	56	-68	67
T-2-70	1047	702	-1053	56	-66	64
T-3-30	1047	649	-1193	61	-78	74
T-3-50	1047	647	-1170	56	-68	67
T-3-70	1047	702	-1053	56	-66	64
T-4-30	1047	649	-1201	61	-78	74
T-4-50	1047	647	-1170	56	-68	67
T-4-70	1047	702	-1053	56	-66	64

5.2 COMPARISON OF PLATOON LOAD EFFECTS

The dynamic effects, referred to as the dynamic load allowance (IM) in AASHTO LRFD Bridge Design Specifications (AASHTO LRFD), 8th Edition, 2017, (23 CFR 625) or impact (I) in AASHTO Standard Specifications for Highway Bridges (AASHTO Standard Specifications), 17th Edition, 2002 (23 CFR 625), are included in the load effects when the design load effects are compared to those from the investigated platoons. The application of the dynamic effects follows the provisions of the two design specifications as follows:

1. For the HL-93 loading: In accordance with AASHTO LRFD (2017), the IM was applied only to the portion of the load effects due to the truck or tandem loads and not to the uniform lane load. Because this work is focused on the strength limit state, the IM corresponding to this limit state (33 percent) was used.
2. For the HS 20 loading: In accordance with AASHTO Standard Specifications (2002), the Impact (I) was applied to the truck load, the lane load (including the concentrated loads), and the tandem load (referred to as the "military load"). The value of the impact factor was determined as prescribed in AASHTO Standard Specifications (2002) using Equation 1:

$$I = \frac{50}{125 + L} \leq 0.3 \tag{1}$$

Where:
I = Impact factor
L = Span length (ft.)

3. For the platoon load effects, the following were applied to the load effects to account for the dynamic effects:
    - When comparing to the HL-93 loading: 33 percent
    - When comparing to the HS 20 loading: the impact corresponding to the span length being considered calculated using Equation 1

Throughout the following sections of this report, the dynamic effects are referred to as "impact" regardless of the design specifications being used or compared to.

The load effects are normalized by the load effects from the design loads being compared to HL-93 or HS 20. The load effect ratios are tabulated for all load effects and span lengths considered. Table 31 shows the ratios between the maximum positive moment from each platoon configuration and that from the HL-93 loading for simple spans. Table 32 shows a similar comparison for the end shear from HL-93 loading on simple span.

Table 33 and Table 34 are similar to Table 31 and Table 32; however, the comparison is made to the HS 20 loading.

In Table 31 through Table 34, for a specific platoon configuration and span length, a ratio greater than 1.0 indicates that the platoon configuration is producing a higher load effect than the design load (HL-93 for Table 31 and Table 32or HS 20 for Table 33 and Table 34).

Comparisons like those shown in Table 31 through Table 34 are shown in Appendix C for all load effects investigated; including those for continuous spans.

Typically, a bridge is considered to have adequate load capacity at the operating level when it has a resistance higher than the load effects produced by AASHTO specialized hauling vehicles (SHVs). Generally, bridges can adequately support the SHVs when they have:

- A rating factor ≥1.00 at the operating level (Item 64 in the NBI expressed as a rating factor) using the Load and Resistance Factor Rating (LRFR) method, or

- A rating factor ≥1.20 at the operating level (Item 64 in the NBI expressed as a rating factor) using the Allowable Stress Rating (ASR) or Load Factor Rating (LFR) methods.

Notice that the 1.2 threshold was selected because bridges with an HS 20 operating rating ≥1.2 typically can support the AASHTO SHVs. This value is an approximate value suitable for bridge screening, however, the actual threshold is dependent on span length and span configuration.

However, when the ASR and LFR methods are used, some States accept bridges with an operating rating factor ≥1.00 (Item 64 in the NBI expressed as a rating factor) as acceptable.

Therefore, for determining bridges that could be affected by the platoons, the team examined two cases:

- Case 1: A bridge was considered to currently have adequate load capacity when it has a rating factor ≥1.00 at the operating level (Item 64 in the NBI expressed as a rating factor) using the LRFR method, or ≥1.20 at the operating level (Item 64 in the NBI expressed as a rating factor) using the ASR or LFR methods. The 1.20 ratio for ASR and LFR rating was selected to ensure the bridge can adequately support the AASHTO SHVs (the latter are considered to generally produce load effects 20 percent higher than HS 20 loading).

- Case 2: A bridge was considered to currently have adequate load capacity when it has a rating factor ≥1.00 at the operating level using the rating method used for the NBI listing (LRFR, ASR or LFR).

5.3 DETERMINATION OF POTENTIALLY AFFECTED SPAN LENGTHS FOR CASE 1

In Table 31 through Table 34 and in Appendix C, the cases where the load effect ratios are higher than those shown above for Case 1 (1.00 when comparing to HL-93 or 1.20 when comparing to HS 20) are shown in bold typeface. These are the cases where the combination of the span length and platoon configuration may cause a bridge that currently has an acceptable operating rating factor (Item 64 in the NBI expressed as a rating factor) to have a substandard rating factor ((Item 64 in the NBI expressed as a rating factor <1.0 for LRFR and <1.2 for LFR and ASR) under the platoon configuration producing the higher load effects and assuming Case 1.

Table 35 lists the platoons and span lengths where the ratio of the platoon load effects is higher than those from the HL-93 design load. Table 36 is similar except it relates to the cases where the platoon load effects are higher than 1.20 times those from the HS 20 design load.

For HL-93 design loads and simple spans, the values in Table 31 and Table 32 indicate that:

- For the two-truck platoons, the ratio to the HL-93 load effects was always below 1.00 for both moment and shear regardless of the spacing between the two trucks.
- For the three- and four-truck platoons, the ratios to the HL-93 load effects for both moment and shear were always below 1.00 when the truck spacing was 50 feet or 70 feet. For 30-foot truck spacing, the ratio remained below 1.00 except for some load effects for longer spans (typically for spans of 250 feet and longer for moment and greater than or equal to 200 feet for shear) as shown in Table 35.

For HS 20 design loads and simple spans, the values in Table 33 and Table 34 indicate that:

- For the two-truck platoons, the ratio to the HS 20 load effects was always below 1.20 for both moment and shear for all truck spacings except for the shear ratio for few cases when the truck spacing was 30 feet (span length 130 feet for 3S2 platoons and 160 feet for Type T platoons)
- For the three- and four-truck platoons, the ratio to the HS 20 load effects for both moment and shear was always below 1.20 when the truck spacing was 50 or 70 feet. For 30-foot truck spacing, the ratio exceeded 1.20 for longer spans (spans longer than 250 feet for moment from Type 3-3 and 200 feet for moment from 3S2 and T platoons, and 160 feet, 130 feet, and 160 feet for shear from Type 3-3, 3S2, and T platoons, respectively) as shown in Table 36 .

Somewhat similar behavior was observed in continuous spans as is shown in Table 35, Table 36, and Appendix C.

Table 31. Platoon Moment Ratio to HL-93 Moment. Positive Moment, Simple Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
50	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
70	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
100	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
130	0.63	0.68	0.63	0.63	0.68	0.63	0.63	0.68	0.63	0.63
160	0.61	0.74	0.63	0.61	0.74	0.63	0.61	0.74	0.63	0.61
200	0.58	0.81	0.69	0.60	0.84	0.69	0.60	0.84	0.69	0.60
250	0.54	0.83	0.74	0.66	0.95	0.77	0.66	0.95	0.77	0.66
300	0.51	0.82	0.74	0.68	**1.01**	0.86	0.71	**1.03**	0.86	0.71

Table 31 (cont'd) Platoon Moment Ratio to HL-93 Moment. Positive Moment, Simple Spans

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
50	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
70	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
100	0.62	0.65	0.62	0.62	0.65	0.62	0.62	0.65	0.62	0.62
130	0.61	0.71	0.61	0.61	0.71	0.61	0.61	0.71	0.61	0.61
160	0.58	0.78	0.64	0.58	0.80	0.64	0.58	0.80	0.64	0.58
200	0.55	0.81	0.70	0.60	0.91	0.70	0.60	0.91	0.70	0.60
250	0.50	0.81	0.72	0.65	0.99	0.81	0.65	**1.01**	0.81	0.65
300	0.47	0.78	0.71	0.66	**1.01**	0.87	0.73	**1.08**	0.87	0.73

Table 31 (cont'd) Platoon Moment Ratio to HL-93 Moment. Positive Moment, Simple Spans

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
50	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
70	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
100	0.62	0.64	0.62	0.62	0.64	0.62	0.62	0.64	0.62	0.62
130	0.62	0.72	0.62	0.62	0.72	0.62	0.62	0.72	0.62	0.62
160	0.61	0.77	0.66	0.61	0.77	0.66	0.61	0.77	0.66	0.61
200	0.58	0.83	0.71	0.62	0.89	0.71	0.62	0.89	0.71	0.62
250	0.54	0.85	0.75	0.67	0.98	0.80	0.67	0.98	0.80	0.67
300	0.50	0.83	0.76	0.69	**1.03**	0.88	0.73	**1.06**	0.88	0.73

Table 32. Platoon Shear Ratio to HL-93 Shear. End Shear, Simple Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
50	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
70	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
100	0.68	0.73	0.68	0.68	0.73	0.68	0.68	0.73	0.68	0.68
130	0.67	0.81	0.73	0.67	0.81	0.73	0.67	0.81	0.73	0.67
160	0.64	0.89	0.79	0.71	0.89	0.79	0.71	0.89	0.79	0.71
200	0.60	0.92	0.85	0.78	0.96	0.85	0.78	0.96	0.85	0.78
250	0.56	0.91	0.86	0.81	**1.05**	0.91	0.81	**1.05**	0.91	0.81
300	0.52	0.88	0.84	0.80	**1.08**	0.97	0.86	**1.13**	0.97	0.86

Table 32 (cont'd). Platoon Shear Ratio to HL-93 Shear. End Shear, Simple Spans

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
50	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
70	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
100	0.66	0.75	0.68	0.66	0.75	0.68	0.66	0.75	0.68	0.66
130	0.63	0.86	0.75	0.67	0.86	0.75	0.67	0.86	0.75	0.67
160	0.60	0.90	0.81	0.73	0.93	0.81	0.73	0.93	0.81	0.73
200	0.56	0.90	0.84	0.78	**1.02**	0.86	0.78	**1.02**	0.86	0.78
250	0.51	0.87	0.83	0.78	**1.07**	0.94	0.81	**1.11**	0.94	0.81
300	0.48	0.83	0.80	0.76	**1.07**	0.97	0.86	**1.18**	0.98	0.86

Table 32 (cont'd). Platoon Shear Ratio to HL-93 Shear. End Shear, Simple Spans

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
50	0.59	0.60	0.59	0.59	0.60	0.59	0.59	0.60	0.59	0.59
70	0.66	0.67	0.66	0.66	0.67	0.66	0.66	0.67	0.66	0.66
100	0.68	0.75	0.68	0.68	0.75	0.68	0.68	0.75	0.68	0.68
130	0.66	0.82	0.74	0.68	0.83	0.74	0.68	0.83	0.74	0.68
160	0.64	0.90	0.80	0.72	0.90	0.80	0.72	0.90	0.80	0.72
200	0.60	0.93	0.86	0.79	0.99	0.86	0.79	0.99	0.86	0.79
250	0.56	0.92	0.87	0.82	**1.07**	0.93	0.82	**1.08**	0.93	0.82
300	0.52	0.88	0.85	0.81	**1.10**	0.99	0.87	**1.16**	0.99	0.87

Table 33. Platoon Moment Ratio to HS 20 Moment. Positive Moment, Simple Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
50	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
70	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
100	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
130	0.94	1.02	0.94	0.94	1.02	0.94	0.94	1.02	0.94	0.94
160	0.92	1.11	0.94	0.92	1.11	0.94	0.92	1.11	0.94	0.92
200	0.81	1.13	0.97	0.84	1.18	0.97	0.84	1.18	0.97	0.84
250	0.71	1.08	0.96	0.86	**1.24**	1.00	0.86	**1.24**	1.00	0.86
300	0.62	1.01	0.92	0.84	**1.24**	1.05	0.87	**1.26**	1.05	0.87

Table 33 (cont'd) Platoon Moment Ratio to HS 20 Moment. Positive Moment, Simple Spans

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
50	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
70	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
100	0.87	0.91	0.87	0.87	0.91	0.87	0.87	0.91	0.87	0.87
130	0.90	1.06	0.90	0.90	1.06	0.90	0.90	1.06	0.90	0.90
160	0.87	1.16	0.96	0.87	1.20	0.96	0.87	1.20	0.96	0.87
200	0.76	1.13	0.98	0.84	**1.27**	0.98	0.84	**1.27**	0.98	0.84
250	0.66	1.05	0.94	0.84	**1.29**	1.06	0.85	**1.31**	1.06	0.85
300	0.58	0.96	0.88	0.81	**1.24**	1.07	0.90	**1.33**	1.07	0.90

Table 33 (cont'd) Platoon Moment Ratio to HS 20 Moment. Positive Moment, Simple Spans

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
50	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
70	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
100	0.87	0.90	0.87	0.87	0.90	0.87	0.87	0.90	0.87	0.87
130	0.93	1.08	0.93	0.93	1.08	0.93	0.93	1.08	0.93	0.93
160	0.91	1.15	0.99	0.91	1.15	0.99	0.91	1.15	0.99	0.91
200	0.81	1.16	0.99	0.86	**1.24**	0.99	0.86	**1.24**	0.99	0.86
250	0.70	1.10	0.98	0.87	**1.28**	1.05	0.87	**1.28**	1.05	0.87
300	0.62	1.02	0.93	0.85	**1.27**	1.08	0.90	**1.31**	1.08	0.90

Table 34. Platoon Shear Ratio to HS 20 Shear. End Shear, Simple Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
50	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
70	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
100	0.93	0.99	0.93	0.93	0.99	0.93	0.93	0.99	0.93	0.93
130	0.97	1.18	1.05	0.98	1.18	1.05	0.98	1.18	1.05	0.98
160	0.88	**1.22**	1.09	0.98	**1.22**	1.09	0.98	**1.22**	1.09	0.98
200	0.78	1.19	1.10	1.01	**1.25**	1.10	1.01	**1.25**	1.10	1.01
250	0.68	1.11	1.05	0.99	**1.29**	1.11	0.99	**1.29**	1.11	0.99
300	0.60	1.02	0.98	0.94	**1.26**	1.13	1.00	**1.31**	1.13	1.00

Table 34 (cont'd). Platoon Shear Ratio to HS 20 Shear. End Shear, Simple Spans

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
50	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
70	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
100	0.90	1.03	0.93	0.90	1.03	0.93	0.90	1.03	0.93	0.90
130	0.91	**1.24**	1.08	0.97	**1.24**	1.08	0.97	**1.24**	1.08	0.97
160	0.82	**1.23**	1.12	1.00	**1.27**	1.12	1.00	**1.27**	1.12	1.00
200	0.73	1.17	1.09	1.01	**1.32**	1.11	1.01	**1.32**	1.11	1.01
250	0.63	1.06	1.01	0.96	**1.31**	1.14	0.99	**1.36**	1.14	0.99
300	0.55	0.97	0.93	0.89	**1.24**	1.12	1.01	**1.38**	1.15	1.01

Table 34 (cont'd). Platoon Shear Ratio to HS 20 Shear. End Shear, Simple Spans

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
50	0.71	0.72	0.71	0.71	0.72	0.71	0.71	0.72	0.71	0.71
70	0.84	0.85	0.84	0.84	0.85	0.84	0.84	0.85	0.84	0.84
100	0.93	1.03	0.93	0.93	1.03	0.93	0.93	1.03	0.93	0.93
130	0.96	1.19	1.07	0.99	1.20	1.07	0.99	1.20	1.07	0.99
160	0.88	**1.23**	1.10	0.99	**1.24**	1.10	0.99	**1.24**	1.10	0.99
200	0.78	1.20	1.11	1.02	**1.29**	1.11	1.02	**1.29**	1.11	1.02
250	0.68	1.12	1.06	1.00	**1.31**	1.13	1.01	**1.32**	1.13	1.01
300	0.60	1.03	0.98	0.94	**1.28**	1.15	1.01	**1.35**	1.15	1.01

Table 35. Spans with Platoon Load Effects Exceeding HL-93 Load Effects

Loading	Simple Span		Two-Span Continuous			
	M midspan	End shear	Pos. M span 1	Neg. M at inter. support	End shear	Shear left of int. support
33-1-00	-	-	-	-	-	-
33-2-30	-	-	-	-	-	-
33-2-50	-	-	-	-	-	-
33-2-70	-	-	-	-	-	-
33-3-30	300	≥250	-	-	≥250	≥250
33-3-50	-	-	-	-	-	-
33-3-70	-	-	-	-	-	-
33-4-30	300	≥250	-	200	≥250	≥200
33-4-50	-	-	-	-	-	-
33-4-70	-	-	-	-	-	-
3S2-1-00	-	-	-	-	-	-
3S2-2-30	-	-	-	-	-	-
3S2-2-50	-	-	-	-	-	-
3S2-2-70	-	-	-	-	-	-
3S2-3-30	300	≥200	-	-	≥250	≥200
3S2-3-50	-	-	-	-	-	-
3S2-3-70	-	-	-	-	-	-
3S2-4-30	≥250	≥200	300	-	≥250	≥200
3S2-4-50	-	-	-	-	-	-
3S2-4-70	-	-	-	-	-	-
T-1-00	-	-	-	-	-	-
T-2-30	-	-	-	-	-	-
T-2-50	-	-	-	-	-	-
T-2-70	-	-	-	-	-	-
T-3-30	300	≥250	-	-	≥250	≥200
T-3-50	-	-	-	-	-	-
T-3-70	-	-	-	-	-	-
T-4-30	300	≥250	300	200	≥250	≥200
T-4-50	-	-	-	-	-	-
T-4-70	-	-	-	-	-	-

Table 35. (cont'd). Spans with Platoon Load Effects Exceeding HL-93 Load Effects

Loading	Three-Span Continuous					
	Pos. M span 1	Pos. M span 2	Neg. M at inter. support	End shear	Shear left of 1st int. support	Shear right of 1st int. support
33-1-00	-	-	-	-	-	-
33-2-30	-	-	-	-	-	-
33-2-50	-	-	-	-	-	-
33-2-70	-	-	-	-	-	-
33-3-30	-	-	-	300	≥250	-
33-3-50	-	-	-	-	-	-
33-3-70	-	-	-	-	-	-
33-4-30	-	-	200	300	≥200	≥250
33-4-50	-	-	-	-	-	-
33-4-70	-	-	-	-	-	-
3S2-1-00	-	-	-	-	-	-
3S2-2-30	-	-	-	-	-	-
3S2-2-50	-	-	-	-	-	-
3S2-2-70	-	-	-	-	-	-
3S2-3-30	-	-	-	≥250	≥200	-
3S2-3-50	-	-	-	-	-	-
3S2-3-70	-	-	-	-	-	-
3S2-4-30	300	300	-	≥250	≥200	≥200
3S2-4-50	-	-	-	-	-	-
3S2-4-70	-	-	-	-	-	-
T-1-00	-	-	-	-	-	-
T-2-30	-	-	-	-	-	-
T-2-50	-	-	-	-	-	-
T-2-70	-	-	-	-	-	-
T-3-30	-	-	-	≥250	≥200	-
T-3-50	-	-	-	-	-	-
T-3-70	-	-	-	-	-	-
T-4-30	-	-	200	≥250	≥200	≥200
T-4-50	-	-	-	-	-	-
T-4-70	-	-	-	-	-	-

Table 36. Spans with Platoon Load Effects Exceeding 1.20 HS 20 Load Effects

Loading	Simple Span		Two-Span Continuous			
	M midspan	End shear	Pos. M span 1	Neg. M at inter. support	End shear	Shear left of int. support
33-1-00	-	-	-	-	-	-
33-2-30	-	160	-	-	-	-
33-2-50	-	-	-	-	-	-
33-2-70	-	-	-	-	-	-
33-3-30	≥250	≥160	≥250	-	≥200	130 to 250
33-3-50	-	-	-	-	-	-
33-3-70	-	-	-	-	-	-
33-4-30	≥250	≥160	≥250	160,200	≥200	≥130
33-4-50	-	-	-	-	-	-
33-4-70	-	-	-	-	-	-
3S2-1-00	-	-	-	-	-	-
3S2-2-30	-	130,160	-	-	160	-
3S2-2-50	-	-	-	-	-	-
3S2-2-70	-	-	-	-	-	-
3S2-3-30	≥160	≥130	≥200	-	≥160	130 to 250
3S2-3-50	-	-	-	-	-	-
3S2-3-70	-	-	-	-	-	-
3S2-4-30	≥160	≥130	≥200	130 to 200	≥160	≥130
3S2-4-50	-	-	-	-	-	-
3S2-4-70	-	-	-	-	-	-
T-1-00	-	-	-	-	-	-
T-2-30	-	160,200	-	-	160 to 200	-
T-2-50	-	-	-	-	-	-
T-2-70	-	-	-	-	-	-
T-3-30	≥200	≥130	≥200	-	≥160	130 to 250
T-3-50	-	-	-	-	-	-
T-3-70	-	-	-	-	-	-
T-4-30	≥200	≥130	≥200	160, 200	≥160	≥130
T-4-50	-	-	-	-	-	-
T-4-70	-	-	-	-	-	-

Table 36. (cont'd). Spans with Platoon Load Effects Exceeding 1.20 HS 20 Load Effects

Loading	Three-Span Continuous					
	Pos. M span 1	Pos. M span 2	Neg. M at inter. support	End shear	Shear left of 1st int. support	Shear right of 1st int. support
33-1-00	-	-	-	-	-	-
33-2-30	-	-	-	-	-	-
33-2-50	-	-	-	-	-	-
33-2-70	-	-	-	-	-	-
33-3-30	-	≥250	-	≥250	130,160, 250	160
33-3-50	-	-	-	-	-	-
33-3-70	-	-	-	-	-	-
33-4-30	-	300	160,200	≥250	≥130	160
33-4-50	-	-	-	-	-	-
33-4-70	-	-	-	-	-	-
3S2-1-00	-	-	-	-	-	-
3S2-2-30	-	-	-	-	-	-
3S2-2-50	-	-	-	-	-	-
3S2-2-70	-	-	-	-	-	-
3S2-3-30	250	≥200	-	≥160	130 to 250	130,160
3S2-3-50	-	-	-	-	-	-
3S2-3-70	-	-	-	-	-	-
3S2-4-30	≥250	≥250	130,160	≥160	≥130	≥130
3S2-4-50	-	-	-	-	-	-
3S2-4-70	-	-	-	-	-	-
T-1-00	-	-	-	-	-	-
T-2-30	-	-	-	-	-	-
T-2-50	-	-	-	-	-	-
T-2-70	-	-	-	-	-	-
T-3-30	-	≥250	-	≥200	≥130	130,160
T-3-50	-	-	-	-	-	-
T-3-70	-	-	-	-	-	-
T-4-30	≥250	300	160,200	≥200	≥130	≥130
T-4-50	-	-	-	-	-	-
T-4-70	-	-	-	-	-	-

5.4 DETERMINATION OF POTENTIALLY AFFECTED SPAN LENGTHS FOR CASE 2

Table 31, Table 32, and Table 35 relate to the load effects from HL-93. They are applicable to Case 2 because the criteria for HL-93 loading is the same for Case 1 and Case 2. Similarly, the observations made regarding the HL-93 loading for Case 1 in the previous section are still applicable to Case 2.

Table 37 and Table 38 are the same as Table 33 and Table 34, respectively, except that the cases where the load effect ratios from the platoons compared to those from HS 20 are higher than 1.00 (instead of 1.20 in Table 33 and Table 34) are shown in bold typeface. These are the cases where the combination of the span length and platoon configuration may cause a bridge that currently has an operating rating factor (Item 64 in the NBI expressed as a rating factor) >1.0 and has a rating factor <1.0 under the platoon configuration producing the higher load effects and assuming HS 20 loading and Case 2.

The observations made regarding the HL-93 loading for Case 1 in the previous section are still applicable to Case 2.

Table 39 lists the platoons and span lengths where the ratio of the platoon load effects is higher than those from the HS 20 load.

For HS 20 design loads and simple spans, the values in Table 37 and Table 38 indicate that:

- The ratio of the platoon moment to the HS 20 moment was always below 1.00 for truck spacing of 70 ft. The same was observed for truck spacing of 50 ft. except for spans of 250 and 300 ft. for the three- and four- truck platoons. For the 30 ft. truck spacing, the ratio exceeded 1.00 for most spans above 130 ft.

- The ratio of the platoon moment to the HS 20 end shear was always below 1.00 for truck spacing of 70 ft. except for some spans above 200 ft. The ratio exceeded 1.00 for most spans longer than 130 ft. and 100 ft for platoons with truck spacing of 50 and 30 ft. respectively.

Somewhat similar behavior was observed in continuous spans as can be seen in Appendix C.

Table 37. Platoon Moment Ratio to HS 20 Moment. Positive Moment, Simple Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
50	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
70	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
100	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
130	0.94	1.02	0.94	0.94	1.02	0.94	0.94	1.02	0.94	0.94
160	0.92	1.11	0.94	0.92	1.11	0.94	0.92	1.11	0.94	0.92
200	0.81	1.13	0.97	0.84	1.18	0.97	0.84	1.18	0.97	0.84
250	0.71	1.08	0.96	0.86	**1.24**	1.00	0.86	**1.24**	1.00	0.86
300	0.62	1.01	0.92	0.84	**1.24**	1.05	0.87	**1.26**	1.05	0.87

Table 37 (cont'd) Platoon Moment Ratio to HS 20 Moment. Positive Moment, Simple Spans

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
50	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
70	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
100	0.87	0.91	0.87	0.87	0.91	0.87	0.87	0.91	0.87	0.87
130	0.90	1.06	0.90	0.90	1.06	0.90	0.90	1.06	0.90	0.90
160	0.87	1.16	0.96	0.87	1.20	0.96	0.87	1.20	0.96	0.87
200	0.76	1.13	0.98	0.84	**1.27**	0.98	0.84	**1.27**	0.98	0.84
250	0.66	1.05	0.94	0.84	**1.29**	1.06	0.85	**1.31**	1.06	0.85
300	0.58	0.96	0.88	0.81	**1.24**	1.07	0.90	**1.33**	1.07	0.90

Table 37 (cont'd) Platoon Moment Ratio to HS 20 Moment. Positive Moment, Simple Spans

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
50	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
70	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
100	0.87	0.90	0.87	0.87	0.90	0.87	0.87	0.90	0.87	0.87
130	0.93	1.08	0.93	0.93	1.08	0.93	0.93	1.08	0.93	0.93
160	0.91	1.15	0.99	0.91	1.15	0.99	0.91	1.15	0.99	0.91
200	0.81	1.16	0.99	0.86	**1.24**	0.99	0.86	**1.24**	0.99	0.86
250	0.70	1.10	0.98	0.87	**1.28**	1.05	0.87	**1.28**	1.05	0.87
300	0.62	1.02	0.93	0.85	**1.27**	1.08	0.90	**1.31**	1.08	0.90

Table 38. Platoon Shear Ratio to HS 20 Shear. End Shear, Simple Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
50	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
70	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
100	0.93	0.99	0.93	0.93	0.99	0.93	0.93	0.99	0.93	0.93
130	0.97	<u>1.18</u>	<u>1.05</u>	0.98	<u>1.18</u>	<u>1.05</u>	0.98	<u>1.18</u>	<u>1.05</u>	0.98
160	0.88	**1.22**	<u>1.09</u>	0.98	**1.22**	<u>1.09</u>	0.98	**1.22**	<u>1.09</u>	0.98
200	0.78	<u>1.19</u>	<u>1.10</u>	<u>1.01</u>	**1.25**	<u>1.10</u>	<u>1.01</u>	**1.25**	<u>1.10</u>	<u>1.01</u>
250	0.68	<u>1.11</u>	<u>1.05</u>	0.99	**1.29**	<u>1.11</u>	0.99	**1.29**	<u>1.11</u>	<u>0.99</u>
300	0.60	<u>1.02</u>	0.98	0.94	**1.26**	<u>1.13</u>	1.00	**1.31**	<u>1.13</u>	1.00

Table 38 (cont'd). Platoon Shear Ratio to HS 20 Shear. End Shear, Simple Spans

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
50	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
70	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
100	0.90	<u>1.03</u>	0.93	0.90	<u>1.03</u>	0.93	0.90	<u>1.03</u>	0.93	0.90
130	0.91	**1.24**	<u>1.08</u>	0.97	**1.24**	<u>1.08</u>	0.97	**1.24**	<u>1.08</u>	0.97
160	0.82	**1.23**	<u>1.12</u>	1.00	**1.27**	<u>1.12</u>	1.00	**1.27**	<u>1.12</u>	1.00
200	0.73	<u>1.17</u>	<u>1.09</u>	<u>1.01</u>	**1.32**	<u>1.11</u>	<u>1.01</u>	**1.32**	<u>1.11</u>	<u>1.01</u>
250	0.63	<u>1.06</u>	<u>1.01</u>	0.96	**1.31**	<u>1.14</u>	0.99	**1.36**	<u>1.14</u>	0.99
300	0.55	0.97	0.93	0.89	**1.24**	<u>1.12</u>	<u>1.01</u>	**1.38**	<u>1.15</u>	<u>1.01</u>

Table 38 (cont'd). Platoon Shear Ratio to HS 20 Shear. End Shear, Simple Spans

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
50	0.71	0.72	0.71	0.71	0.72	0.71	0.71	0.72	0.71	0.71
70	0.84	0.85	0.84	0.84	0.85	0.84	0.84	0.85	0.84	0.84
100	0.93	1.03	0.93	0.93	1.03	0.93	0.93	1.03	0.93	0.93
130	0.96	1.19	1.07	0.99	1.20	1.07	0.99	1.20	1.07	0.99
160	0.88	**1.23**	1.10	0.99	**1.24**	1.10	0.99	**1.24**	1.10	0.99
200	0.78	1.20	1.11	1.02	**1.29**	1.11	1.02	**1.29**	1.11	1.02
250	0.68	1.12	1.06	1.00	**1.31**	1.13	1.01	**1.32**	1.13	1.01
300	0.60	1.03	0.98	0.94	**1.28**	1.15	1.01	**1.35**	1.15	1.01

Table 39. Spans with Platoon Load Effects Exceeding HS 20 Load Effects

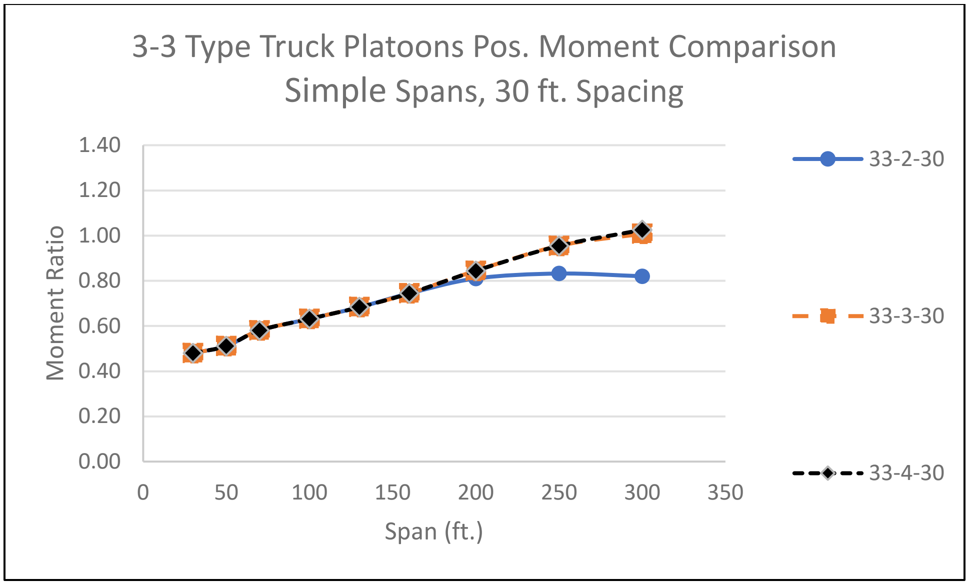
Loading	Simple Span		Two-Span Continuous			
	M midspan	End shear	Pos. M Span 1	Neg. M at inter. support	End shear	Shear left of interior support
33-1-00	-	-	-	-	-	-
33-2-30	≥130	≥130	≥160	70, 100	≥130	100 to 250
33-2-50	-	130 to 250	-	100	≥160	100, 160, 200
33-2-70	-	200	-	-	200	-
33-3-30	≥130	≥130	≥160	70 to 160	≥130	≥100
33-3-50	≥250	≥130	300	100	≥160	≥100
33-3-70	-	200	-	-	200	200
33-4-30	≥130	≥130	≥160	70 to 250	≥130	≥100
33-4-50	300	≥130	≥250	100, 200, 250	>160	≥100
33-4-70	-	200	-	-	200	200
3S2-1-00	-	-	-	-	-	-
3S2-2-30	130 to 250	100 to 250	≥130	50 to 100	≥130	100 to 200
3S2-2-50	-	130 to 250	200	70, 100	130 to	130 to 200
3S2-2-70	-	200	-	100	200	-
3S2-3-30	≥130	≥100	≥130	50 to 130	≥130	≥100
3S2-3-50	≥250	≥130	≥200	70, 100	≥130	≥100
3S2-3-70	-	200, 300	-	100	200	-
3S2-4-30	≥130	≥100	≥130	50 to 200	≥130	≥100
3S2-4-50	≥250	≥130	≥200	70, 100, 160, 200	≥130	≥100
3S2-4-70	-	200, 300	-	100	200	-
T-1-00	-	-	-	-	-	-
T-2-30	≥130	≥100	≥130	70, 100	≥130	100 to 250
T-2-50	-	130 to 250	200, 250	100	≥160	100 to 200
T-2-70	-	200	-	-	200	-
T-3-30	≥130	≥100	≥130	70 to 160	≥130	≥100
T-3-50	≥250	≥130	≥200	100	≥160	≥100
T-3-70	-	≥200	-	-	≥200	200
T-4-30	≥130	≥100	≥130	70 to 250	≥130	≥100
T-4-50	≥250	≥130	≥200	100, 160 to 250	≥160	≥100
T-4-70	-	≥200	-	-	≥200	200 to 250

Figure 17 through Figure 36 present some cases of truck platoons having load effects larger than the design loads. Figure 17 through Figure 26 show comparisons of the load effect ratios to HL-93 loading while Figure 27 through Figure 36 show the comparison to HS 20 loading.

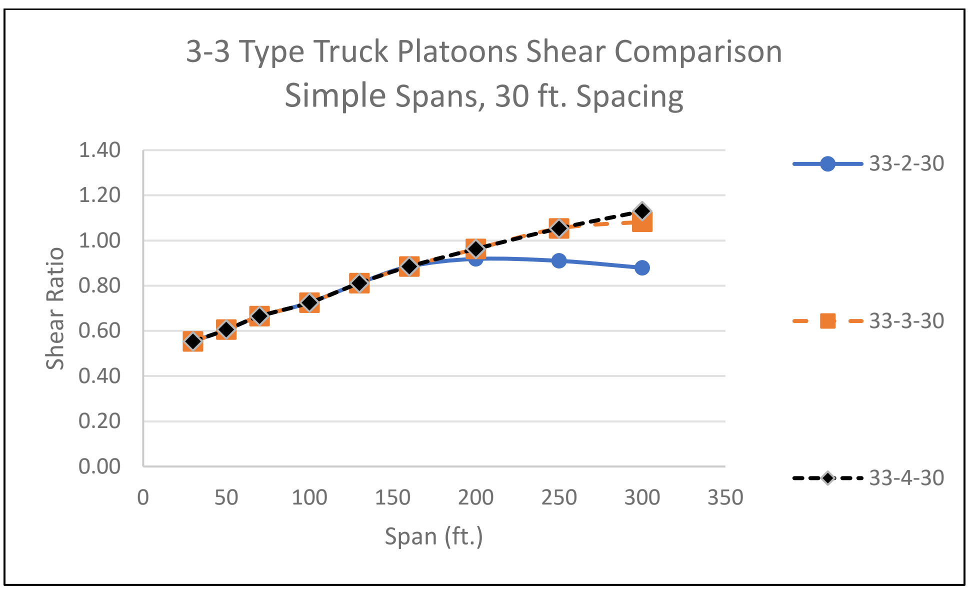
Figure 17 through Figure 19 show the comparison of the two-, three-, and four-truck platoons composed of Type 3-3, 3S2, and Type T trucks, respectively, for simple spans. Only results for platoons with 30 ft. truck spacing are shown as these are the ones that have some ratios of platoon load effects to HL-93 exceeding 1.00. As shown in Figure 17 through Figure 19, regardless of the type of trucks, the results for the two-, three-, and four-truck platoons are the same for shorter spans. The results for the two-truck platoons become smaller than for the larger platoons starting at about 160 ft. spans and the results for the three truck-platoons become smaller than the four-truck platoons at the longest spans investigated (300 ft.).

Figure 20 compares the results for the two-truck platoons using different truck types. The difference between the three truck types is small. Results for all trucks are very similar for spans less than 160 ft. except that Type T platoons control for the shortest spans (50 ft. and shorter). This is because for short spans the moments and shears are controlled by the weight of two consecutive axles. With Type T truck having heavier axles, this truck controls for short spans. For spans longer than 160 ft., Type 3-3 and Type T platoons give very close results with the 3S2 platoons giving lower results. This is because for longer spans the moments and shears are controlled by the weight and compactness of the platoons with the former having more significance. With Type 3-3 and Type T trucks weighing 80 kips and the 3S2 trucks weighing 72 kips, the latter gives lower results.

Figure 21 compares the results for the four-truck platoons using different truck types. For the shortest spans (approximately 50 ft. and shorter), Type T truck platoons produce higher moments and shears. This is because the short spans are controlled by the heavier tandems of the T truck rather than the total truck weight or configuration. For spans longer than approximately 100 ft., all four-truck platoons produced similar shears and moments with the 3S2 truck platoons producing slightly higher values. This was caused by the compactness of the truck even though it has less GVW.

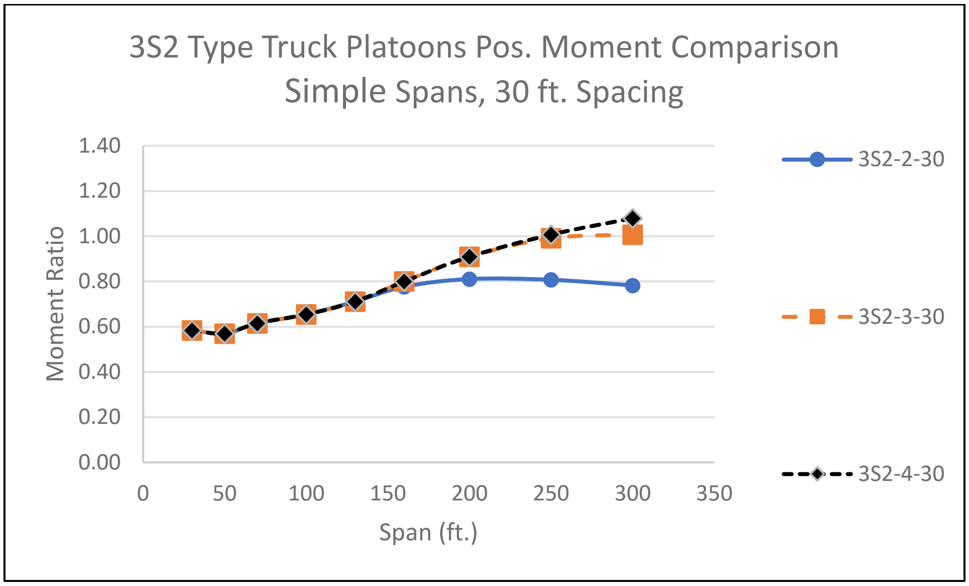


(a) Moment

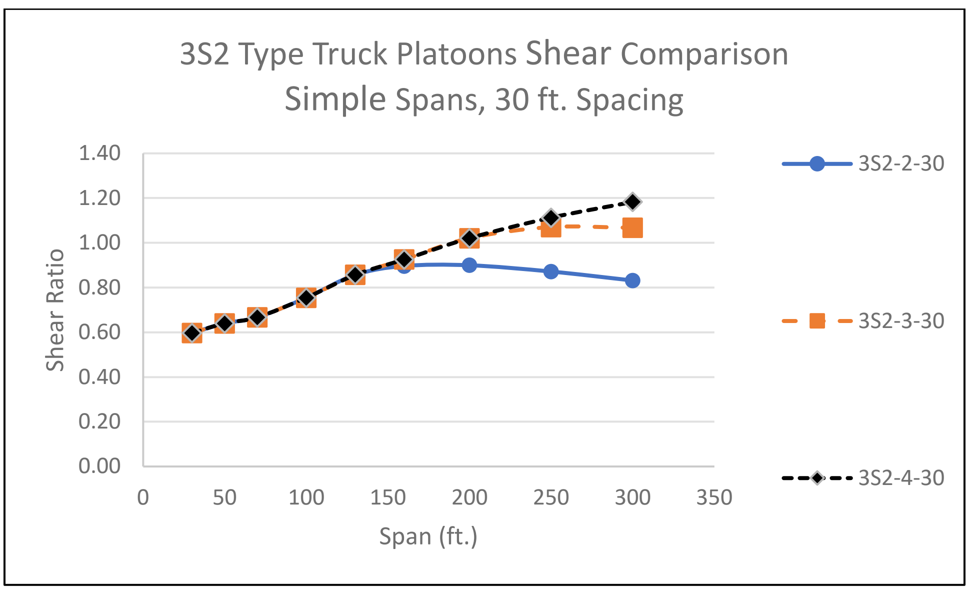


(b) Shear

Figure 17. Comparison of Type 3-3 Platoons to HL-93, Simple Spans, 30 ft. Truck Spacing

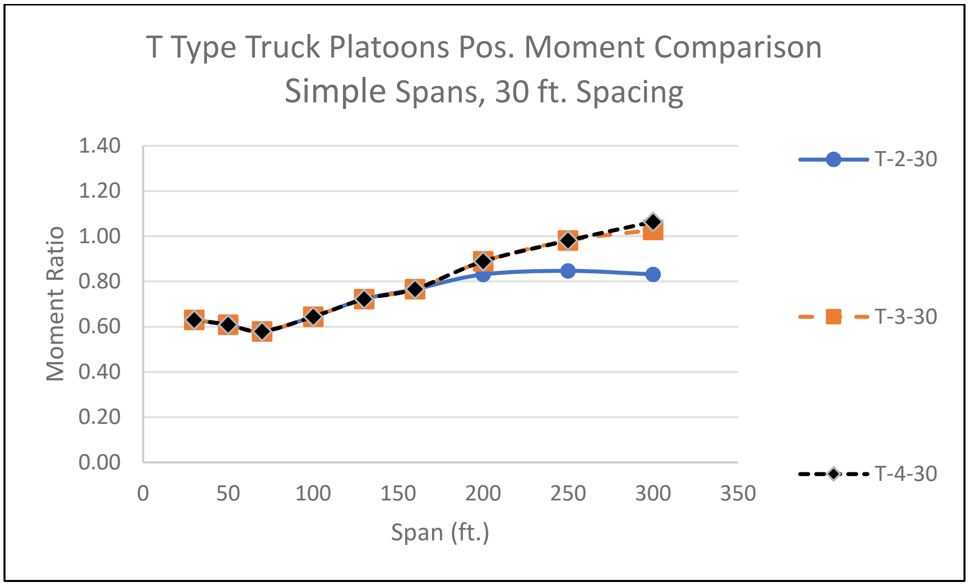


(a) Moment

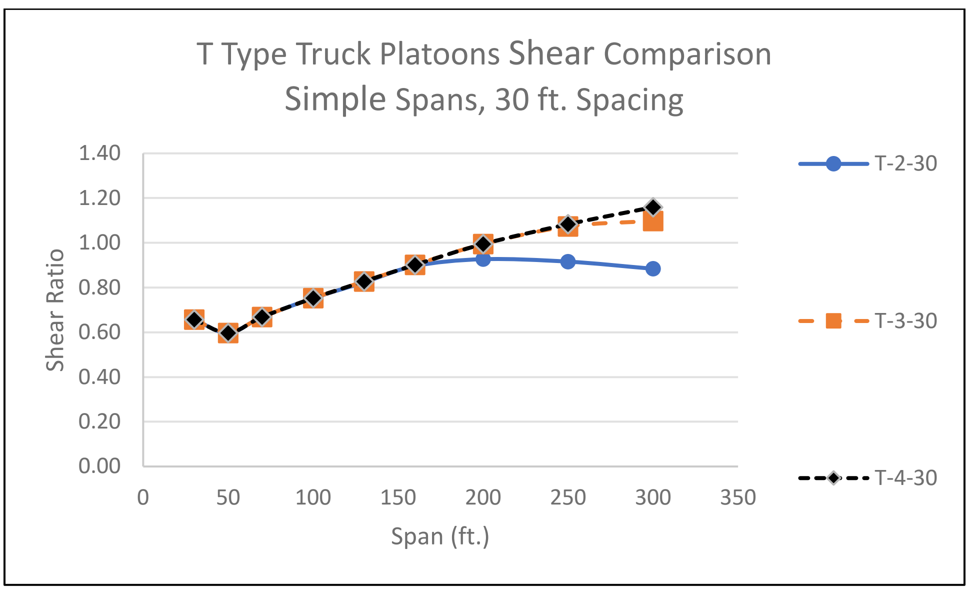


(b) Shear

Figure 18. Comparison of 3S2 Platoons to HL-93, Simple Spans, 30 ft. Truck Spacing

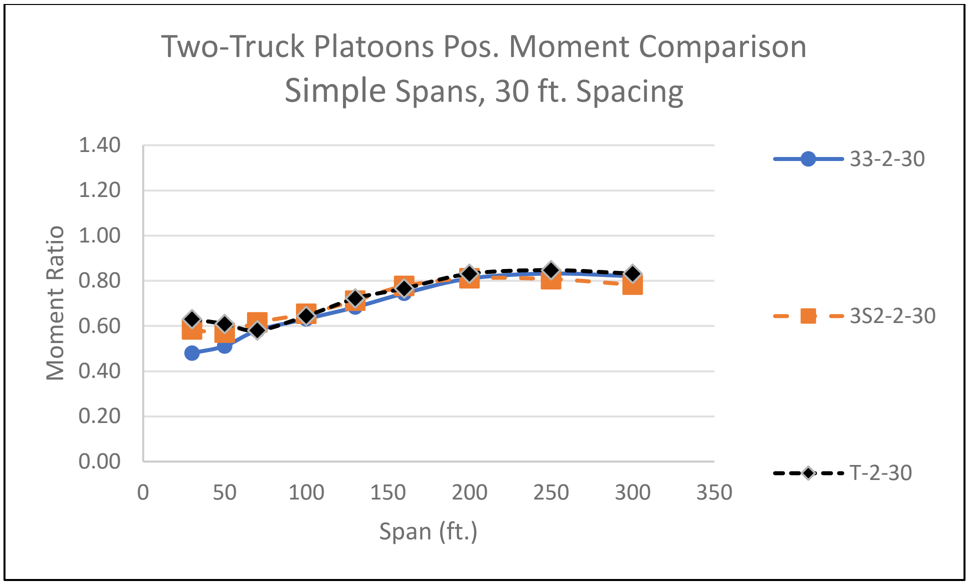


(a) Moment

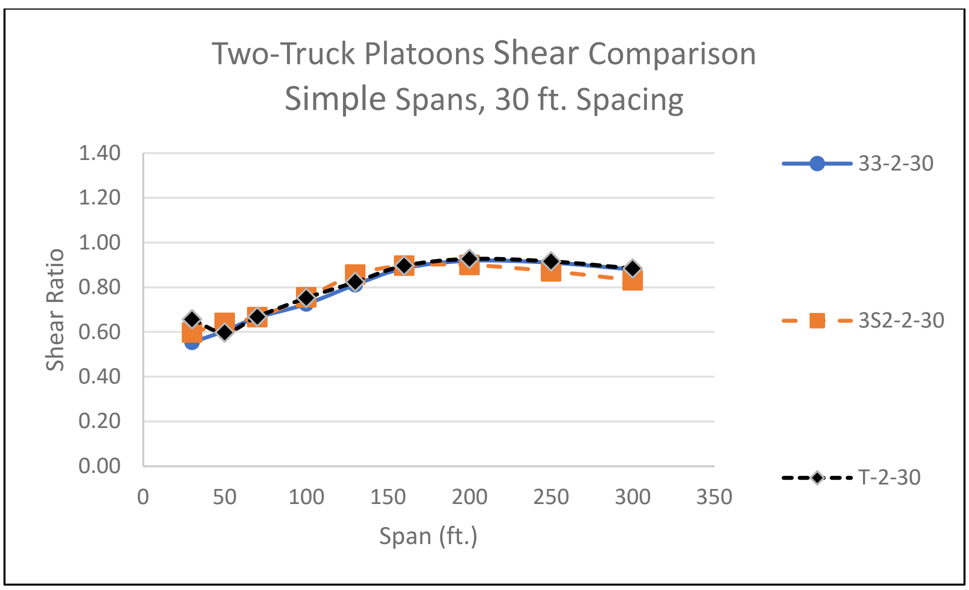


(b) Shear

Figure 19. Comparison of Type T Platoons to HL-93, Simple Spans, 30 ft. Truck Spacing

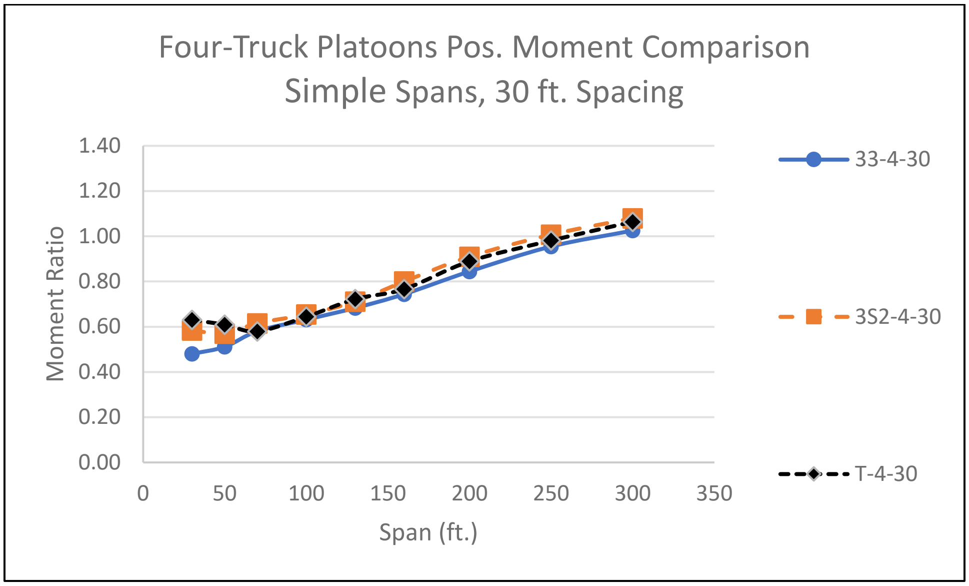


(a) Moment

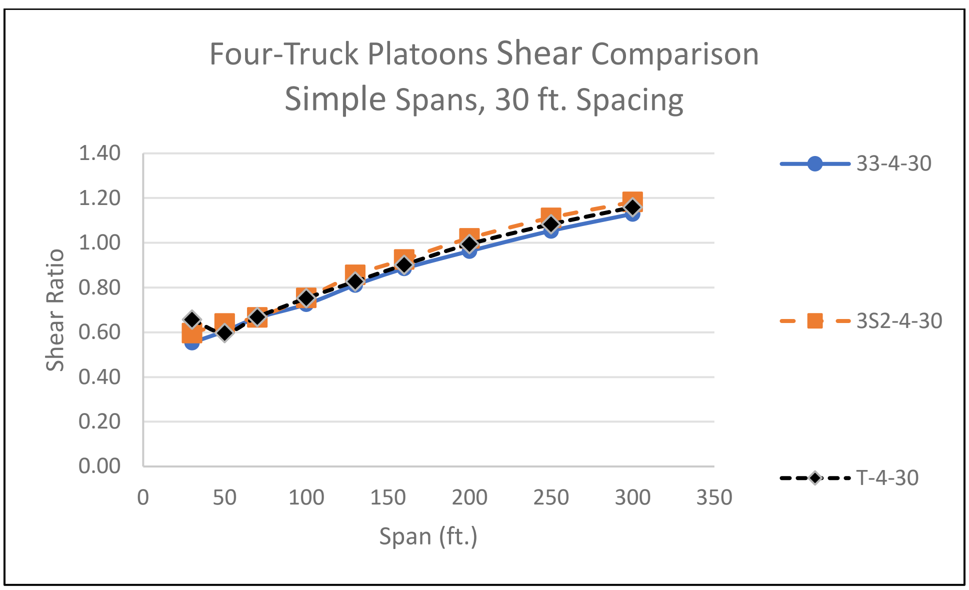


(b) Shear

Figure 20. Comparison of Two-Truck Platoons to HL-93, Simple Spans, 30 ft. Truck Spacing



(a) Moment



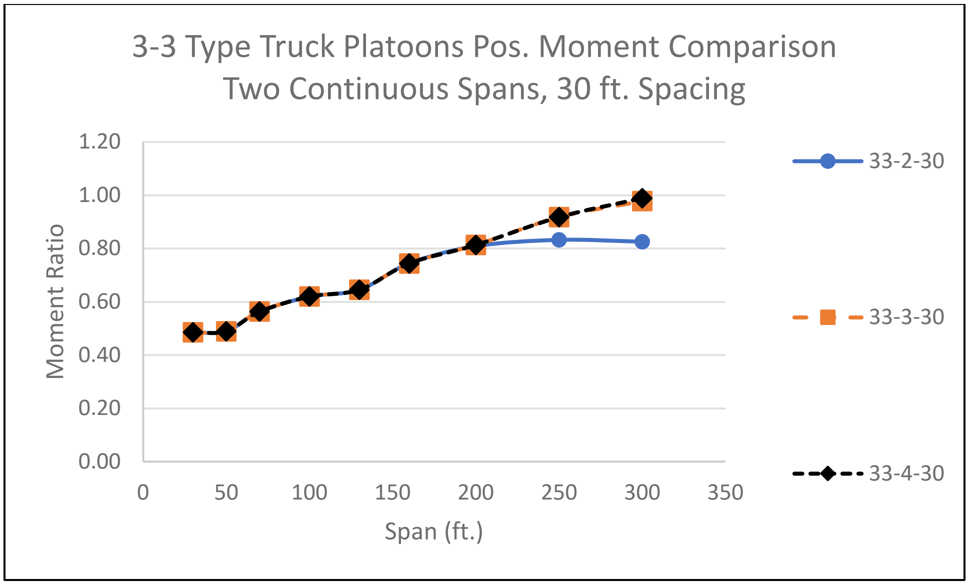
(b) Shear

Figure 21. Comparison of Four-Truck Platoons to HL-93, Simple Spans, 30 ft. Truck Spacing

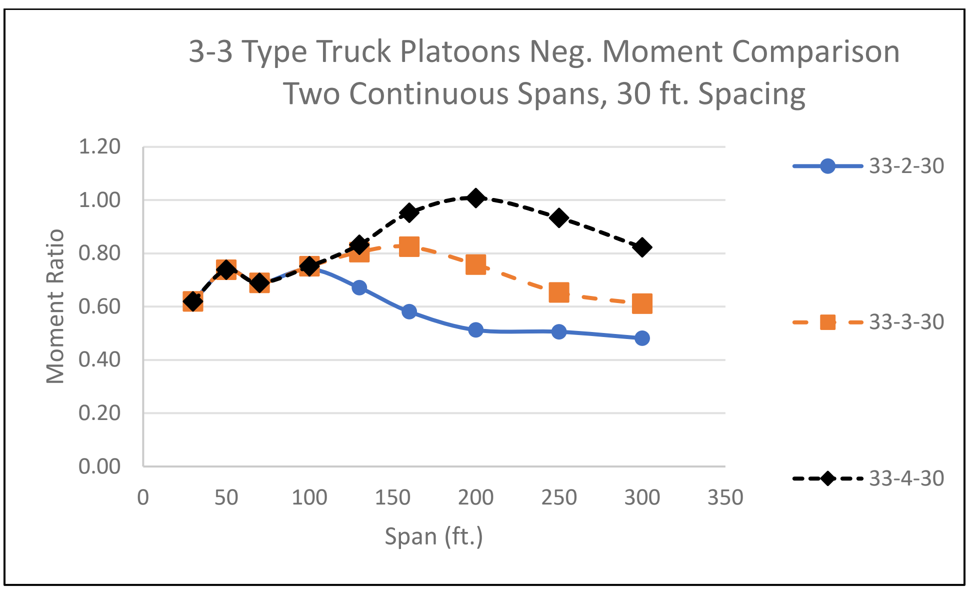
Figure 22 through Figure 26 show the comparison of the two-, three-, and four-truck platoons composed of Type 3-3, 3S2 and Type T trucks, respectively, for two equal continuous spans. Only results for platoons with 30 ft. truck spacing are shown as these are the ones that have some platoon load effect ratios to HL-93 exceeding 1.00. As shown in Figure 22 through Figure 24, regardless of the type of trucks, the results for the two-, three-, and four-truck platoons are the same for shorter spans. The results for the two-truck platoons become smaller than for the larger platoons starting at about 200 ft., 100 ft. 160 ft. and 70 ft. spans for the in-span positive moment, middle support negative moment, end shear and middle support shear, respectively. The results for the three truck-platoons become smaller than the four-truck platoons at varying span lengths for different truck types. The reason for the varying deviation points is that the change in the span lengths combined with the length of the platoons change how many of the axles can be positioned where they increase the load effects with the other axles either outside the bridge or positioned at locations where they reduce the load effect being investigated. On average, the three-truck platoons results start to become smaller than those for the four-truck platoons at approximately 250 ft., 100 ft., 200 ft. and 130 ft. spans for the in-span positive moment, middle support negative moment, end shear and middle support shear, respectively.

Figure 25 compares the results for the two-truck platoons using different truck types. The differences between the results from different truck types are not significant except for the shortest spans. Generally, Type 3-3 and Type T platoons give similar results with the 3S2 platoons giving slightly lower results for the longer spans. For the shortest spans the controlling type of trucks changes from one span to another.

Figure 26 compares the results for the four-truck platoons using different truck types. Except for the negative moment at the middle support, Type T truck platoons produce higher moments and shears for the shortest spans (approximately 50 ft. and shorter) while the 3S2 truck platoons produce the highest moments and shears for the longer spans (approximately 100 ft. and longer). For the negative moment at the middle support, the 3S2 platoons produce the highest moment for spans up to about 160 ft. while the Type T platoons produce the highest moment for longer spans. This reversal in order is the result of the difference in the length of the trucks and, consequently, the total length of the platoons relative to the span length.

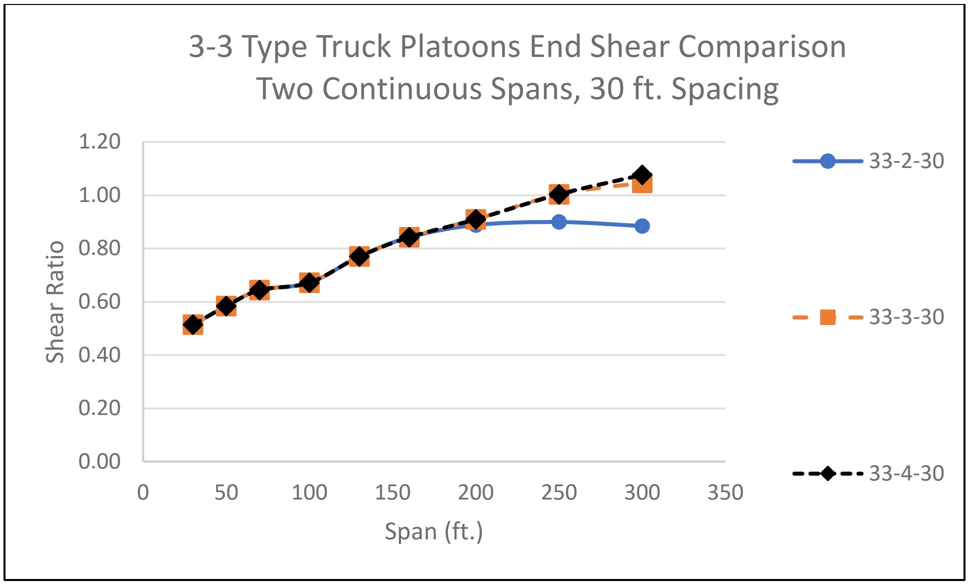


(a) Positive Moment

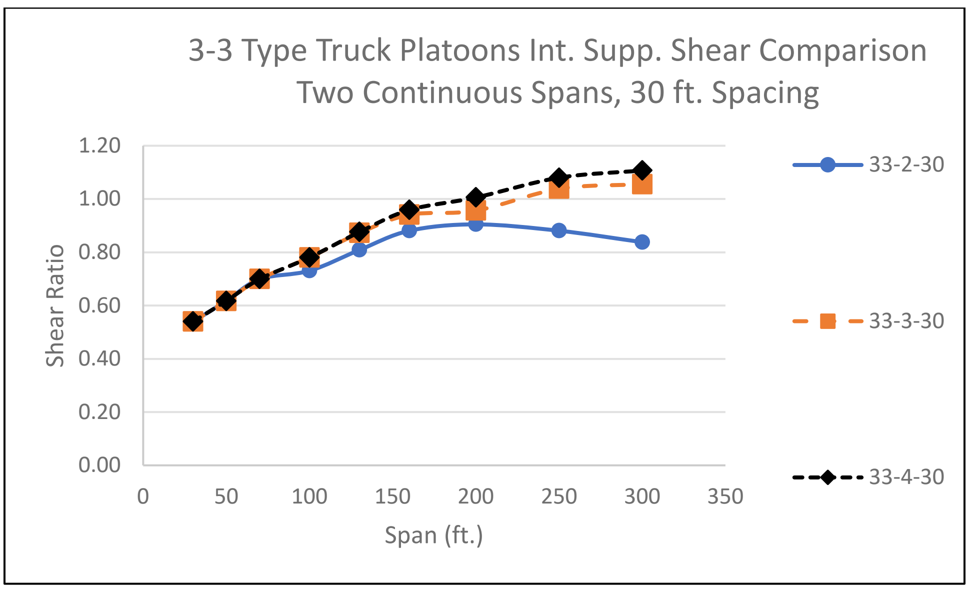


(b) Negative Moment

Figure 22. Comparison of Type 3-3 Platoons to HL-93, Two Equal Continuous Spans, 30 ft. Truck Spacing

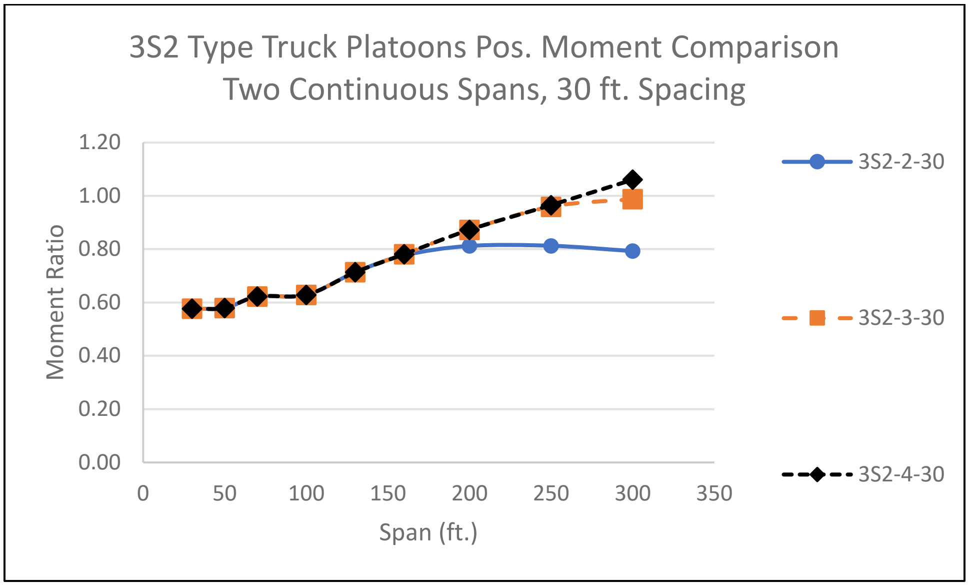


(c) End Shear

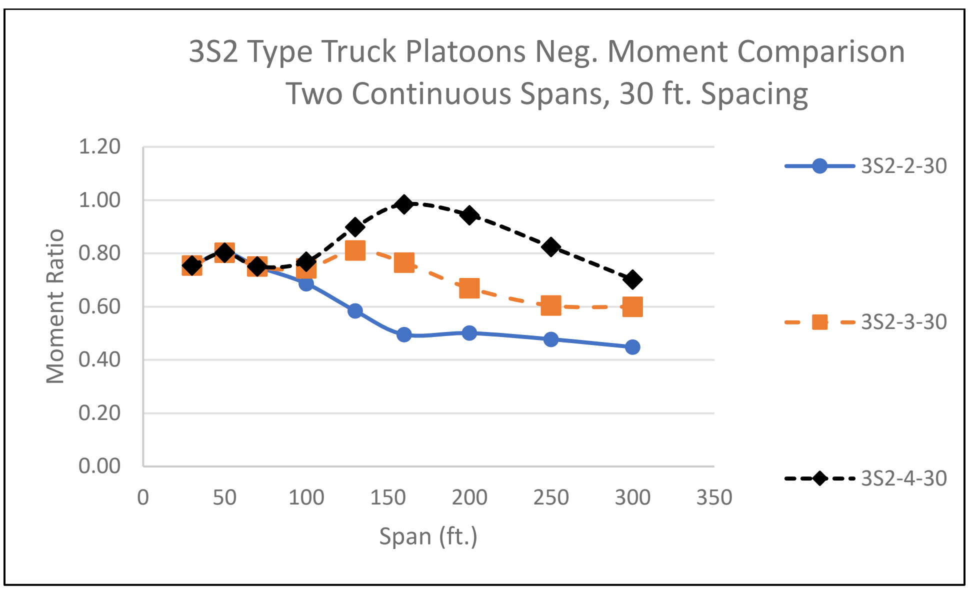


(d) Shear at Middle support

Figure 22. (cont'd) Comparison of Type 3-3 Platoons to HL-93, Two Equal Continuous Spans, 30 ft. Truck Spacing

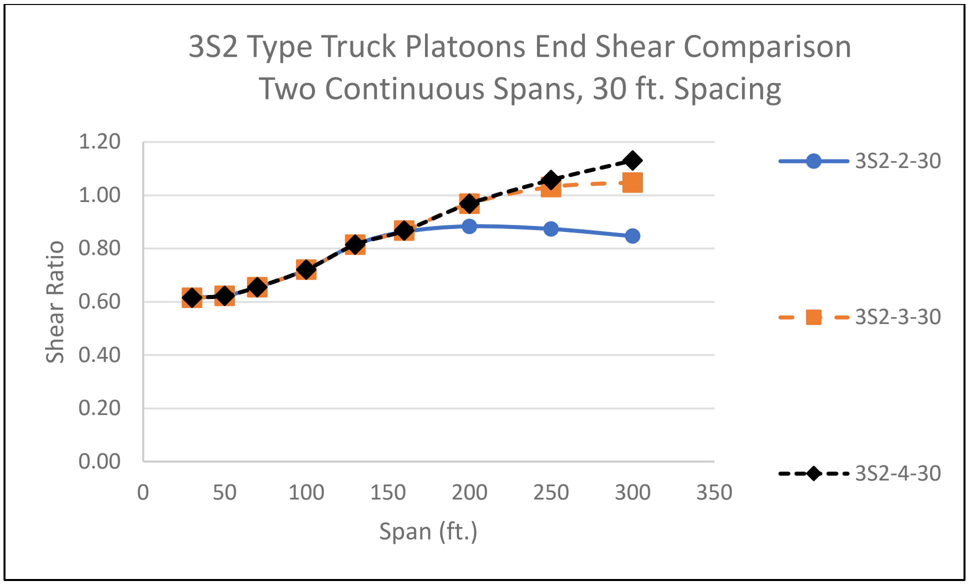


(a) Positive Moment

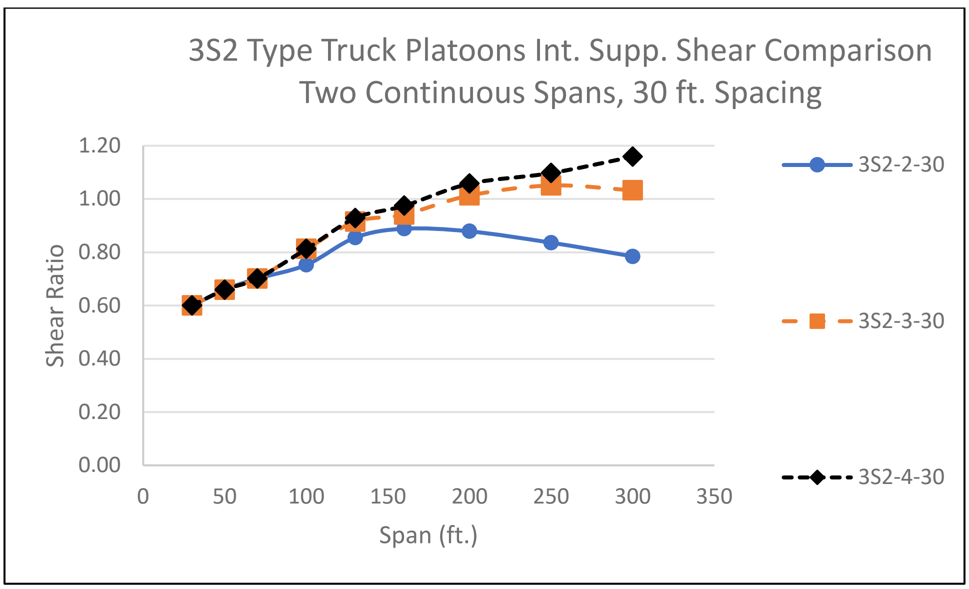


(b) Negative Moment

Figure 23. Comparison of 3S2 Platoons to HL-93, Two Equal Continuous Spans, 30 ft. Truck Spacing

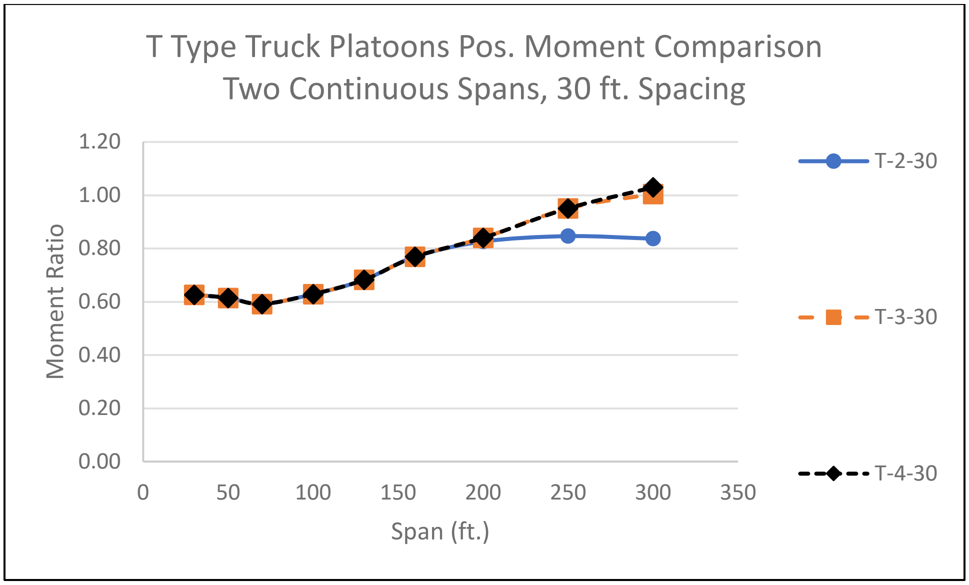


(c) End Shear

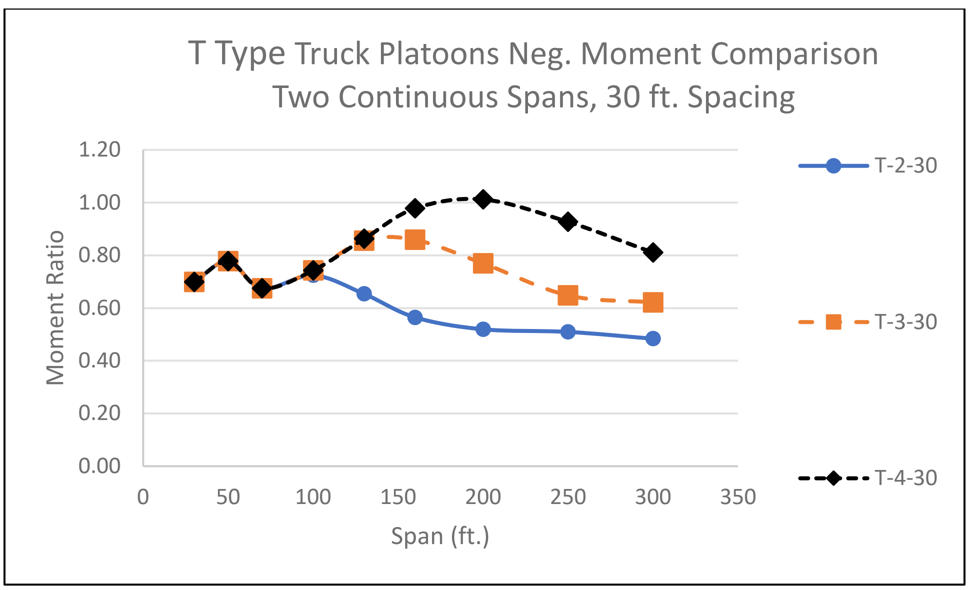


(d) Shear at Middle Support

Figure 23. (cont'd) Comparison of 3S2 Platoons to HL-93, Two Equal Continuous Spans, 30 ft. Truck Spacing

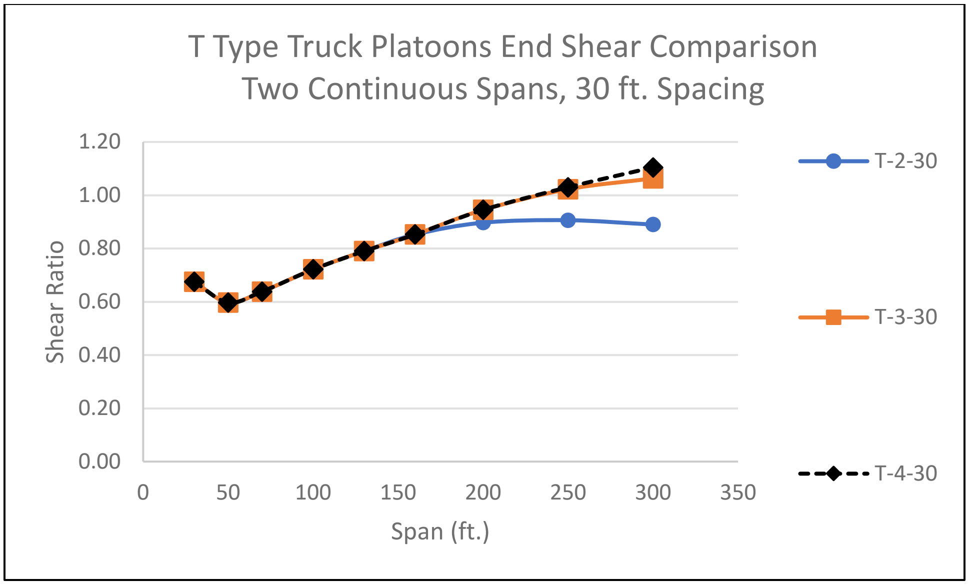


(a) Positive Moment

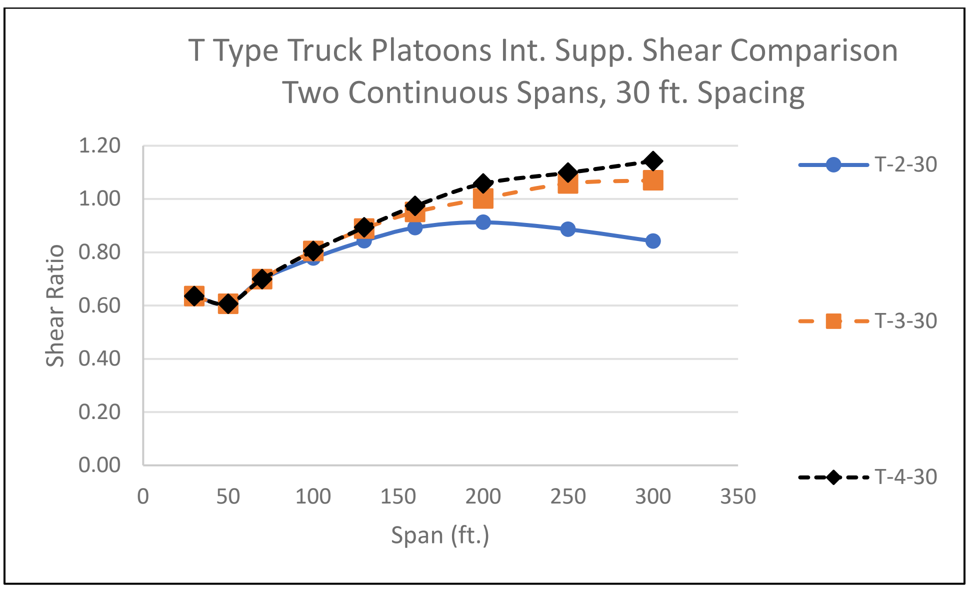


(b) Negative Moment

Figure 24. Comparison of Type T Platoons to HL-93, Two Equal Continuous Spans, 30 ft. Truck Spacing

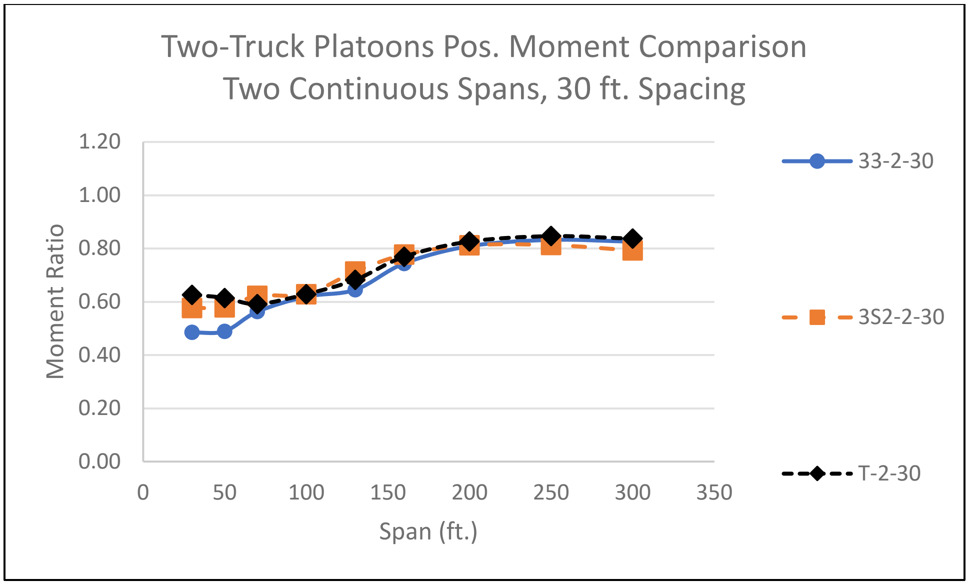


(c) End Shear

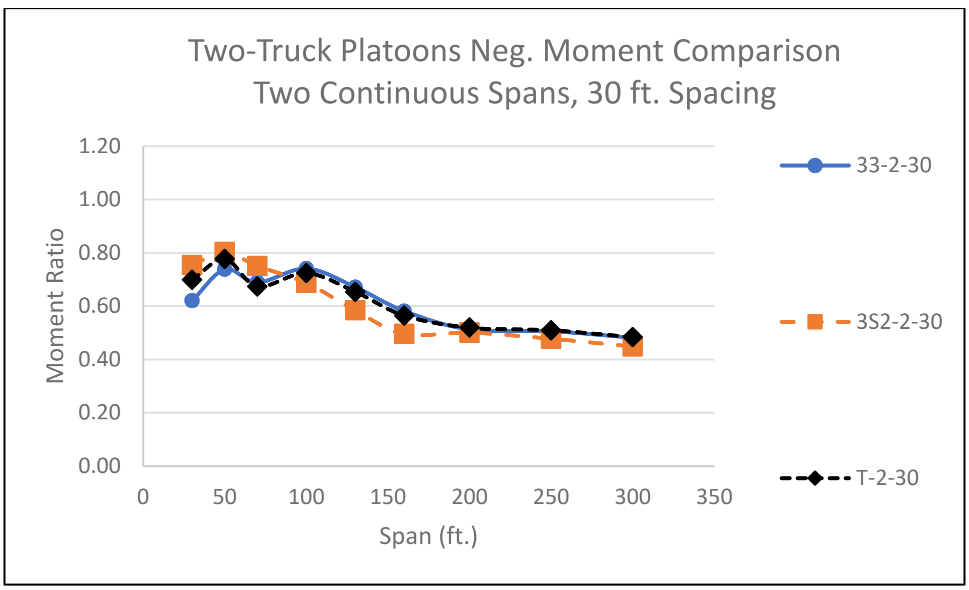


(d) Shear at Middle support

Figure 24. (cont'd) Comparison of Type T Platoons to HL-93, Two Equal Continuous Spans, 30 ft. Truck Spacing

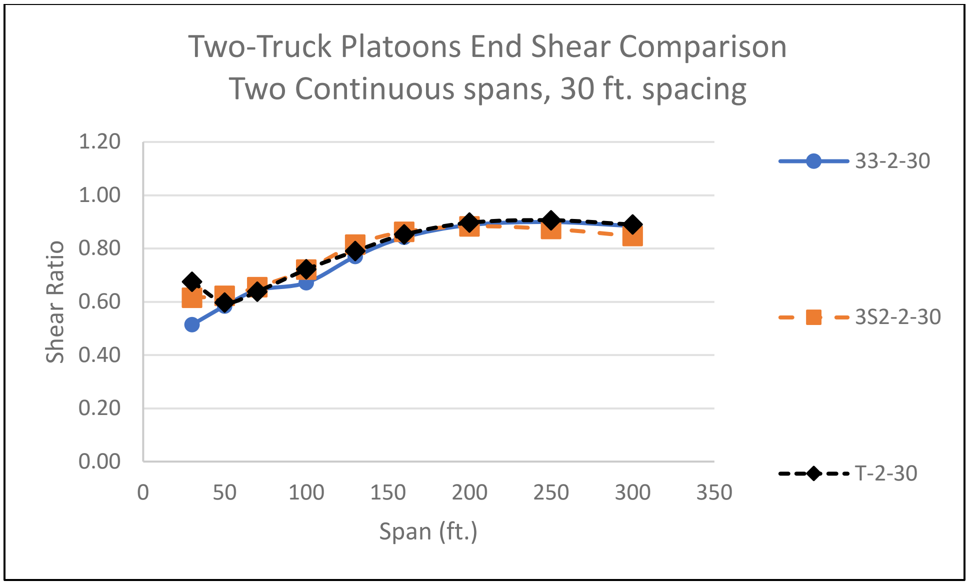


(a) Positive Moment

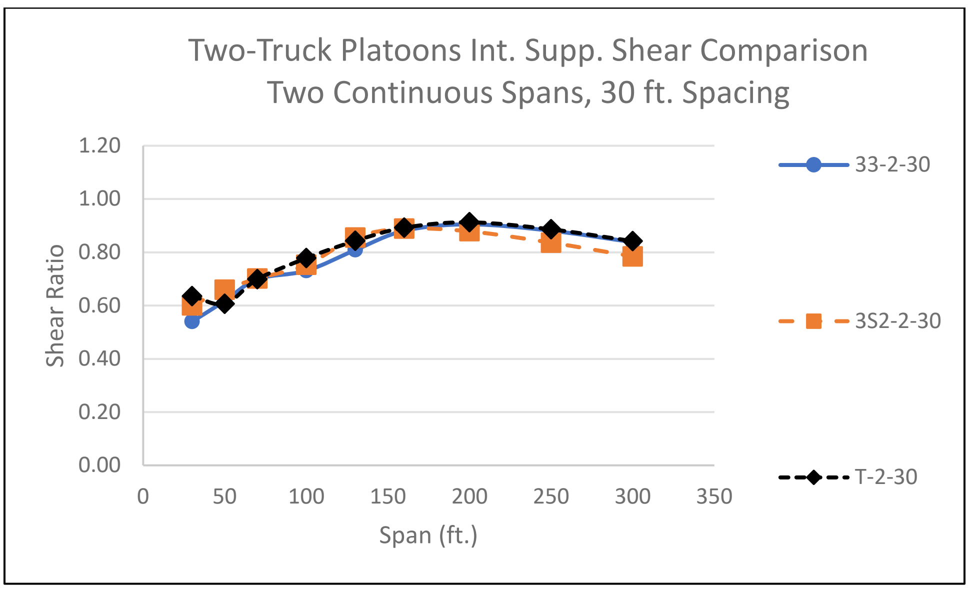


(b) Negative Moment

Figure 25. Comparison of Four-Truck Platoons to HL-93, Two Equal Continuous Spans, 30 ft. Truck Spacing

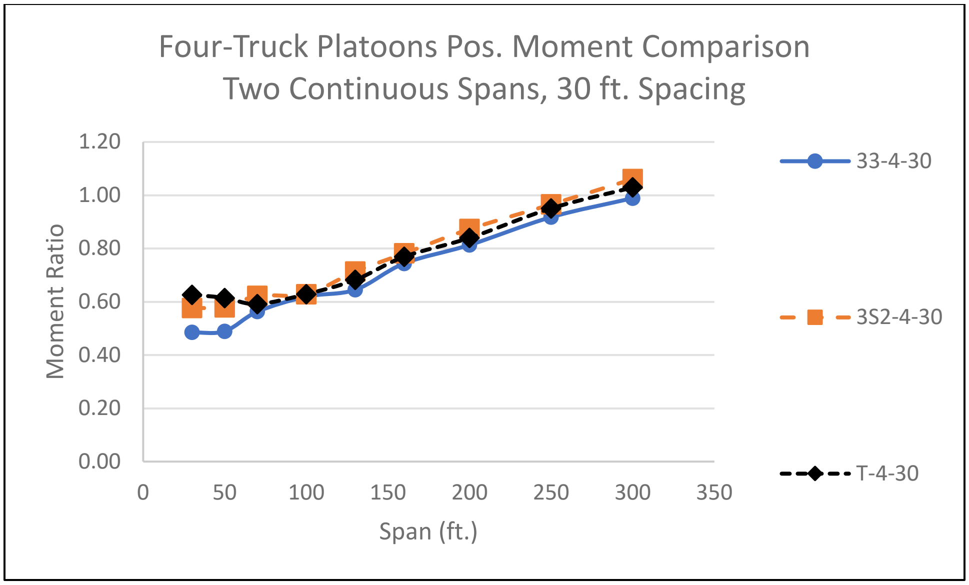


(c) End Shear

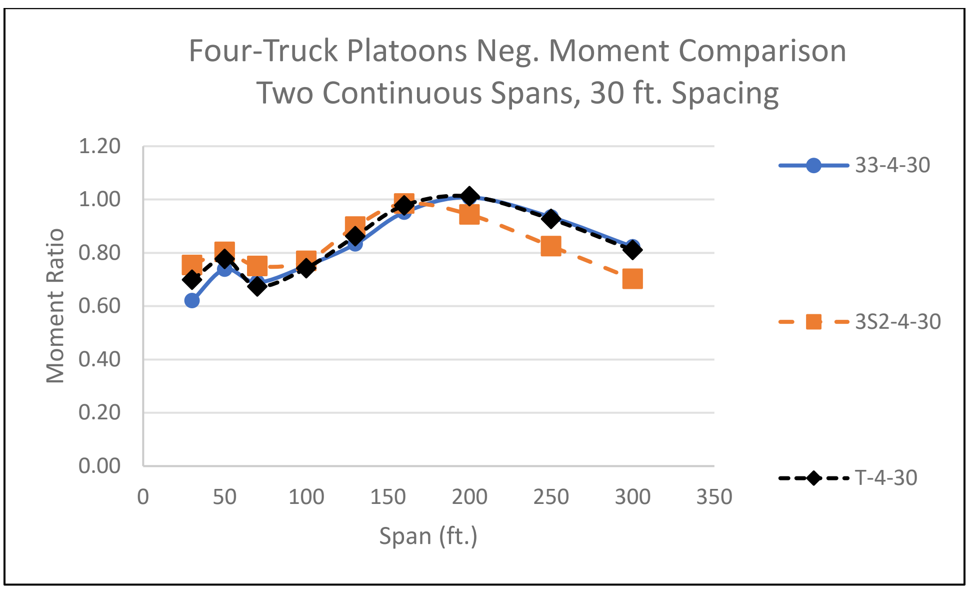


(d) Shear at Middle support

Figure 25. (cont'd) Comparison of Two-Truck Platoons to HL-93, Two Equal Continuous Spans, 30 ft. Truck Spacing

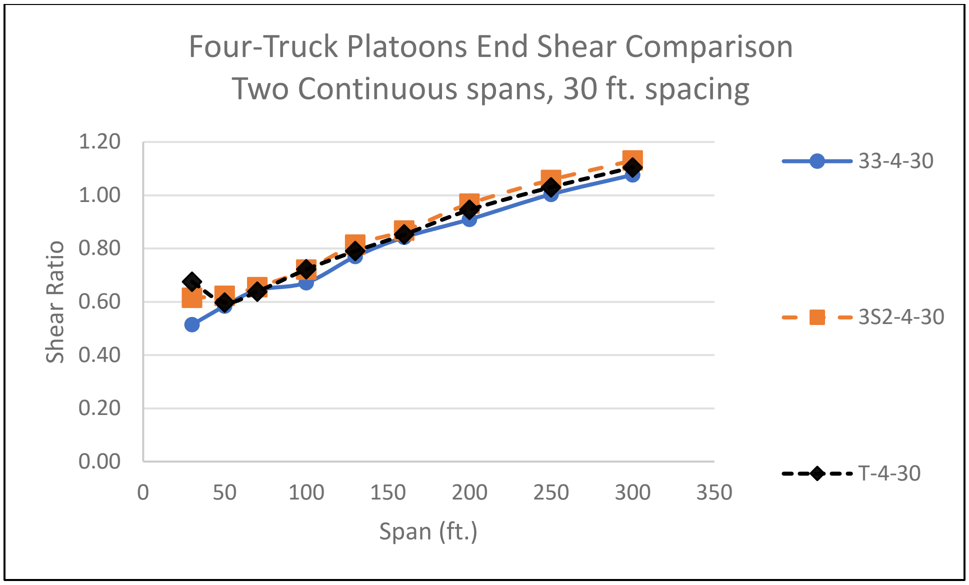


(a) Positive Moment

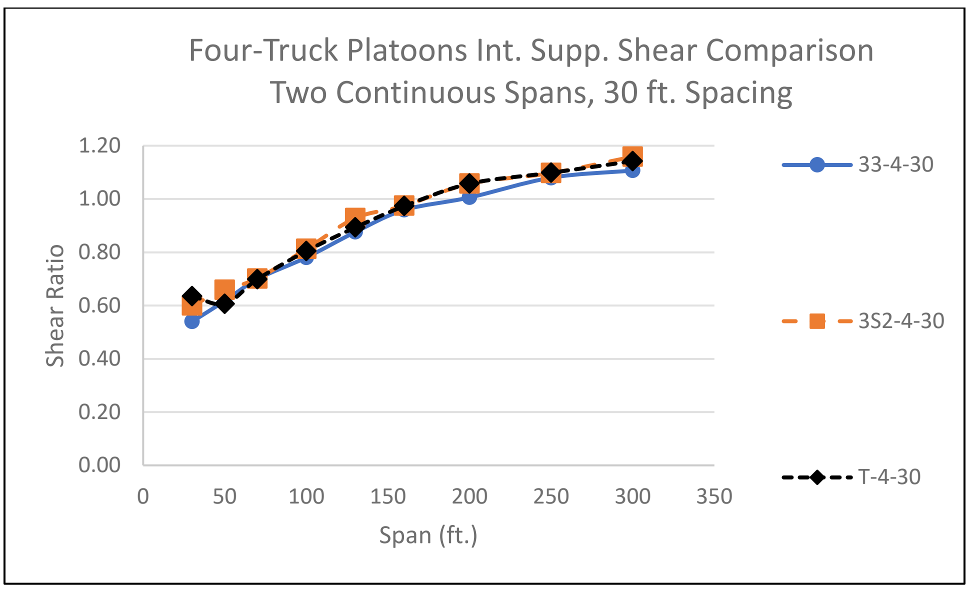


(b) Negative Moment

Figure 26. Comparison of Four-Truck Platoons to HL-93, Two Equal Continuous Spans, 30 ft. Truck Spacing



(c) End Shear



(d) Shear at Middle support

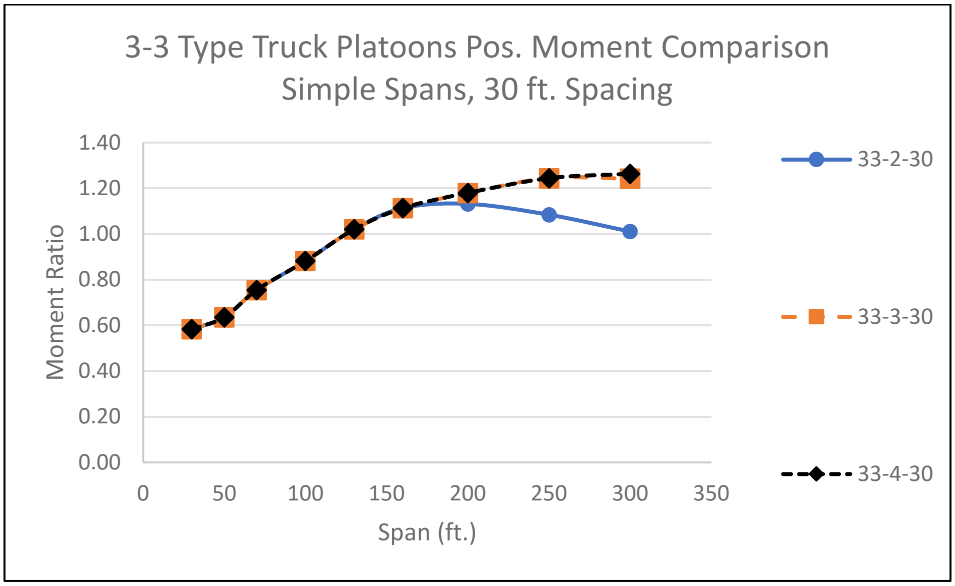
Figure 26. (cont'd) Comparison of Four-Truck Platoons to HL-93, Two Equal Continuous Spans, 30 ft. Truck Spacing

Figure 27 through Figure 36 are similar to Figure 17 through Figure 26 except that they show comparisons of the load effect ratios to HS 20 design loads.

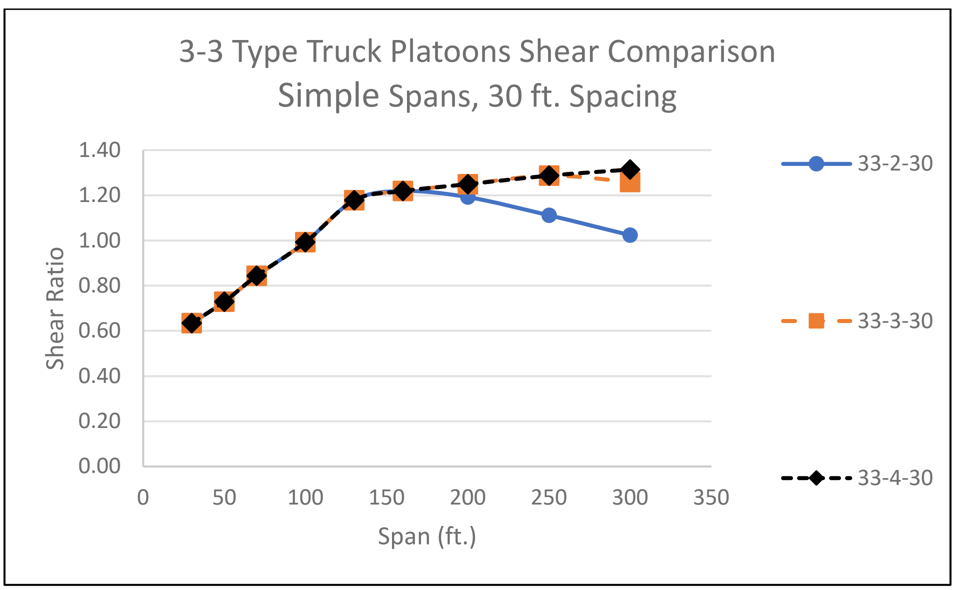
Figure 27 through Figure 29 show the comparison of the two-, three-, and four-truck platoons composed of Type 3-3, 3S2 and Type T trucks, respectively, for simple spans. Only results for platoons with 30 ft. truck spacing are shown as these are the ones that have some platoon load effect ratios to HS 20 exceeding 1.20. Regardless of the type of trucks, the results for the two-, three-, and four-truck platoons are the same for shorter spans. The results for the two-truck platoons become smaller than for the larger platoons starting at about 130 ft. spans for the 3S2 platoons and 160 ft. spans for Type 3-3 and Type T platoons. The results for the three truck-platoons become smaller than the four-truck platoons at about 200 ft. spans for the 3S2 platoons and 250 ft. spans for Type 3-3 and Type T platoons.

Figure 30 compares the results for the two-truck platoons using different truck types. The difference between the three truck types is small. Results for all trucks are very similar for spans less than 160 ft. except that Type T platoons control for the shortest spans (50 ft. and shorter). As discussed earlier, this is because for short spans the moments and shears are controlled by the weight of two consecutive axles and Type T trucks have the heaviest axles among the three truck types. For spans longer than 160 ft., Type 3-3 and Type T platoons give very close results with the 3S2 platoons giving lower results due to their lighter weight.

Figure 31 compares the results for the four-truck platoons using different truck types. For the shortest spans (approximately 70 ft. and shorter), Type T truck platoons produce higher moments and shears. For spans longer than approximately 100 ft., the 3S2 truck platoons produce the highest moments and shears.

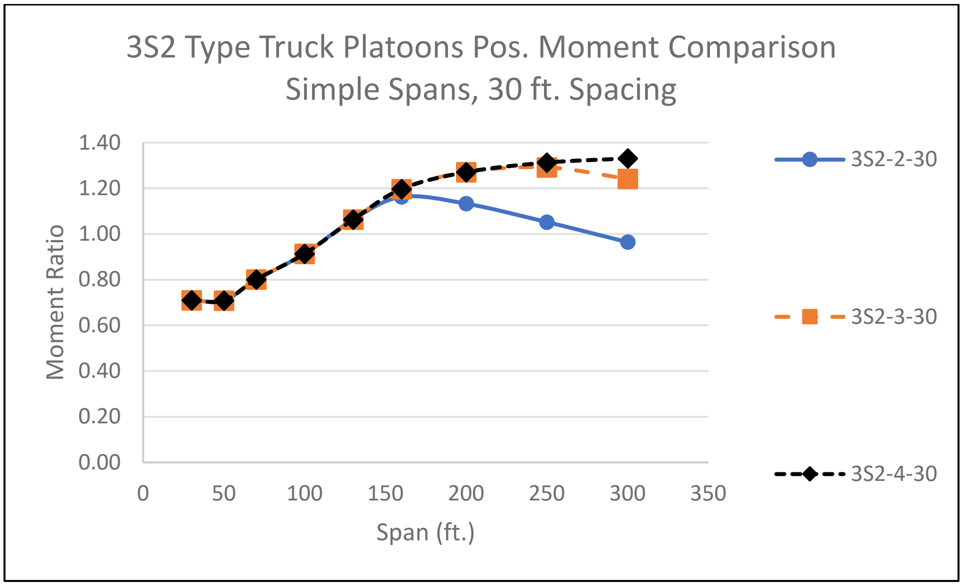


(a) Moment

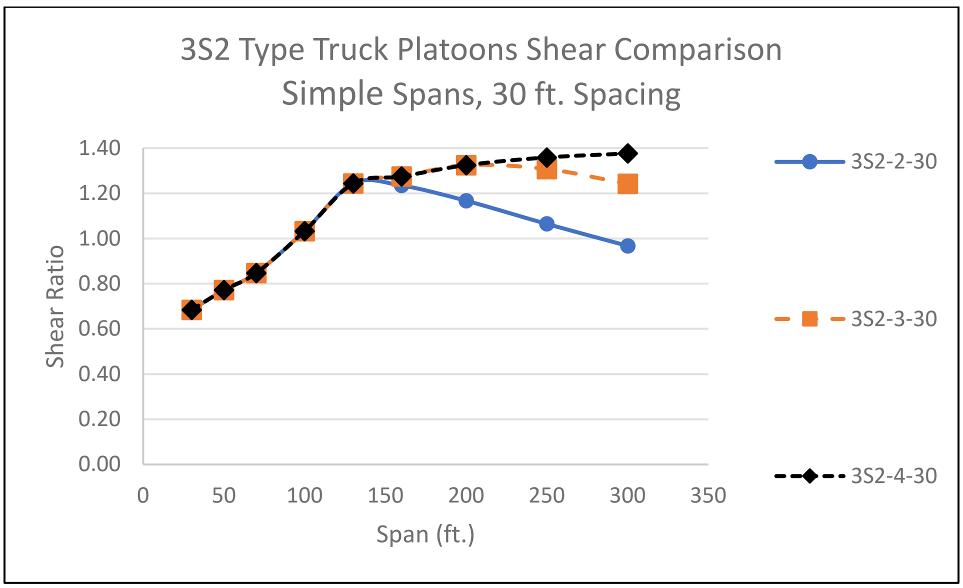


(b) Shear

Figure 27. Comparison of Type 3-3 Platoons to HS 20, Simple Spans, 30 ft. Truck Spacing

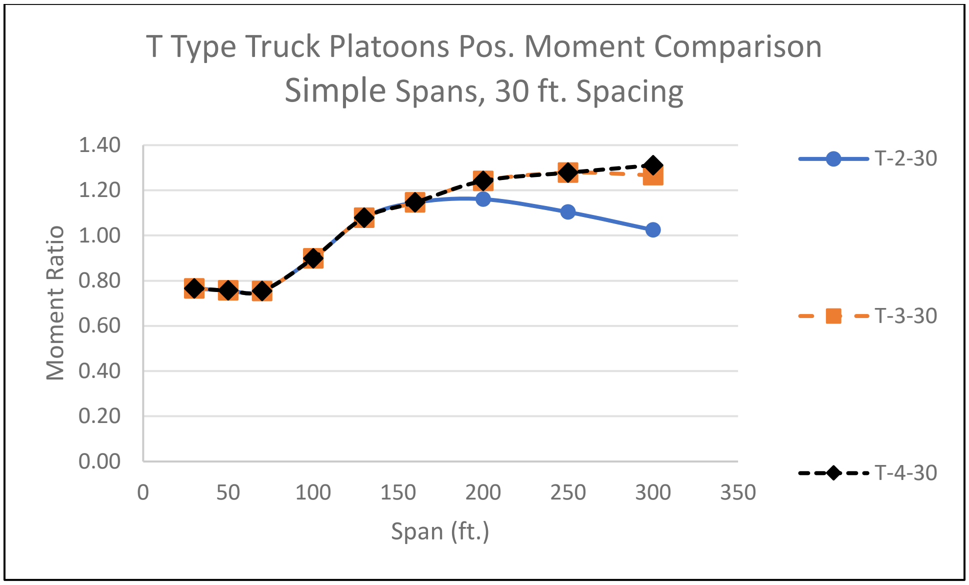


(a) Moment

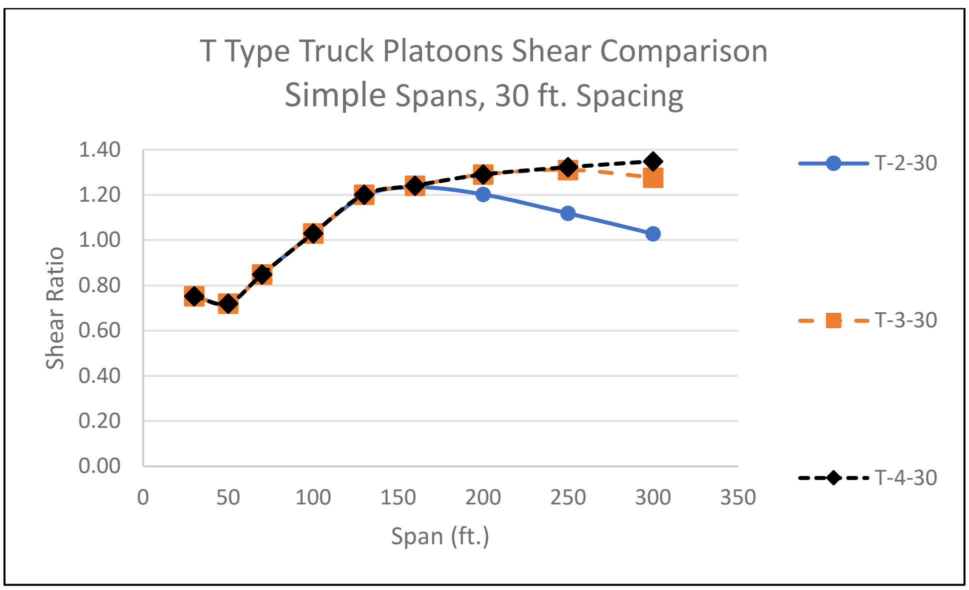


(b) Shear

Figure 28. Comparison of 3S2 Platoons to HS 20, Simple Spans, 30 ft. Truck Spacing

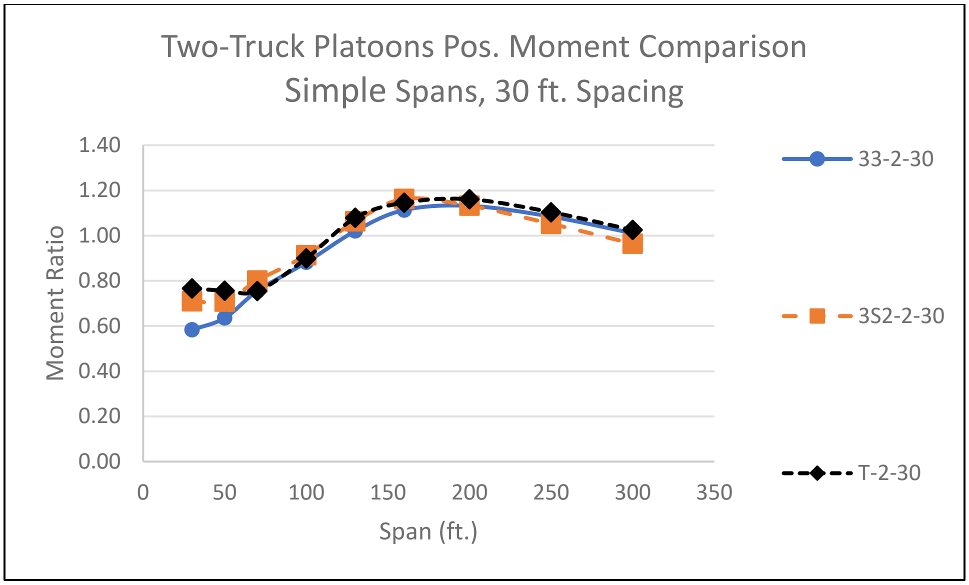


(a) Moment

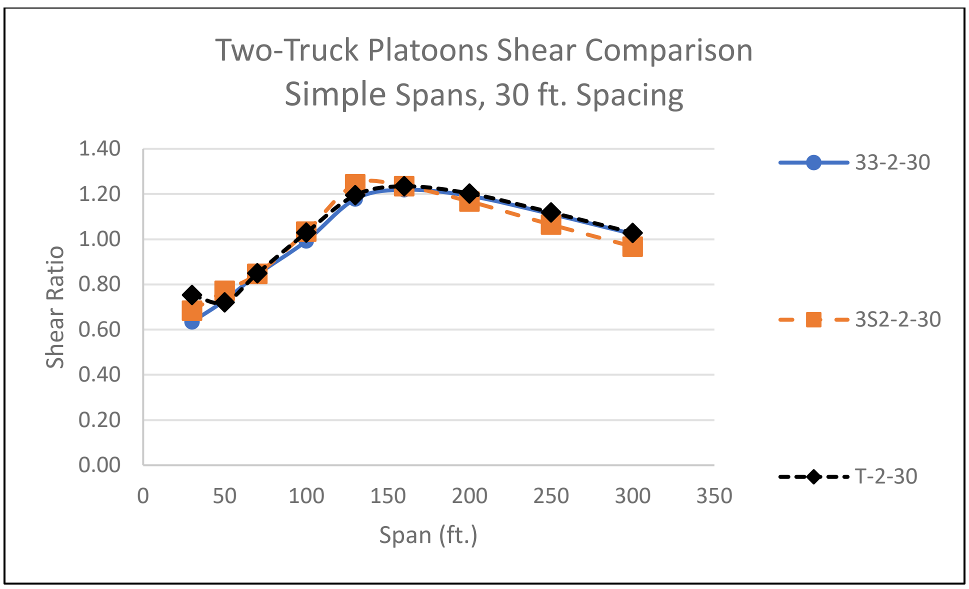


(b) Shear

Figure 29. Comparison of Type T Platoons to HS 20, Simple Spans, 30 ft. Truck Spacing

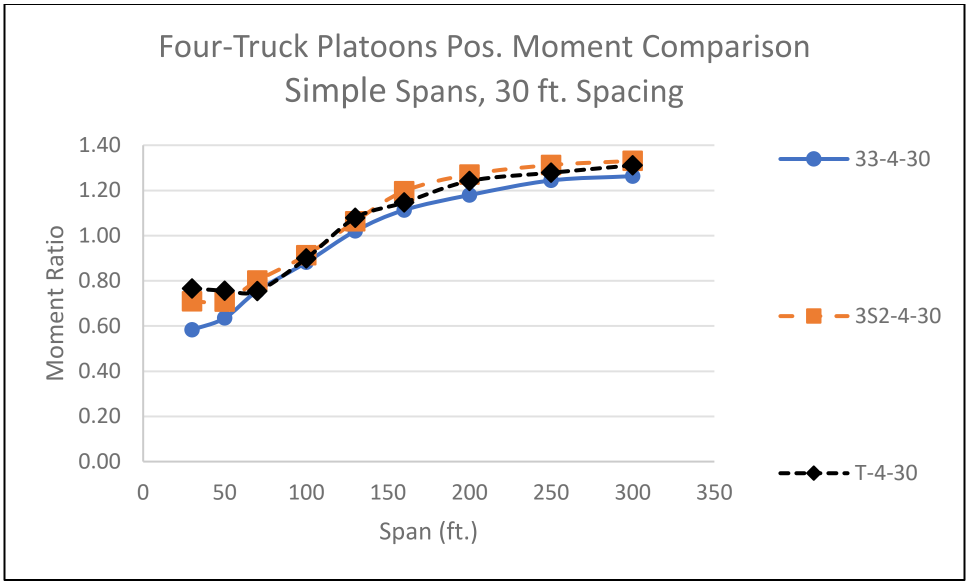


(a) Moment

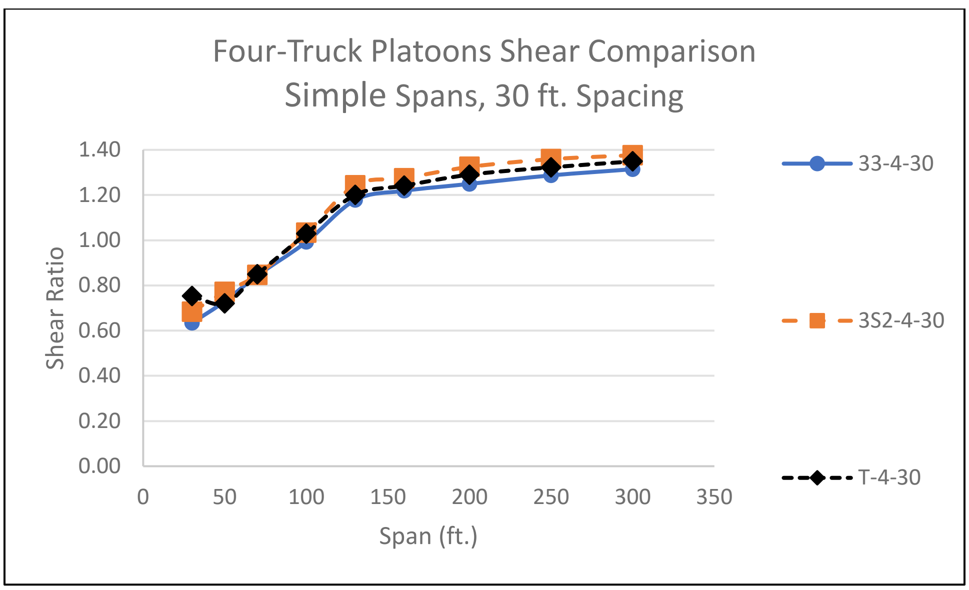


(b) Shear

Figure 30. Comparison of Two-Truck Platoons to HS 20, Simple Spans, 30 ft. Truck Spacing



(a) Moment



(b) Shear

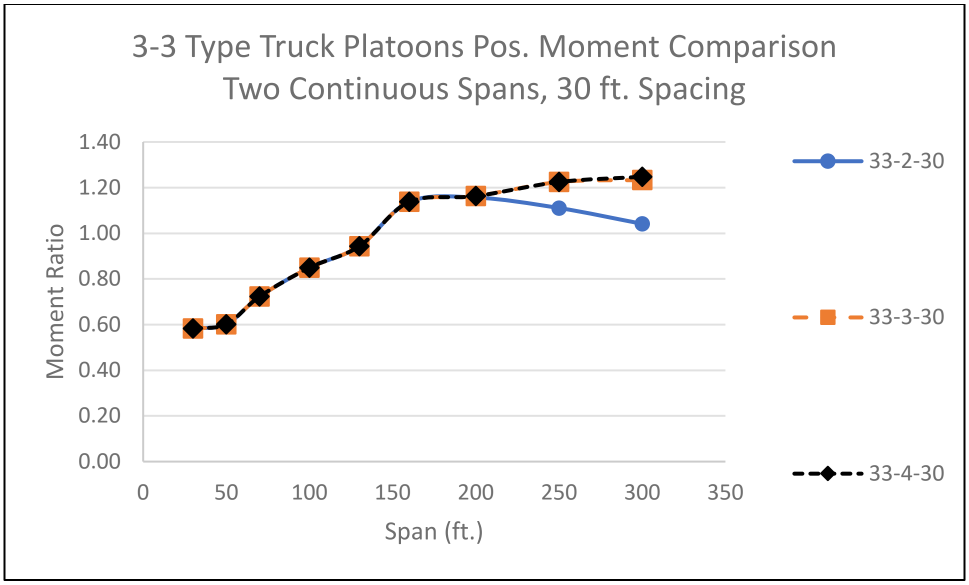
Figure 31. Comparison of Four-Truck Platoons to HS 20, Simple Spans, 30 ft. Truck Spacing

Figure 32 through Figure 36 show the comparison of the two-, three-, and four-truck platoons for platoons composed of Type 3-3, 3S2 and Type T trucks, respectively, for two equal continuous spans. Only results for platoons with 30 ft. truck spacing are shown as these are the ones that have some platoon load effect ratios to HS 20 exceeding 1.20. As shown in Figure 32 through Figure 34, regardless of the type of trucks, the results for the two-, three-, and four-truck platoons are the same for shorter spans. The results for the two-truck platoons become smaller than for the larger platoons starting at about 160 ft., 100 ft. 160 ft. and 70 ft. spans for the in-span positive moment, middle support negative moment, end shear and middle support shear, respectively. The results for the three truck-platoons become smaller than the four-truck platoons at varying span lengths for different truck types. The reason for the varying deviation points is that the change in the span lengths combined with the length of the platoons change how many of the axles can be positioned where they increase the load effects with the other axles either outside the bridge or positioned at locations where they reduce the load effect being investigated. On average, the three-truck platoons results start to become smaller than those for the four-truck platoons at approximately 250 ft., 100 ft., 250 ft. and 130 ft. spans for the in-span positive moment, middle support negative moment, end shear and middle support shear, respectively.

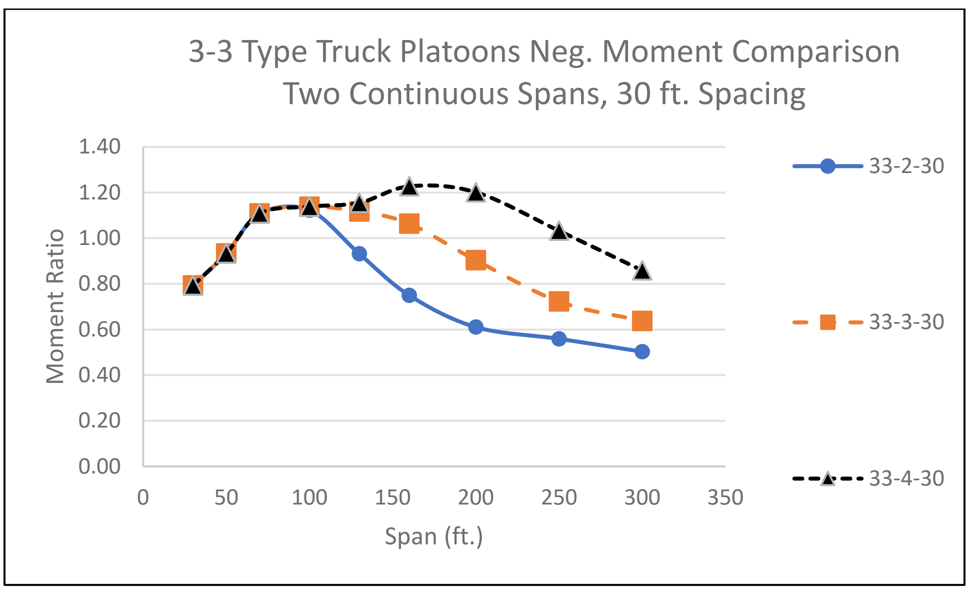
Figure 35 compares the results for the two-truck platoons using different truck types. The differences between the results from different truck types are not significant except for the shortest spans. Generally, Type 3-3 and Type T platoons give similar results with the 3S2 platoons giving slightly lower results for the longer spans. For the shortest spans the controlling type of trucks changes from one span to another.

Figure 36 compares the results for the four-truck platoons using different truck types. For the in-span positive moments and the end shear, Type T truck platoons produce higher moments and shears for the shortest spans (approximately 50 ft. and shorter) while the 3S2 truck platoons produce the highest moments and shears for the longer spans (approximately 100 ft. and longer); albeit the difference between the 3S2 platoons and the Type T platoons was minimal with the Type 3-3 platoons generally giving slightly lower results. For the negative moment at the middle support, the 3S2 platoons produce the highest moment for spans up to about 160 ft. then gave the lowest results for longer spans with Type 3-3 and Type T platoons essentially giving the same results for most span ranges (the exception is the spans 50 ft. and shorter where Type T is higher). For the shear at the middle support, the 3S2 and Type T platoons gave essentially the same results for the full range of spans with Type 3-3 platoons giving slightly lower results. The difference in the length of the trucks and, consequently, the total length of the platoons relative to the span length affected the results for the negative moment at the middle support.

The results for the three continuous spans followed trends similar to those for the two continuous spans with small differences between similar platoons of different types of trucks.

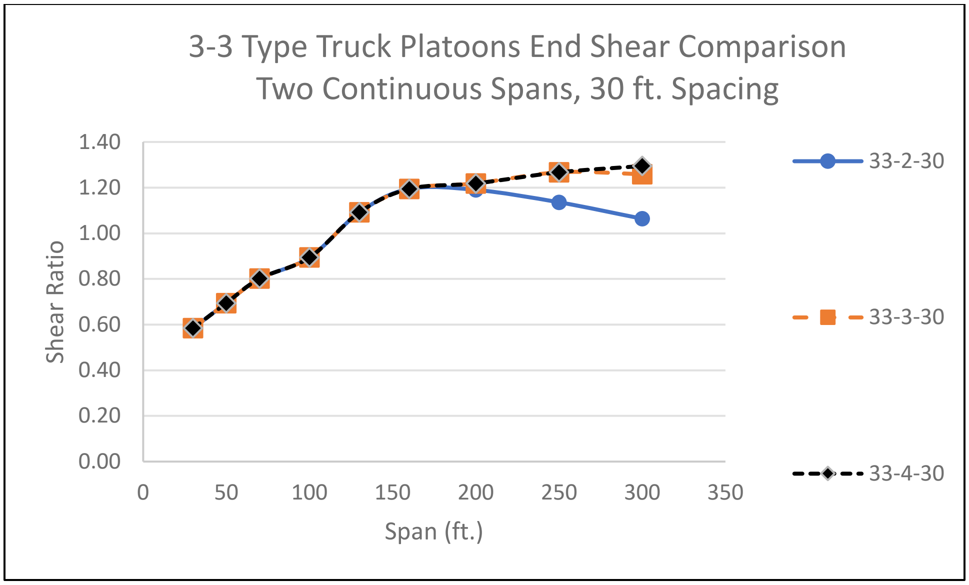


(a) Positive Moment

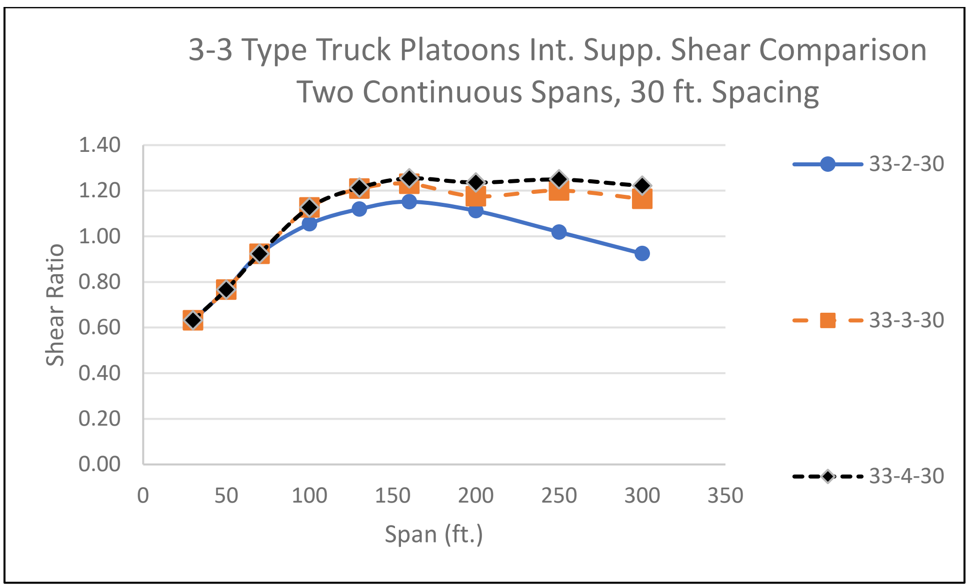


(b) Negative Moment

Figure 32. Comparison of Type 3-3 Platoons to HS 20, Two Equal Continuous Spans, 30 ft. Truck Spacing

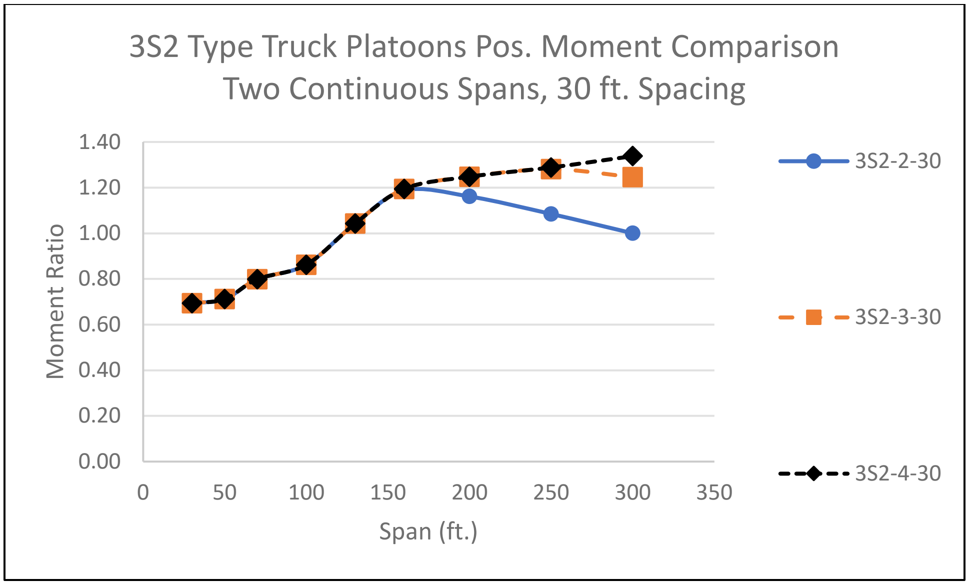


(c) End Shear

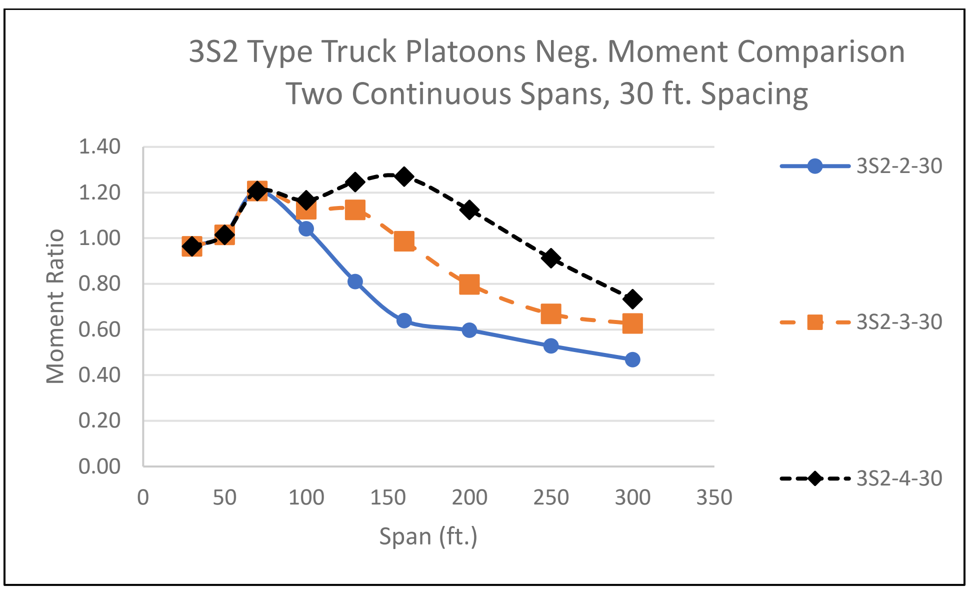


(d) Shear at Middle Support

Figure 32. (cont'd) Comparison of Type 3-3 Platoons to HS 20, Two Equal Continuous Spans, 30 ft. Truck Spacing

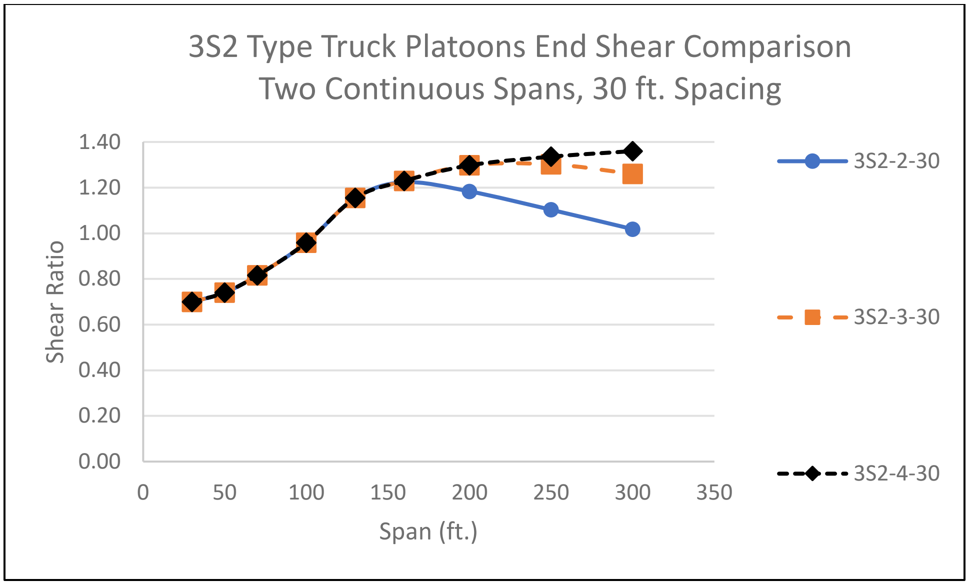


(a) Positive Moment

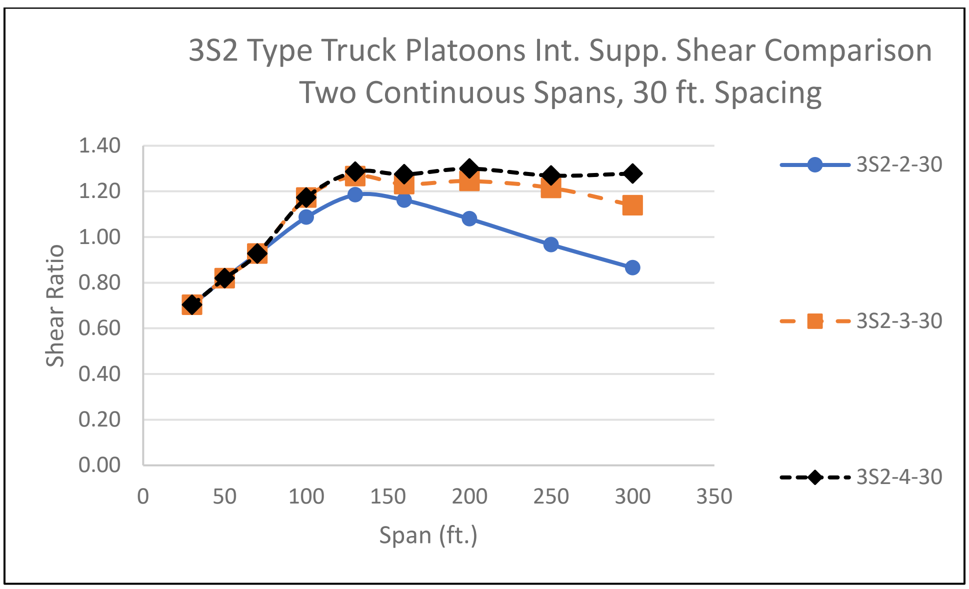


(b) Negative Moment

Figure 33. Comparison of 3S2 Platoons to HS 20, Two Equal Continuous Spans, 30 ft. Truck Spacing

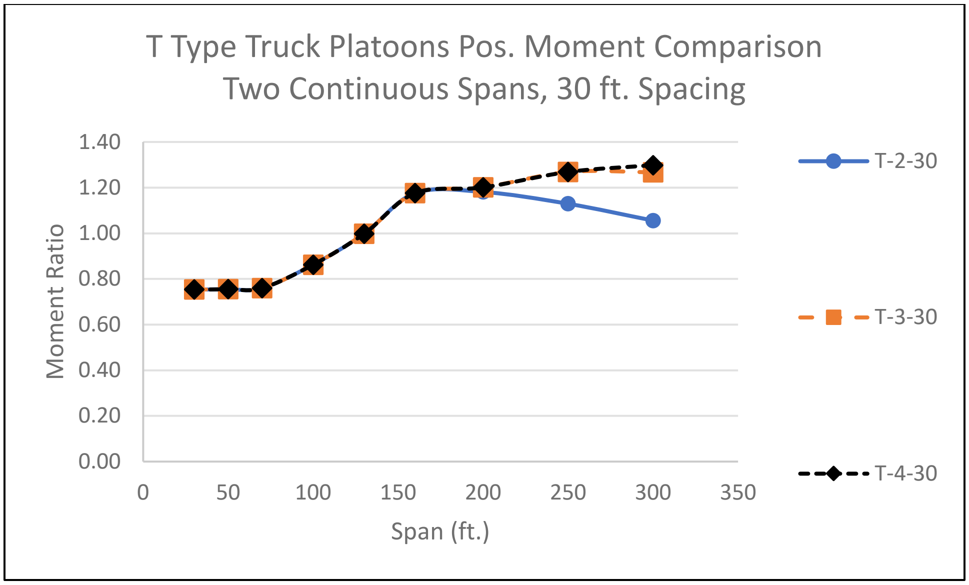


(c) End Shear

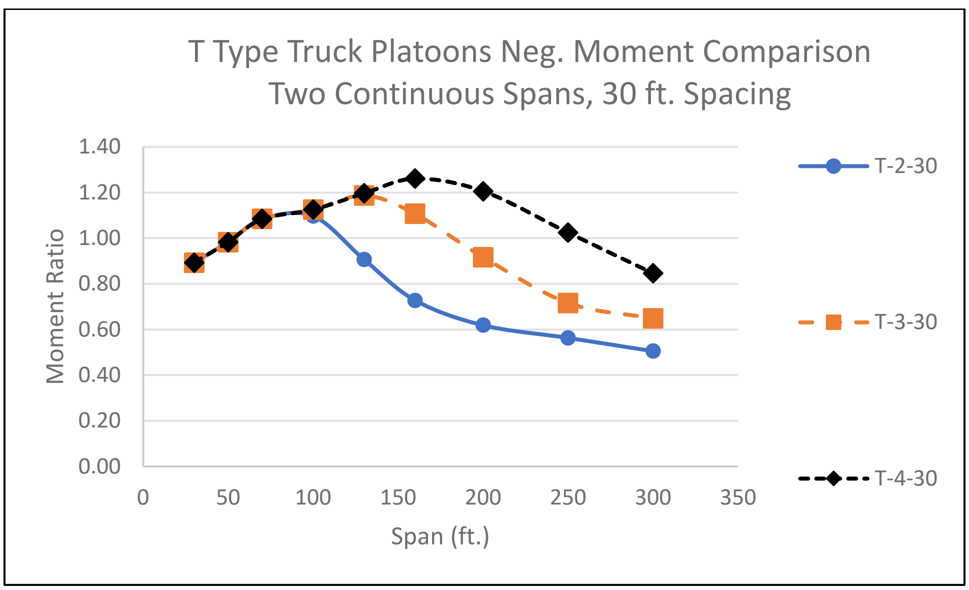


(d) Shear at Middle Support

Figure 33. (cont'd) Comparison of 3S2 Platoons to HS 20, Two Equal Continuous Spans, 30 ft. Truck Spacing

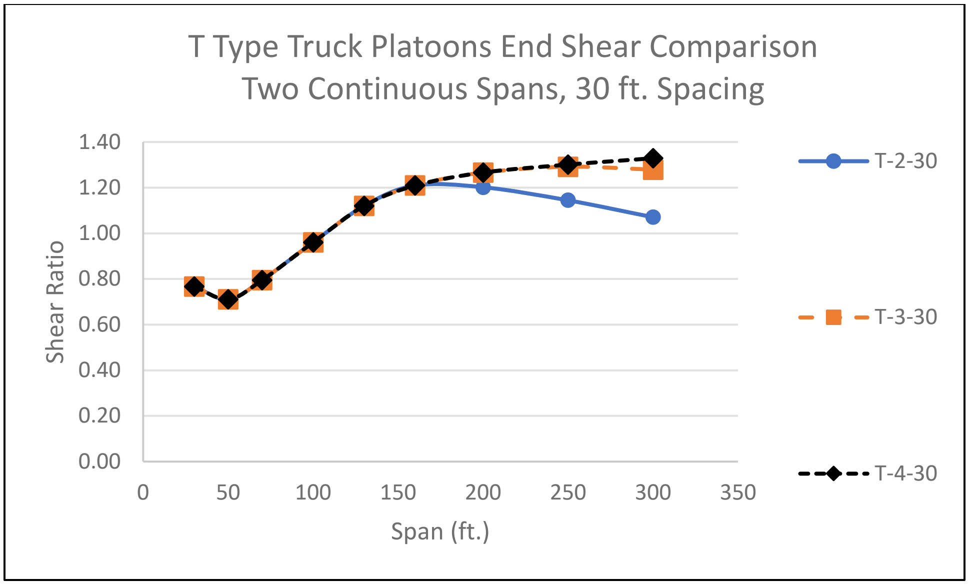


(a) Positive Moment

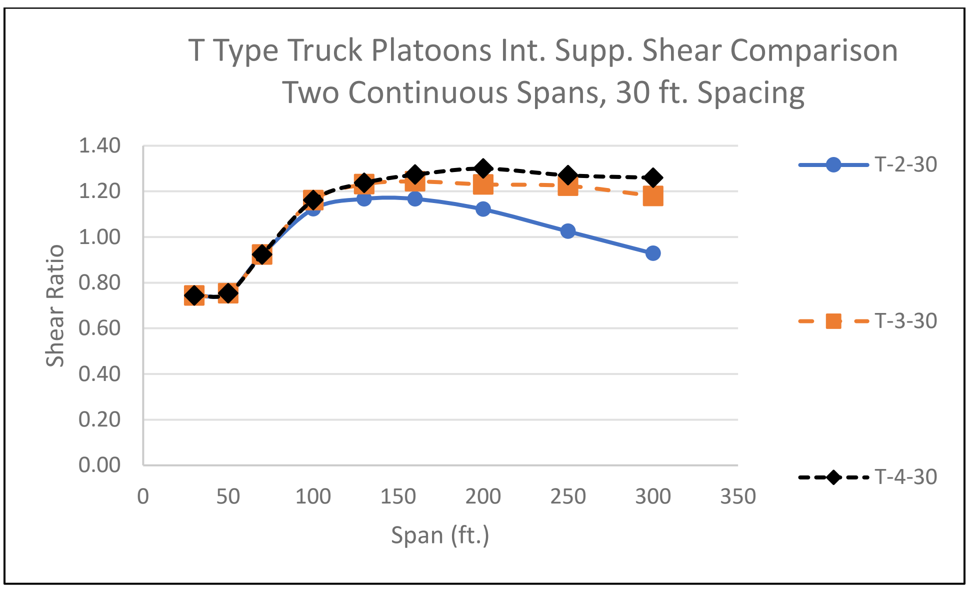


(b) Negative Moment

Figure 34. Comparison of Type T Platoons to HS 20, Two Equal Continuous Spans, 30 ft. Truck Spacing

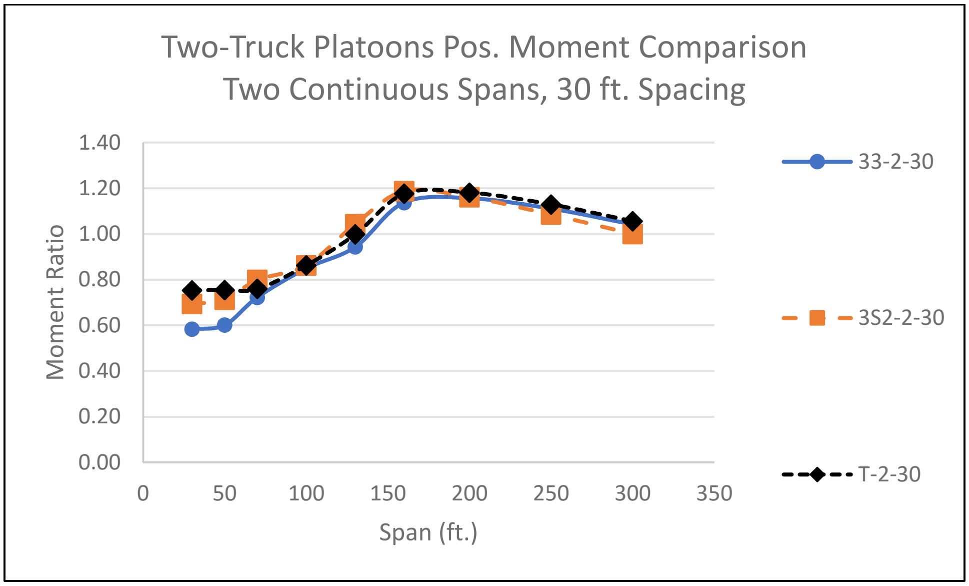


(c) End Shear

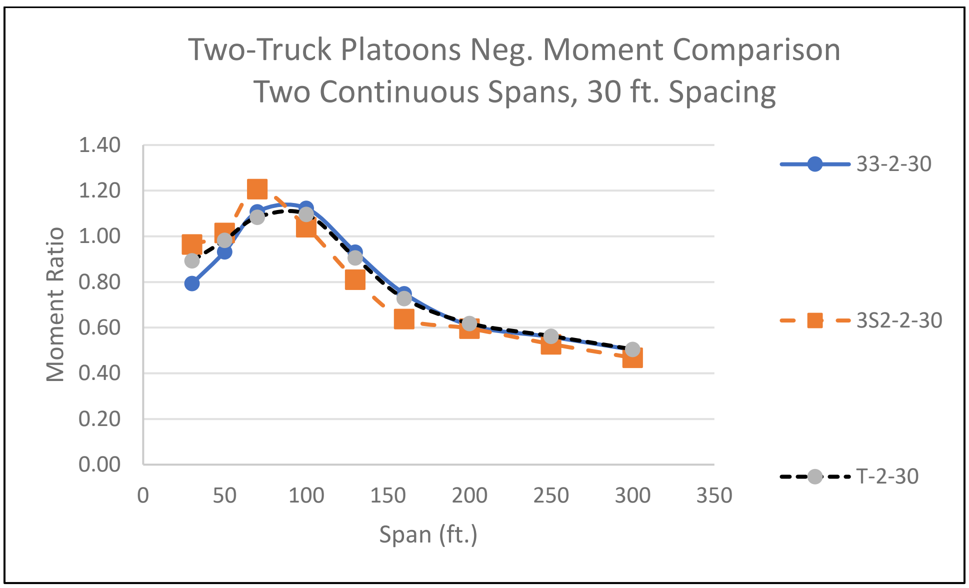


(d) Shear at Middle Support

Figure 34. (cont'd) Comparison of Type T Platoons to HS 20, Two Equal Continuous Spans, 30 ft. Truck Spacing

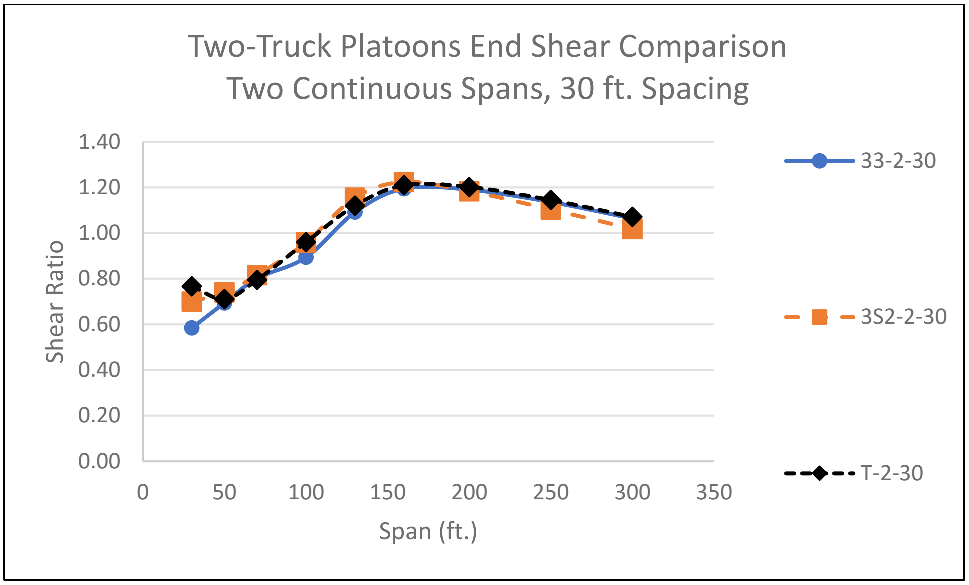


(a) Positive Moment

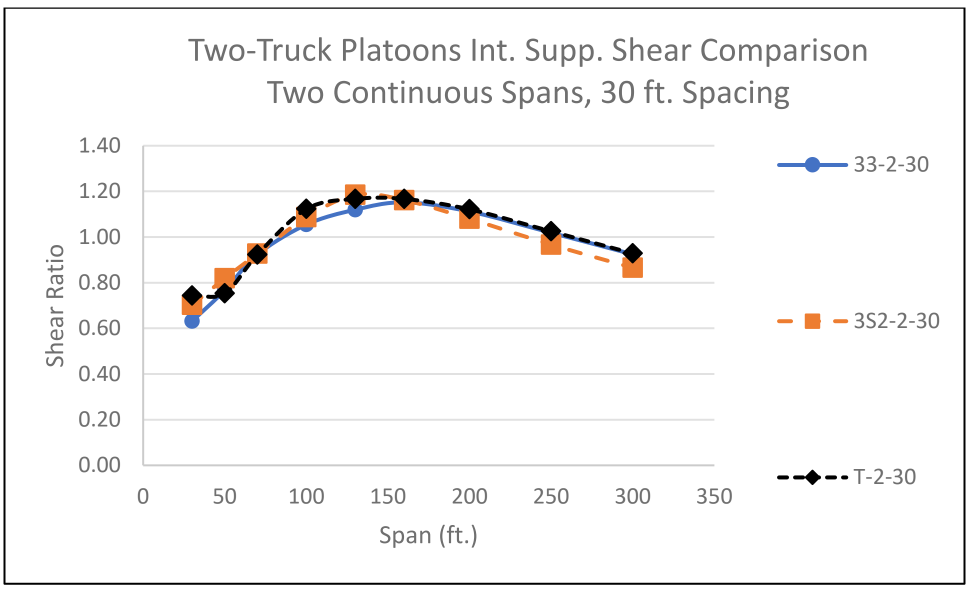


(b) Negative Moment

Figure 35. Comparison of Two-Truck Platoons to HS 20, Two Equal Continuous Spans, 30 ft. Truck Spacing

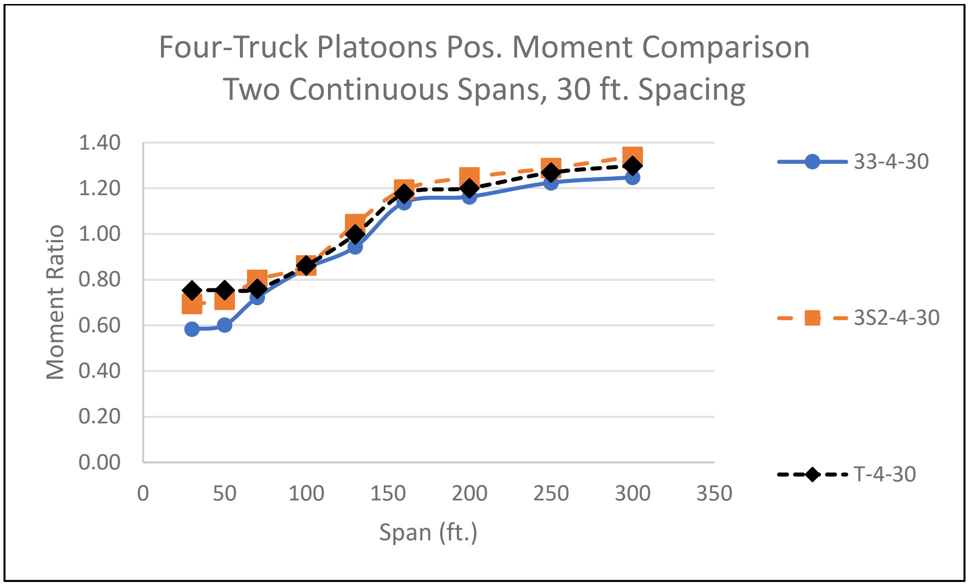


(c) End Shear

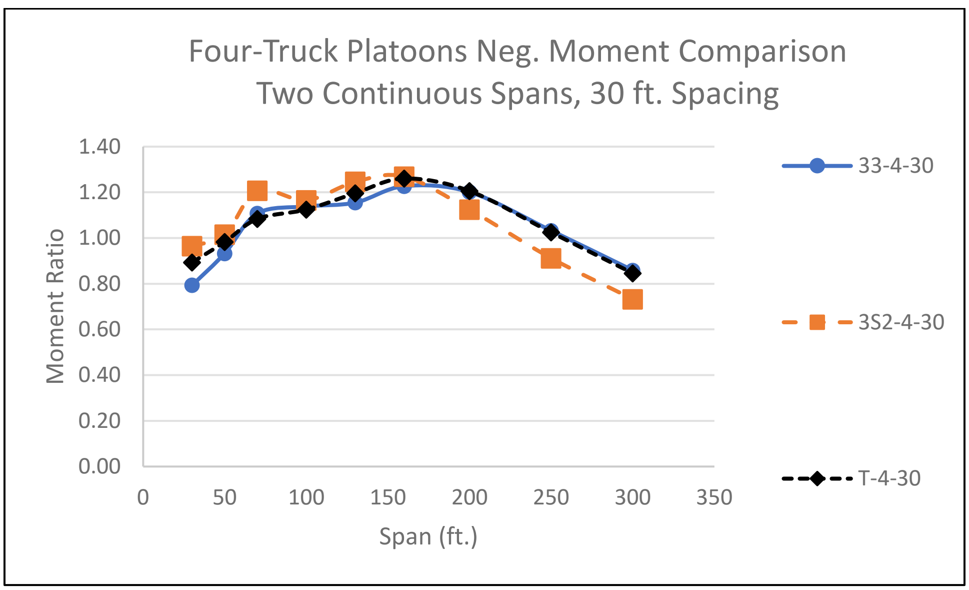


(d) Shear at Middle Support

Figure 35. (cont'd) Comparison of Two-Truck Platoons to HS 20, Two Equal Continuous Spans, 30 ft. Truck Spacing

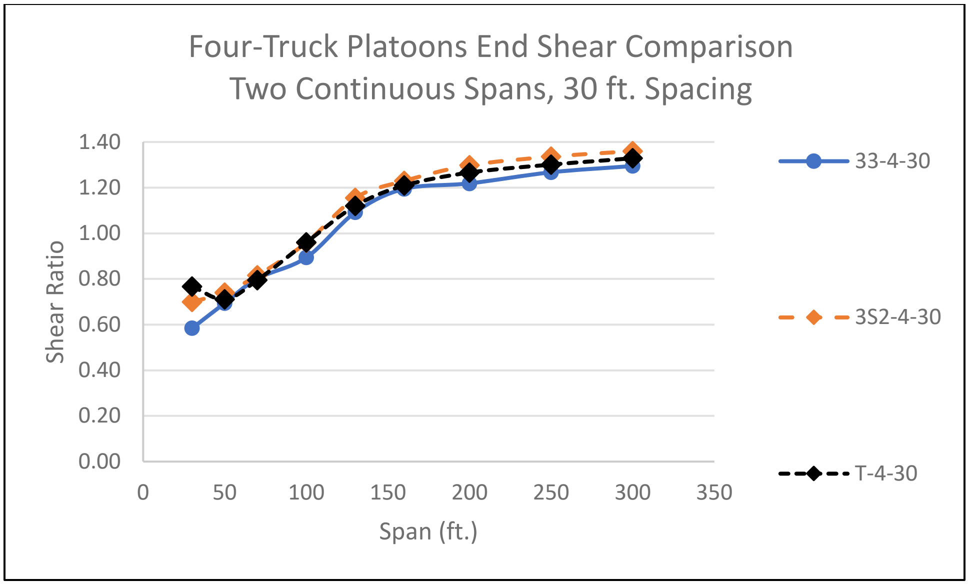


(a) Positive Moment

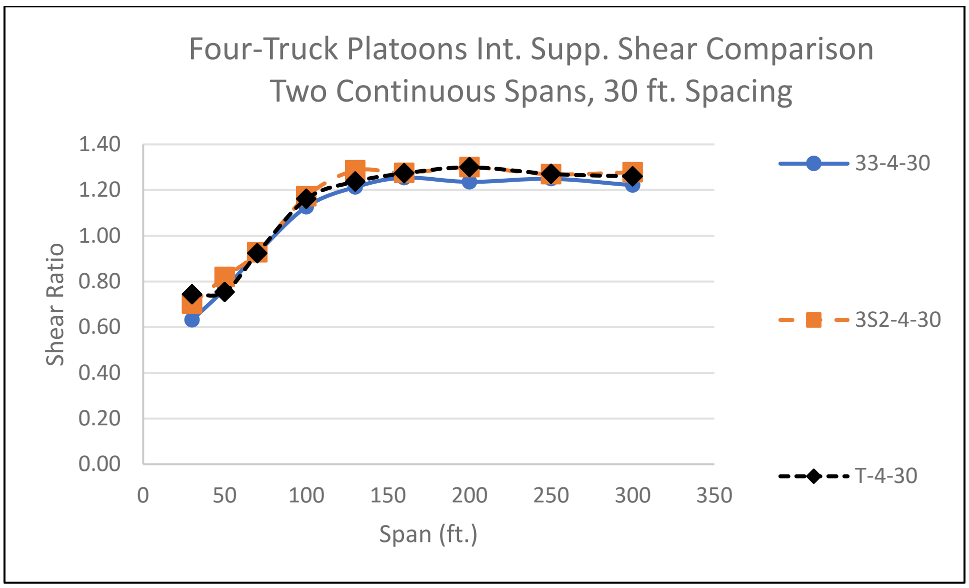


(b) Negative Moment

Figure 36. Comparison of Four-Truck Platoons to HS 20, Two Equal Continuous Spans, 30 ft. Truck Spacing



(c) End Shear



(d) Shear at Middle Support

Figure 36. (cont'd) Comparison of Four-Truck Platoons to HS 20, Two Equal Continuous Spans, 30 ft. Truck Spacing

5.5 OBSERVATIONS REGARDING PLATOON LOAD EFFECTS

The following observations can be made:

- For some spans, some of the truck platoons investigated produced load effects exceeding those produced by the HL-93 design loads and 1.20 of those of the HS 20 design loads when the clear spacing between the front axle of one truck and the rear axle of the preceding truck is 30 ft. Platoons utilizing spacing of 50 ft. or 70 ft. did not produce load effects greater than 1.00 HL-93 or 1.20 HS 20 load effects.

- The ratio between the truck platoon load effects to the load effects from design loads for the two-span continuous girders was generally similar to that for the three-span continuous girders. The ratio for the two-span case was typically slightly higher than that for the three-span case except for few cases. This led to the conclusion that only simple spans and two-span continuous girders may be used for further analysis. Eliminating the three-span case from further analysis will not significantly affect the results. It's worth noting that the calibration of AASHTO LRFD was performed using simple and two equal continuous spans only.

- For two-, three- or four-truck platoons utilizing the same type of truck and truck spacing, the results for shorter spans are the same or very close. This is because short spans cannot accommodate the full length of the longer platoons and the additional axles fall outside the span and they do not affect the results.

- For the longer spans, the platoon load effect ratio to the design load increases with the increase in the number of trucks in the platoons when the same type of truck and truck spacing are used.

- Type 3-3 truck platoons rarely produced load effects higher than those from the 3S2 and Type T truck platoons. In the few instances they did, the difference between the type 3-3 platoons and the next one was insignificant. This indicates that the 3-3 platoons may be eliminated from future analysis with negligible effect on the controlling load effects.

- Type T truck platoons and the 3S2 platoons alternated as the controlling case depending on the type of structure (simple span or continuous spans), span length, number of trucks in the platoon and the load effect being compared. Generally, the difference in magnitude of the load effects for similar platoons utilizing these two types of trucks is small. While for the time being both types of trucks should be considered in further analysis, at some point in the future it may be possible to drop one of the two truck types.

Based on the observations above, later tasks of the project were performed considering the following structures and platoon configurations:

- Simple and two-equal continuous span girders

- Two-, three- and four-truck platoons with clear spacing between the front axle of one truck and the rear axle of the preceding truck of 30 ft. and 50 ft. The latter spacing was included to confirm that it will not produce results that are more critical than design loads).

- Platoons composed of 3S2 and Type T trucks.

6.0 NBI DATABASE ANALYSES

6.1 VERSION OF DATABASE USED

An advance copy of the 2018 NBI database was used.

6.2 REVIEW OF THE NBI DATABASE

The research team screened the NBI database to determine the bridges that could be negatively affected by the truck platoon configurations investigated. During review, the team noticed that some records caused error messages to appear. A thorough validation of the database identified records containing errors, missing information, or irregularities and the following conclusions:

- 24 records from several States were shifted one or two columns to the left. These records were shifted back to their correct positions and remained in the database.
- 29 records in Louisiana did not have the method of rating listed. Except for two bridges built in 1984 and one bridge built in 1985, all these bridges were built between 2015 and 2017. As such, they are not likely to have significant deficiencies, if any. The research team concluded that deleting these records from the database will not affect the number of bridges that could be affected by the platoons. These records were deleted from the database.
- About 45,000 records did not have the percentage of trucks in traffic listed. For this project, this information is only needed for bridges rated using the LRFR method. The percentage of trucks in the traffic is used to determine the single-lane ADTT and the load factor for routine commercial traffic. With the percentage of bridges rated using the LRFR is relatively small relative to the total bridge population, the number of bridges rated using LRFR among these 45,000 bridges is expected to be relatively small compared to about 615,000 bridges in the NBI database. The team decided to assume a truck percentage of 10 percent of the total traffic for these records, and the records were used as modified.

The length of culverts along the direction of traffic is not likely to exceed the length of a truck plus the spacing between two consecutive trucks in the platoon. This will make the load effects of a truck platoon the same as from a single truck similar to those in the platoon. Structures listed in the NBI database to have a span length less than 20 ft. were also excluded as these structures are not considered to be bridges per National Bridge Inspection Standards, thus not completely inventoried in the NBI. In addition, the short length of the structure will not allow axles from more than one truck to exist on the structure at the same time, i.e. load effects from a single truck will be the same as those from a platoon composed of similar trucks.

7.0 BRIDGES THAT COULD BE NEGATIVELY AFFECTED BY TRUCK PLATOONS

7.1 APPROACH FOR NBI DATABASE SCREENING

The two criteria designated as Case 1 and Case 2 in Section 5.2 were used in screening the NBI database to determine the number of bridges that could be negatively affected by different truck platoon configurations.

The number of potentially affected bridges for the IS and for the NHS, and the NN was determined per State. Because some routes are included in more than one of the three highway systems considered (IS, NHS, and NN), some affected bridges are counted in more than one of the three systems. Therefore, the total number of bridges on the three systems combined was also determined; the total number is less than the sum of the three individual numbers.

Culverts were not considered because the length of culverts along the direction of traffic is not likely to exceed the length of a truck plus the spacing between two consecutive trucks in the platoon. This will make the load effects of a truck platoon the same as from a single truck similar to those in the platoon. Structures listed in the NBI database with a span length less than 20 feet were also excluded because these structures are not considered bridges per NBI Standards; they are not completely inventoried in the NBI.

7.1.1 Live Load Effects from the Truck Platoon Configurations Investigated for Different Bridge Span Lengths

Live load effects were determined for simple span, two-span continuous, and three-span continuous bridges of several lengths as described in Section 2. Each span length analyzed represents a range of span lengths as shown in Table 40. In determining affected bridges, the ratio between the load effects for the rating load used in the operating rating (Item 63 in the NBI) and for a platoon configuration was considered to be the same for all bridges in the span length range represented by the span length analyzed. For example, the ratio between the positive moment for HL-93 and the T-2-35 platoon configuration calculated for a simple span length of 70 feet was assumed applicable to all bridges with simple span length of 60 feet to less than 85 feet.

As shown earlier and in Appendix B, the Maximum Unfactored Load Effects for the HS 20, HL-93, and the investigated truck platoon configurations were tabulated for different span lengths.

The ratio of the load effects from each of the investigated truck platoon configurations and the HS 20 and HL-93 loads was also tabulated for simple and continuous spans (see Section 2 and Appendix C); the NBI allows the determination of whether a bridge is a simple span or a continuous span bridge. However, for continuous spans, the NBI only lists the length of the longest span. Furthermore, the NBI database does not list which load effect controlled the rating or at what location. As an approximation, for any bridge under the effect of a certain platoon configuration, the operating rating under the platoon loading was determined as follows:

Table 40. Span Lengths for Analysis

Span Length Used to Determine the Load Effect Ratios (ft.)	Span Range for Which the Load Effect Ratio is Used (ft.)
30	20 to <40
50	40 to <60
70	60 to <85
100	85 to <115
130	115 to <145
160	145 to <180
200	180 to <225
250	225 to <275
300	275-325

- The maximum factored moments and shears for the load effects tabulated in Appendix B were determined for the rating load using the method of rating listed in the NBI (determined by factoring the load effects shown in Appendix B).

- The maximum factored moment and shears from the platoon configuration being considered and using the load factors corresponding to the method of rating used to calculate the operating rating listed in the NBI assuming the platoons to be routine commercial traffic (i.e., legal loads) (determined by factoring the load effects shown in Appendix B).

- The ratio of each platoon load effect to the corresponding rating load effect was determined for different load effects that may control the design, i.e. maximum in-span positive moments, maximum negative moment at interior supports, end shear, shear near intermediate supports.

- The maximum load effect ratio was determined. The load effect that controlled the rating was assumed to be that with the maximum load effect ratio.

- The estimated rating factor for the platoon was determined considering the operating rating factor listed in the NBI, the load factor for the operating rating, the load factor for the platoon assuming it to be a routine commercial traffic (i.e., legal load) and the maximum ratio between the rating load effect and the platoon load effect.

7.1.2 Rating Factor for Bridges Under the Investigated Truck Platoon Configurations

Using the ratios of load effects of the platoons to the rating load used in determining the rating in the NBI, all bridges in the NBI database were checked per the following procedure:

1. ADTT for each direction was determined by multiplying the ADT (Item 29 in the NBI) by the percentage of trucks (Item 109). For a bridge with two-way traffic, the number was divided by 2 to determine the ADTT for one direction.

2. The generalized live load factor for routine commercial traffic was determined based on the ADTT using Table 6A.4.4.3.2a-1 of the AASHTO Manual for Bridge Evaluation (AASHTO MBE), 3rd Edition, 2018 (23 CFR 650) (see a copy below). The load factors were interpolated for one-direction ADTT between 1000 and 5000. These values were used for determining the legal load rating for bridges using the LRFR method. For ASR/LFR rating, the platoons load factor used was the same as that for the operating rating for the HS 20 load.

Table 41. AASHTO MBE Table 6A.4.4.2.3a-1—Generalized Live Load Factors, γ_L for Routine Commercial Traffic

Traffic Volume (one direction)	Load Factor
Unknown	1.45
ADTT ≥ 5000	1.45
ADTT ≤ 1000	1.30

3. The data in Item 64 of the NBI database provided was expressed in metric tons. The values in Item 64 were converted to an equivalent rating factor by dividing by the weight of the HS 20 truck expressed in metric tons (32.4 metric tons)

   In the general case where the data in Item 64 may be expressed in metric tons or in terms of rating factor the process would be different. First, the data in Item 63 of the NBI database for each record would be used to determine whether the operating rating in Item 64 is expressed in metric tons or as a rating factor. Then, in case it is in tons, the value would be converted to an equivalent rating factor by dividing by the weight of the HS 20 truck expressed in metric tons (32.4 metric tons). For records where the operating rating in Item 64 is expressed as a rating factor, the value does not change.

4. Using the information in the NBI database, it was determined whether the bridge is a simple span or continuous spans (Item 43B), whether the rating is LRFR or ASD/LFD rating (Item 63), and whether the bridge is longer than 300 ft. The 300 ft. represented the longest span length used in the analysis. For bridges with span length greater than 300 ft., the $\text{Ratio}_{\text{Platoon/Operating}}$ (see definition below) for 300 ft. long span was used in the analysis.

   For a multi-span bridge, the NBI database only lists the length of the longest span (Item 48) and the total structure length (Item 49). Due to the absence of information on the length of spans other than the maximum span length, determination of the force ratio and whether the span exceeds 300 ft. was based on the maximum span (Item 48).

5. The information from Step 4 above was used to determine the estimated maximum ratio between the force effects of the platoon configurations investigated and those from the rating load used for the operating rating listed in the NBI database.

6. The controlling rating factor for each platoon configurations investigated ($RF_{Platoon}$) was then determined using the following equation:

$$RF_{Platoon} = (RF_{Operating} / Ratio_{Platoon/Operating}) (LF_{Operating}/LF_{Platoon})$$

Where:

$LF_{Operating}$: Load factor for operating rating (1.35 for Strength in LRFR, 1.00 for ASD rating or 1.30 for Strength in LFR)

$LF_{Platoon}$: Load factor for Platoon load (from Step 2 above for LRFR, 1.00 for ASD rating or 1.30 for Strength in LFR)

$RF_{operating}$: Rating factor for operating rating (from Step 3 above)

$Ratio_{Platoon/Operating}$: Rratio between the platoon load effects and operating rating load effects, (Step 5 above).

7. Step 6 was repeated for each bridge in the NBI database for each of the platoon configurations investigated to determine the rating factor, $RF_{Platoon}$. A value of $RF_{Platoon} \geq 1.00$ indicates that the bridge has adequate load capacity to carry the platoon being investigated as a legal load.

7.1.3 Bridges That Could Be Affected Under Different Platoon Configurations

As indicated earlier, two cases were examined:

- Case 1: A bridge was considered to currently have adequate load capacity when it has a rating factor ≥ 1.00 (Item 64 in the NBI expressed as a rating factor) at the operating level using the Load and Resistance Factor Rating (LRFR) method, or ≥ 1.20 (Item 64 in the NBI expressed as a rating factor) using the Allowable Stress Rating (ASR) or Load Factor Rating (LFR) methods.

  Under this scenario, for each platoon configuration investigated, all bridges that have an operating rating factor greater than ≥ 1.00 for LRFR (bridges with $RF_{Operating} \geq 1.00$) or an operating rating factor greater than ≥ 1.20 for ASR or LFR (bridges with $RF_{Operating} \geq 1.20$) in the NBI database, i.e. bridges that are likely to have adequate load capacity under the SHV's, but do not pass the operating rating under the platoon ($RF_{Platoon} < 1.00$ in Step 7 above) were considered to potentially be negatively affected if the platoon configuration is allowed. This approach identifies bridges that are currently considered adequate under routine commercial traffic (legal loads) but will not have adequate load capacity to safely support the platoon being investigated.

- Case 2: A bridge was considered to currently have adequate load capacity when it has a rating factor ≥ 1.00 at the operating level using the rating method used for the NBI listing.

Under this scenario, for each platoon configuration investigated, all bridges that have an operating rating factor greater than ≥ 1.00 for LRFR, ASR or LFR (bridges with $RF_{Operating} \geq 1.00$) in the NBI database, but do not pass the operating rating under the platoon ($RF_{Platoon} < 1.00$ in Step 7 above) were considered to potentially be negatively affected if the platoon configuration being investigated is allowed.

7.1.4 Number of Bridges That Could Potentially Be Affected Under Different Platoon Configurations and Assuming Case 1

The number of bridges that will potentially be affected by different platoon configurations per State for all platoon configurations was tabulated in the following tables:

- Table 42, Table 43, and Table 44 list the number of potentially affected bridges on the Interstate (IS) highways per State for the Type 3-3, 3S2 and Type T truck platoons, respectively.
- Table 45, Table 46, and Table 47 list the number of potentially affected bridges on the National Highway System (NHS) per State for the Type 3-3, 3S2 and Type T truck platoons, respectively.
- Table 48, Table 49, and Table 50 list the number of potentially affected bridges on the National Network for Trucks (NN) per State for the Type 3-3, 3S2 and Type T truck platoons, respectively.
- Table 51, Table 52, and Table 53 list the total number of potentially affected bridges on the IS, NHS and NN combined per State for the Type 3-3, 3S2 and Type T truck platoons, respectively.
- Table 54 summarizes the total number of potentially affected bridges, assuming Case 1, for the entire country for the IS, NHS and NN separately and the combined number for the three highway systems. Notice that some routes are included in more than one of the three highway systems considered (SI, NHS and NN). This caused the total number of potentially affected bridges for the three systems combined to be less than the sum of the potentially affected bridges for the individual systems.

7.1.5 Number of Potentially Affected Bridges

The number of potentially affected bridges seems smaller than originally anticipated. This is due to several reasons:

- The scope of this project only includes the strength limit state. Service and fatigue limit states may cause additional bridges to be impacted.
- The truck platoons were considered to be Routine Commercial Traffic (i.e. legal loads); not inventory level loads. With the load factor for the inventory level rating always higher than that for the routine commercial traffic, the load effects from the platoons should be significantly higher than those from the design loads or the inventory level rating has to be low for the bridge to have a rating factor less than

1.00 at the operating level rating under the truck platoons. Following are some examples:

- For LRFR rating method, the load factor for the inventory rating is 1.75 and that for routine commercial traffic is 1.35 to 1.45. Considering that bridges designed using AASHTO LRFD are all relatively new and are likely to have an inventory level rating factor not less than 1.00 and considering the most severe operating load factor for routine commercial traffic of 1.45, a bridge with an inventory rating factor of 1.00 using the LRFR method of rating will have an operating rating factor for routine commercial traffic of 1.20 (the ratio between the inventory and routine commercial traffic load factors: 1.75/1.45). For such a bridge to have an operating rating factor of 1.00 or less under a certain truck platoon, the truck platoon should produce load effects greater than 1.20 those of the HL-93. The highest load effect truck platoon to HL-93 observed was 1.18. This means that bridges designed using AASHTO LRFD are not likely to be impacted by truck platoons.

- For bridges rated using AASHTO LFR, the load factor for the inventory rating is 2.17 and that for the operating rating (including routine commercial traffic or legal loads) is 1.30. The highest ratio between the unfactored truck platoons load effects to those from the HS 20 load is 1.38 (most ratios are below this value). For this highest ratio, for a bridge to produce an operating rating factor ≤ 1.00 under a platoon, the inventory rating for the bridge must be ≤ 0.82 (1.3 x 1.38 / 2.17 = 0.82). For load effect ratios below 1.38, which is the case for most spans for all platoons) the inventory rating must be even a smaller value. It is not likely that many bridges on the major highway systems investigated have an inventory rating factor below 0.82.

- The number of potentially affected bridges in Indiana and Ohio is disproportionate to the number of bridges in the two States compared to other States. A review of the NBI database revealed that there are some irregularities in the values listed for the inventory and operating rating for some bridges. For example, the ratio between the operating rating factor to the inventory rating factor for a bridge rated using the LFR method of rating must be 1.67 (the ratio between the load factors for inventory and operating ratings: 2.17/1.3). However, many of the bridges that seem to be affected by the platoons appear to have a lower ratio even though most of these bridges are listed to have been rated using the LFR method. The operating rating factor listed in the NBI for most of these bridges is about 40.5 metric tons which is equivalent to an operating rating factor of 1.25.

The research team contacted the Ohio DOT rating group. It was indicated that they are aware of some discrepancies in the data for some bridges that were rated some time ago and they are in the process of re-rating these bridges using the current rating methods.

The research team contacted Indiana Rating Engineer. The response from Indiana rating group also indicated that they are aware of some discrepancies and they are working towards re-rating many of their bridges.

Table 55 and Table 56 summarize the total number of potentially affected bridges in Indiana and Ohio, respectively. Based on these two tables, significant numbers of the potentially affected bridges in the entire country appear to be in these two States (about 58 percent for the 3S2-3-30 platoons, 54 percent for the 3S2-4-30 platoons, 36 percent for the T-3-30 platoons and 42 percent for the T-4-30 platoons). Assuming that the NBI data for both States needs to be revised and that the revised numbers of affected bridges in the two States will follow the same trends observed for other States, the number of potentially affected bridges on the three highway systems for the entire country (Table 54) will drop by about 50 percent for the 3S2 platoons and about one third for the T Platoons.

- About 85 percent of all bridges that will potentially be negatively affected by the truck platoons investigated are simple and continuous span steel girder bridges. Most of the remaining potentially affected bridges are prestressed concrete girder bridges.

Table 42. Case 1, Number of Affected Bridges on the Interstate Highways Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Alabama	0	0	0	0	5	0	0	5	0	0
Alaska	0	0	0	0	0	0	0	0	0	0
Arizona	0	0	0	0	1	0	0	1	0	0
Arkansas	0	0	0	0	1	0	0	1	0	0
California	0	0	0	0	0	0	0	1	0	0
Colorado	0	0	0	0	2	0	0	3	0	0
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	0	0	0	0	0	0
DC	0	0	0	0	0	0	0	0	0	0
Florida	0	0	0	0	1	0	0	4	0	0
Georgia	0	0	0	0	0	0	0	0	0	0
Hawaii	0	0	0	0	0	0	0	0	0	0
Idaho	0	0	0	0	0	0	0	0	0	0
Illinois	0	0	0	0	0	0	0	1	0	0
Indiana	0	0	0	0	4	0	0	4	0	0
Iowa	0	0	0	0	0	0	0	0	0	0
Kansas	0	0	0	0	0	0	0	0	0	0
Kentucky	0	0	0	0	4	0	0	6	0	0
Louisiana	0	0	0	0	1	0	0	1	0	0
Maine	0	0	0	0	0	0	0	0	0	0
Maryland	0	0	0	0	1	0	0	1	0	0
Massachusetts	0	0	0	0	0	0	0	0	0	0
Michigan	0	0	0	0	0	0	0	1	0	0
Minnesota	0	0	0	0	2	0	0	2	0	0
Mississippi	0	0	0	0	0	0	0	0	0	0
Missouri	0	0	0	0	3	0	0	3	0	0
Montana	0	0	0	0	2	0	0	2	0	0

Table 42. (Cont'd) Case 1, Number of Affected Bridges on the Interstate Highways Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Nebraska	0	0	0	0	0	0	0	0	0	0
Nevada	0	0	0	0	0	0	0	0	0	0
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	0	0	0	0	0	0	0	0	0	0
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	0	0	0	1	0	0	2	0	0
North Carolina	0	0	0	0	0	0	0	0	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	0	0	0	0	8	0	0	38	0	0
Oklahoma	0	0	0	0	0	0	0	0	0	0
Oregon	0	0	0	0	3	0	0	3	1	0
Pennsylvania	0	0	0	0	4	0	0	6	0	0
Rhode Island	0	0	0	0	0	0	0	0	0	0
South Carolina	0	0	0	0	0	0	0	0	0	0
South Dakota	0	0	0	0	1	0	0	1	0	0
Tennessee	0	0	0	0	4	0	0	5	0	0
Texas	0	0	0	0	0	0	0	0	0	0
Utah	0	0	0	0	5	0	0	8	0	0
Vermont	0	0	0	0	0	0	0	0	0	0
Virginia	0	0	0	0	0	0	0	1	0	0
Washington	0	0	0	0	6	1	0	7	1	0
West Virginia	0	0	0	0	1	0	0	2	0	0
Wisconsin	0	0	0	0	0	0	0	0	0	0
Wyoming	0	0	0	0	0	0	0	0	0	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	60	1	0	109	2	0

Table 43. Case 1, Number of Affected Bridges on the Interstate Highways Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Alabama	0	0	0	0	11	0	0	21	0	0
Alaska	0	0	0	0	0	0	0	1	0	0
Arizona	0	0	0	0	1	0	0	1	0	0
Arkansas	0	0	0	0	1	0	0	3	0	0
California	0	0	0	0	3	0	0	3	0	0
Colorado	0	0	0	0	4	0	0	6	1	0
Connecticut	0	0	0	0	0	0	0	1	0	0
Delaware	0	0	0	0	0	0	0	2	0	0
DC	0	0	0	0	0	0	0	0	0	0
Florida	0	0	0	0	2	0	0	6	0	0
Georgia	0	1	0	0	2	0	0	2	0	0
Hawaii	0	0	0	0	0	0	0	4	0	0
Idaho	0	0	0	0	1	0	0	1	0	0
Illinois	0	0	0	0	1	0	0	6	0	0
Indiana	0	1	0	0	35	0	0	53	0	0
Iowa	0	0	0	0	0	0	0	1	0	0
Kansas	0	0	0	0	0	0	0	1	0	0
Kentucky	0	0	0	0	6	0	0	8	0	0
Louisiana	0	1	0	0	1	0	0	2	0	0
Maine	0	0	0	0	0	0	0	0	0	0
Maryland	0	0	0	0	1	0	0	1	0	0
Massachusetts	0	1	0	0	2	0	0	3	0	0
Michigan	0	0	0	0	0	0	0	1	0	0
Minnesota	0	0	0	0	2	0	0	2	0	0
Mississippi	0	0	0	0	0	0	0	0	0	0
Missouri	0	1	0	0	8	0	0	9	0	0
Montana	0	0	0	0	4	0	0	6	0	0

Table 43. (Cont'd) Case 1, Number of Affected Bridges on the Interstate Highways Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Nebraska	0	1	0	0	1	0	0	2	0	0
Nevada	0	0	0	0	1	0	0	1	0	0
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	0	0	0	0	2	0	0	3	0	0
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	0	0	0	0	0	0	2	0	0
North Carolina	0	0	0	0	1	0	0	1	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	0	2	0	0	134	0	0	169	0	0
Oklahoma	0	0	0	0	0	0	0	0	0	0
Oregon	0	1	0	0	5	0	0	8	1	0
Pennsylvania	0	2	0	0	11	0	0	13	0	0
Rhode Island	0	0	0	0	0	0	0	0	0	0
South Carolina	0	0	0	0	0	0	0	0	0	0
South Dakota	0	0	0	0	1	0	0	1	0	0
Tennessee	0	0	0	0	4	0	0	6	0	0
Texas	0	1	0	0	1	0	0	4	0	0
Utah	0	0	0	0	8	0	0	10	1	0
Vermont	0	0	0	0	0	0	0	0	0	0
Virginia	0	0	0	0	0	0	0	1	0	0
Washington	0	1	0	0	10	0	0	13	2	0
West Virginia	0	0	0	0	0	0	0	2	0	0
Wisconsin	0	1	0	0	2	0	0	2	0	0
Wyoming	0	0	0	0	0	0	0	0	0	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	0	0	0	0	0	0	0	0	0
Total	0	14	0	0	266	0	0	382	5	0

Table 44. Case 1, Number of Affected Bridges on the Interstate Highways Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Alabama	0	0	0	0	9	0	0	15	0	0
Alaska	0	0	0	0	0	0	0	1	0	0
Arizona	0	0	0	0	1	0	0	1	0	0
Arkansas	0	0	0	0	1	0	0	3	0	0
California	0	0	0	0	3	0	0	3	0	0
Colorado	0	0	0	0	3	0	0	5	1	1
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	0	0	0	1	0	0
DC	0	0	0	0	0	0	0	0	0	0
Florida	0	0	0	0	4	0	0	4	0	0
Georgia	0	0	0	0	0	0	0	0	0	0
Hawaii	0	0	0	0	0	0	0	0	0	0
Idaho	0	0	0	0	0	0	0	1	0	0
Illinois	0	0	0	0	0	0	0	1	0	0
Indiana	0	1	0	0	10	0	0	27	0	0
Iowa	0	0	0	0	0	0	0	1	0	0
Kansas	0	0	0	0	0	0	0	1	0	0
Kentucky	0	0	0	0	6	0	0	8	0	0
Louisiana	0	0	0	0	1	0	0	1	0	0
Maine	0	0	0	0	0	0	0	0	0	0
Maryland	0	0	0	0	1	0	0	1	0	0
Massachusetts	0	0	0	0	1	0	0	2	0	0
Michigan	0	0	0	0	0	0	0	1	0	0
Minnesota	0	0	0	0	2	0	0	2	0	0
Mississippi	0	0	0	0	0	0	0	0	0	0
Missouri	0	0	0	0	4	0	0	4	0	0
Montana	0	0	0	0	2	0	0	5	0	0

Table 44. (Cont'd) Case 1, Number of Affected Bridges on the Interstate Highways Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Nebraska	0	0	0	0	0	0	0	1	0	0
Nevada	0	0	0	0	0	0	0	1	0	0
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	0	0	0	0	2	0	0	3	0	0
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	0	0	0	1	0	0	2	0	0
North Carolina	0	0	0	0	1	0	0	1	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	0	0	0	0	32	0	0	62	0	0
Oklahoma	0	0	0	0	0	0	0	0	0	0
Oregon	0	0	0	0	4	0	0	5	1	1
Pennsylvania	0	1	0	0	8	0	0	10	0	0
Rhode Island	0	0	0	0	0	0	0	0	0	0
South Carolina	0	0	0	0	0	0	0	0	0	0
South Dakota	0	0	0	0	1	0	0	1	0	0
Tennessee	0	0	0	0	4	0	0	6	0	0
Texas	0	0	0	0	0	0	0	0	0	0
Utah	0	0	0	0	8	0	0	10	1	1
Vermont	0	0	0	0	0	0	0	0	0	0
Virginia	0	0	0	0	0	0	0	1	0	0
Washington	0	1	0	0	10	2	0	12	2	0
West Virginia	0	0	0	0	1	0	0	2	0	0
Wisconsin	0	0	0	0	0	0	0	0	0	0
Wyoming	0	0	0	0	0	0	0	0	0	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	0	0	0	0	0	0	0	0	0
Total	0	3	0	0	120	2	0	205	5	3

Table 45. Case 1, Number of Affected Bridges on the National Highway System Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Alabama	0	0	0	0	9	0	0	9	0	0
Alaska	0	0	0	0	0	0	0	0	0	0
Arizona	0	0	0	0	1	0	0	1	0	0
Arkansas	0	0	0	0	1	0	0	3	0	0
California	0	0	0	0	0	0	0	2	0	0
Colorado	0	0	0	0	3	0	0	5	0	0
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	2	0	0	2	0	0
DC	0	0	0	0	0	0	0	0	0	0
Florida	0	0	0	0	4	0	0	10	0	0
Georgia	0	0	0	0	2	0	0	2	0	0
Hawaii	0	0	0	0	0	0	0	1	0	0
Idaho	0	0	0	0	0	0	0	0	0	0
Illinois	0	0	0	0	1	0	0	5	0	0
Indiana	0	0	0	0	4	0	0	5	0	0
Iowa	0	0	0	0	2	0	0	2	0	0
Kansas	0	0	0	0	0	0	0	0	0	0
Kentucky	0	0	0	0	4	0	0	8	0	0
Louisiana	0	2	0	0	5	0	0	6	1	0
Maine	0	0	0	0	1	0	0	1	0	0
Maryland	0	0	0	0	3	0	0	4	0	0
Massachusetts	0	0	0	0	3	0	0	3	0	0
Michigan	0	0	0	0	0	0	0	1	0	0
Minnesota	0	0	0	0	3	0	0	4	0	0
Mississippi	0	0	0	0	3	0	0	5	0	0
Missouri	0	0	0	0	5	0	0	5	0	0
Montana	0	0	0	0	2	0	0	2	0	0

Table 45. (Cont'd) Case 1, Number of Affected Bridges on the National Highway System Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Nebraska	0	0	0	0	2	0	0	4	0	0
Nevada	0	0	0	0	0	0	0	0	0	0
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	0	1	0	0	3	0	0	3	0	0
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	0	0	0	1	0	0	4	0	0
North Carolina	0	0	0	0	0	0	0	0	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	0	0	0	0	34	0	0	99	0	0
Oklahoma	0	0	0	0	0	0	0	0	0	0
Oregon	0	0	0	0	7	0	0	8	1	0
Pennsylvania	0	0	0	0	11	0	0	18	0	0
Rhode Island	0	0	0	0	0	0	0	0	0	0
South Carolina	0	0	0	0	0	0	0	0	0	0
South Dakota	0	0	0	0	1	0	0	1	0	0
Tennessee	0	0	0	0	4	0	0	5	0	0
Texas	0	0	0	0	0	0	0	1	0	0
Utah	0	0	0	0	6	0	0	11	0	0
Vermont	0	0	0	0	0	0	0	0	0	0
Virginia	0	0	0	0	0	0	0	1	0	0
Washington	0	0	0	0	16	1	0	19	1	0
West Virginia	0	0	0	0	1	0	0	2	0	0
Wisconsin	0	0	0	0	1	0	0	2	0	0
Wyoming	0	0	0	0	0	0	0	0	0	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	0	0	0	0	0	0	0	0	0
Total	0	3	0	0	145	1	0	264	3	0

Table 46. Case 1, Number of Affected Bridges on the National Highway System Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Alabama	0	3	0	0	20	0	0	35	0	0
Alaska	0	0	0	0	0	0	0	1	0	0
Arizona	0	0	0	0	1	0	0	1	0	0
Arkansas	0	0	0	0	3	0	0	6	0	0
California	0	1	0	0	7	0	0	8	0	0
Colorado	0	1	0	0	6	0	0	10	1	0
Connecticut	0	0	0	0	0	0	0	1	0	0
Delaware	0	0	0	0	2	0	0	4	0	0
DC	0	0	0	0	1	0	0	1	0	0
Florida	0	9	0	0	15	0	0	25	0	0
Georgia	0	3	0	0	8	0	0	10	0	0
Hawaii	0	3	0	0	4	0	0	9	0	0
Idaho	0	1	0	0	4	0	0	4	0	0
Illinois	0	0	0	0	4	0	0	13	0	0
Indiana	0	1	0	0	53	0	0	82	0	0
Iowa	0	1	0	0	2	0	0	8	0	0
Kansas	0	2	0	0	2	0	0	4	0	0
Kentucky	0	0	0	0	7	0	0	11	0	0
Louisiana	0	4	0	0	8	0	0	11	0	0
Maine	0	0	0	0	2	0	0	2	0	0
Maryland	0	1	0	0	4	0	0	7	0	0
Massachusetts	0	3	0	0	8	0	0	11	0	0
Michigan	0	0	0	0	0	0	0	1	0	0
Minnesota	0	0	0	0	4	0	0	5	0	0
Mississippi	0	2	0	0	10	0	0	12	0	0
Missouri	0	2	0	0	12	0	0	17	0	0
Montana	0	0	0	0	5	0	0	7	0	0

Table 46. (Cont'd) Case 1, Number of Affected Bridges on the National Highway System Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Nebraska	0	2	0	0	5	0	0	9	0	0
Nevada	0	0	0	0	1	0	0	1	0	0
New Hampshire	0	1	0	0	1	0	0	1	0	0
New Jersey	0	1	0	0	5	0	0	6	0	0
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	0	0	0	1	0	0	6	0	0
North Carolina	0	0	0	0	2	0	0	3	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	0	2	0	0	291	0	0	372	0	0
Oklahoma	0	2	0	0	3	0	0	4	0	0
Oregon	0	6	0	0	14	0	0	19	1	0
Pennsylvania	0	5	0	0	19	0	0	31	0	0
Rhode Island	0	0	0	0	0	0	0	1	0	0
South Carolina	0	0	0	0	0	0	0	0	0	0
South Dakota	0	0	0	0	1	0	0	1	0	0
Tennessee	0	0	0	0	5	0	0	11	0	0
Texas	0	10	0	0	11	0	0	22	0	0
Utah	0	0	0	0	10	0	0	15	1	0
Vermont	0	0	0	0	0	0	0	0	0	0
Virginia	0	1	0	0	1	0	0	2	0	0
Washington	0	2	0	0	31	0	0	38	2	0
West Virginia	0	0	0	0	1	0	0	4	0	0
Wisconsin	0	1	0	0	4	0	0	5	0	0
Wyoming	0	0	0	0	1	0	0	1	0	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	1	0	0	1	0	0	1	0	0
Total	0	71	0	0	600	0	0	859	5	0

Table 47. Case 1, Number of Affected Bridges on the National Highway System Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Alabama	0	0	0	0	13	0	0	23	0	0
Alaska	0	0	0	0	0	0	0	1	0	0
Arizona	0	0	0	0	1	0	0	1	0	0
Arkansas	0	0	0	0	3	0	0	5	0	0
California	0	0	0	0	4	0	0	6	0	0
Colorado	0	0	0	0	4	0	0	7	1	1
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	2	0	0	3	0	0
DC	0	0	0	0	0	0	0	1	0	0
Florida	0	6	0	0	14	0	0	18	0	0
Georgia	0	1	0	0	4	0	0	5	0	0
Hawaii	0	0	0	0	0	0	0	1	0	0
Idaho	0	0	0	0	2	0	0	3	0	0
Illinois	0	0	0	0	2	0	0	7	0	0
Indiana	0	1	0	0	17	0	0	45	0	0
Iowa	0	1	0	0	2	0	0	3	0	0
Kansas	0	0	0	0	0	0	0	2	0	0
Kentucky	0	0	0	0	8	0	0	10	0	0
Louisiana	0	2	0	0	6	0	0	7	1	1
Maine	0	0	0	0	1	0	0	2	0	0
Maryland	0	0	0	0	4	0	0	6	0	0
Massachusetts	0	1	0	0	6	0	0	8	0	0
Michigan	0	0	0	0	0	0	0	1	0	0
Minnesota	0	0	0	0	3	0	0	4	0	0
Mississippi	0	0	0	0	5	0	0	7	0	0
Missouri	0	0	0	0	7	0	0	8	0	0
Montana	0	0	0	0	2	0	0	6	0	0

Table 47. (Cont'd) Case 1, Number of Affected Bridges on the National Highway System Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Nebraska	0	0	0	0	4	0	0	6	0	0
Nevada	0	0	0	0	0	0	0	1	0	0
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	0	1	0	0	4	0	0	5	0	0
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	0	0	0	1	0	0	4	0	0
North Carolina	0	0	0	0	1	0	0	1	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	0	1	0	0	79	0	0	146	0	0
Oklahoma	0	0	0	0	0	0	0	0	0	0
Oregon	0	0	0	0	9	0	0	11	1	1
Pennsylvania	0	2	0	0	17	0	0	26	0	0
Rhode Island	0	0	0	0	0	0	0	1	0	0
South Carolina	0	0	0	0	0	0	0	0	0	0
South Dakota	0	0	0	0	1	0	0	1	0	0
Tennessee	0	0	0	0	4	0	0	6	0	0
Texas	0	0	0	0	1	0	0	2	0	0
Utah	0	0	0	0	10	0	0	14	1	1
Vermont	0	0	0	0	0	0	0	0	0	0
Virginia	0	1	0	0	1	0	0	2	0	0
Washington	0	1	0	0	26	2	0	31	2	0
West Virginia	0	0	0	0	1	0	0	3	0	0
Wisconsin	0	0	0	0	2	0	0	3	0	0
Wyoming	0	0	0	0	0	0	0	1	0	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	0	0	0	0	0	0	0	0	0
Total	0	18	0	0	271	2	0	454	6	4

Table 48. Case 1, Number of Affected Bridges on the National Network for Trucks Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Alabama	0	0	0	0	7	0	0	7	0	0
Alaska	0	0	0	0	0	0	0	0	0	0
Arizona	0	0	0	0	1	0	0	1	0	0
Arkansas	0	0	0	0	1	0	0	4	0	0
California	0	0	0	0	0	0	0	1	0	0
Colorado	0	0	0	0	3	0	0	5	0	0
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	0	0	0	0	0	0
DC	0	0	0	0	0	0	0	0	0	0
Florida	0	0	0	0	1	0	0	4	0	0
Georgia	0	0	0	0	1	0	0	1	0	0
Hawaii	0	0	0	0	0	0	0	0	0	0
Idaho	0	0	0	0	0	0	0	0	0	0
Illinois	0	0	0	0	0	0	0	1	0	0
Indiana	0	0	0	0	6	0	0	8	0	0
Iowa	0	0	0	0	2	0	0	2	0	0
Kansas	0	0	0	0	0	0	0	0	0	0
Kentucky	0	0	0	0	4	0	0	7	0	0
Louisiana	0	2	0	0	5	0	0	6	1	0
Maine	0	0	0	0	0	0	0	0	0	0
Maryland	0	0	0	0	3	0	0	3	0	0
Massachusetts	0	0	0	0	1	0	0	1	0	0
Michigan	0	0	0	0	0	0	0	1	0	0
Minnesota	0	0	0	0	2	0	0	2	0	0
Mississippi	0	0	0	0	4	0	0	7	0	0
Missouri	0	0	0	0	4	0	0	4	0	0
Montana	0	0	0	0	3	0	0	4	0	0

Table 48. (Cont'd) Case 1, Number of Affected Bridges on the National Network for Trucks Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Nebraska	0	0	0	0	3	0	0	5	0	0
Nevada	0	0	0	0	0	0	0	0	0	0
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	0	1	0	0	1	0	0	1	0	0
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	0	0	0	1	0	0	2	0	0
North Carolina	0	0	0	0	1	0	0	1	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	0	0	0	0	8	0	0	39	0	0
Oklahoma	0	0	0	0	0	0	0	0	0	0
Oregon	0	0	0	0	5	0	0	5	1	0
Pennsylvania	0	0	0	0	4	0	0	7	0	0
Rhode Island	0	0	0	0	0	0	0	0	0	0
South Carolina	0	0	0	0	0	0	0	0	0	0
South Dakota	0	0	0	0	1	0	0	1	0	0
Tennessee	0	0	0	0	4	0	0	6	0	0
Texas	0	0	0	0	0	0	0	0	0	0
Utah	0	0	0	0	5	0	0	9	0	0
Vermont	0	0	0	0	0	0	0	0	0	0
Virginia	0	0	0	0	0	0	0	1	0	0
Washington	0	1	0	0	18	1	0	22	1	0
West Virginia	0	0	0	0	1	0	0	2	0	0
Wisconsin	0	0	0	0	0	0	0	1	0	0
Wyoming	0	0	0	0	0	0	0	0	0	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	0	0	0	0	0	0	0	0	0
Total	0	4	0	0	100	1	0	171	3	0

Table 49. Case 1, Number of Affected Bridges on the National Network for Trucks Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Alabama	0	0	0	0	15	0	0	27	0	0
Alaska	0	0	0	0	0	0	0	1	0	0
Arizona	0	0	0	0	1	0	0	1	0	0
Arkansas	0	0	0	0	3	0	0	7	0	0
California	0	0	0	0	3	0	0	3	0	0
Colorado	0	1	0	0	6	0	0	10	1	0
Connecticut	0	0	0	0	0	0	0	1	0	0
Delaware	0	0	0	0	0	0	0	2	0	0
DC	0	0	0	0	0	0	0	0	0	0
Florida	0	0	0	0	3	0	0	7	0	0
Georgia	0	2	0	0	4	0	0	4	0	0
Hawaii	0	0	0	0	0	0	0	0	0	0
Idaho	0	0	0	0	2	0	0	2	0	0
Illinois	0	0	0	0	1	0	0	6	0	0
Indiana	0	2	0	0	72	0	0	102	0	0
Iowa	0	1	0	0	2	0	0	8	0	0
Kansas	0	4	0	0	4	0	0	6	0	0
Kentucky	0	0	0	0	7	0	0	9	0	0
Louisiana	0	4	0	0	7	0	0	10	0	0
Maine	0	0	0	0	1	0	0	1	0	0
Maryland	0	0	0	0	2	0	0	4	0	0
Massachusetts	0	1	0	0	2	0	0	3	0	0
Michigan	0	0	0	0	0	0	0	1	0	0
Minnesota	0	0	0	0	2	0	0	2	0	0
Mississippi	0	2	0	0	13	0	0	16	0	0
Missouri	0	2	0	0	11	0	0	14	0	0
Montana	0	1	0	0	8	0	0	10	0	0

Table 49. (Cont'd) Case 1, Number of Affected Bridges on the National Network for Trucks Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Nebraska	0	2	0	0	11	0	0	14	0	0
Nevada	0	0	0	0	1	0	0	1	0	0
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	0	2	0	0	3	0	0	4	0	0
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	0	0	0	1	0	0	3	0	0
North Carolina	0	1	0	0	3	0	0	4	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	0	2	0	0	135	0	0	171	0	0
Oklahoma	0	0	0	0	0	0	0	0	0	0
Oregon	0	5	0	0	11	0	0	14	1	0
Pennsylvania	0	2	0	0	11	0	0	14	0	0
Rhode Island	0	0	0	0	0	0	0	0	0	0
South Carolina	0	0	0	0	0	0	0	0	0	0
South Dakota	0	0	0	0	1	0	0	1	0	0
Tennessee	0	0	0	0	4	0	0	7	0	0
Texas	0	5	0	0	5	0	0	9	0	0
Utah	0	0	0	0	8	0	0	11	0	0
Vermont	0	0	0	0	0	0	0	0	0	0
Virginia	0	1	0	0	1	0	0	2	0	0
Washington	0	5	0	0	36	0	0	45	2	0
West Virginia	0	0	0	0	0	0	0	2	0	0
Wisconsin	0	1	0	0	4	0	0	5	0	0
Wyoming	0	0	0	0	1	0	0	1	0	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	0	0	0	0	0	0	0	0	0
Total	0	46	0	0	405	0	0	565	4	0

Table 50. Case 1, Number of Affected Bridges on the National Network for Trucks Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Alabama	0	0	0	0	11	0	0	18	0	0
Alaska	0	0	0	0	0	0	0	1	0	0
Arizona	0	0	0	0	1	0	0	1	0	0
Arkansas	0	0	0	0	3	0	0	6	0	0
California	0	0	0	0	3	0	0	3	0	0
Colorado	0	0	0	0	4	0	0	7	1	1
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	0	0	0	1	0	0
DC	0	0	0	0	0	0	0	0	0	0
Florida	0	0	0	0	4	0	0	4	0	0
Georgia	0	0	0	0	2	0	0	2	0	0
Hawaii	0	0	0	0	0	0	0	0	0	0
Idaho	0	0	0	0	1	0	0	2	0	0
Illinois	0	0	0	0	0	0	0	1	0	0
Indiana	0	1	0	0	25	0	0	53	0	0
Iowa	0	1	0	0	2	0	0	3	0	0
Kansas	0	0	0	0	0	0	0	2	0	0
Kentucky	0	0	0	0	7	0	0	9	0	0
Louisiana	0	2	0	0	6	0	0	6	1	1
Maine	0	0	0	0	0	0	0	1	0	0
Maryland	0	0	0	0	3	0	0	4	0	0
Massachusetts	0	0	0	0	1	0	0	2	0	0
Michigan	0	0	0	0	0	0	0	1	0	0
Minnesota	0	0	0	0	2	0	0	2	0	0
Mississippi	0	0	0	0	7	0	0	10	0	0
Missouri	0	0	0	0	6	0	0	7	0	0
Montana	0	0	0	0	4	0	0	8	0	0

Table 50. (Cont'd) Case 1, Number of Affected Bridges on the National Network for Trucks Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Nebraska	0	0	0	0	5	0	0	9	0	0
Nevada	0	0	0	0	0	0	0	1	0	0
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	0	1	0	0	2	0	0	3	0	0
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	0	0	0	1	0	0	2	0	0
North Carolina	0	0	0	0	2	0	0	2	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	0	0	0	0	32	0	0	63	0	0
Oklahoma	0	0	0	0	0	0	0	0	0	0
Oregon	0	0	0	0	6	0	0	7	1	1
Pennsylvania	0	1	0	0	8	0	0	11	0	0
Rhode Island	0	0	0	0	0	0	0	0	0	0
South Carolina	0	0	0	0	0	0	0	0	0	0
South Dakota	0	0	0	0	1	0	0	1	0	0
Tennessee	0	0	0	0	4	0	0	7	0	0
Texas	0	0	0	0	0	0	0	0	0	0
Utah	0	0	0	0	8	0	0	11	0	0
Vermont	0	0	0	0	0	0	0	0	0	0
Virginia	0	1	0	0	1	0	0	2	0	0
Washington	0	2	0	0	30	2	0	36	2	0
West Virginia	0	0	0	0	1	0	0	2	0	0
Wisconsin	0	0	0	0	1	0	0	2	0	0
Wyoming	0	0	0	0	0	0	0	1	0	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	0	0	0	0	0	0	0	0	0
Total	0	9	0	0	194	2	0	314	5	3

Table 51. Case 1, Total Number of Affected Bridges on IS, NHS and NN Highways Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Alabama	0	0	0	0	9	0	0	9	0	0
Alaska	0	0	0	0	0	0	0	0	0	0
Arizona	0	0	0	0	1	0	0	1	0	0
Arkansas	0	0	0	0	1	0	0	4	0	0
California	0	0	0	0	0	0	0	2	0	0
Colorado	0	0	0	0	3	0	0	5	0	0
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	2	0	0	2	0	0
DC	0	0	0	0	0	0	0	0	0	0
Florida	0	0	0	0	4	0	0	10	0	0
Georgia	0	0	0	0	2	0	0	2	0	0
Hawaii	0	0	0	0	0	0	0	1	0	0
Idaho	0	0	0	0	0	0	0	0	0	0
Illinois	0	0	0	0	1	0	0	5	0	0
Indiana	0	0	0	0	6	0	0	9	0	0
Iowa	0	0	0	0	2	0	0	2	0	0
Kansas	0	0	0	0	0	0	0	0	0	0
Kentucky	0	0	0	0	4	0	0	9	0	0
Louisiana	0	2	0	0	7	0	0	8	1	0
Maine	0	0	0	0	1	0	0	1	0	0
Maryland	0	0	0	0	3	0	0	4	0	0
Massachusetts	0	0	0	0	3	0	0	3	0	0
Michigan	0	0	0	0	0	0	0	1	0	0
Minnesota	0	0	0	0	3	0	0	4	0	0
Mississippi	0	0	0	0	4	0	0	7	0	0
Missouri	0	0	0	0	5	0	0	5	0	0
Montana	0	0	0	0	3	0	0	4	0	0

Table 51. (Cont'd) Case 1, Total Number of Affected Bridges on IS, NHS and NN Highways Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Nebraska	0	0	0	0	3	0	0	5	0	0
Nevada	0	0	0	0	0	0	0	0	0	0
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	0	1	0	0	3	0	0	3	0	0
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	0	0	0	1	0	0	4	0	0
North Carolina	0	0	0	0	1	0	0	1	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	0	0	0	0	34	0	0	103	0	0
Oklahoma	0	0	0	0	0	0	0	0	0	0
Oregon	0	0	0	0	7	0	0	8	1	0
Pennsylvania	0	0	0	0	11	0	0	18	0	0
Rhode Island	0	0	0	0	0	0	0	0	0	0
South Carolina	0	0	0	0	0	0	0	0	0	0
South Dakota	0	0	0	0	1	0	0	1	0	0
Tennessee	0	0	0	0	4	0	0	6	0	0
Texas	0	0	0	0	0	0	0	1	0	0
Utah	0	0	0	0	6	0	0	11	0	0
Vermont	0	0	0	0	0	0	0	0	0	0
Virginia	0	0	0	0	0	0	0	1	0	0
Washington	0	1	0	0	19	1	0	23	1	0
West Virginia	0	0	0	0	1	0	0	2	0	0
Wisconsin	0	0	0	0	1	0	0	2	0	0
Wyoming	0	0	0	0	0	0	0	0	0	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	0	0	0	0	0	0	0	0	0
Total	0	4	0	0	156	1	0	287	3	0

Table 52. Case 1, Total Number of Affected Bridges on IS, NHS and NN Highways Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Alabama	0	3	0	0	20	0	0	36	0	0
Alaska	0	0	0	0	0	0	0	1	0	0
Arizona	0	0	0	0	1	0	0	1	0	0
Arkansas	0	0	0	0	3	0	0	7	0	0
California	0	1	0	0	7	0	0	8	0	0
Colorado	0	1	0	0	6	0	0	10	1	0
Connecticut	0	0	0	0	0	0	0	1	0	0
Delaware	0	0	0	0	2	0	0	4	0	0
DC	0	0	0	0	1	0	0	1	0	0
Florida	0	9	0	0	15	0	0	25	0	0
Georgia	0	3	0	0	8	0	0	10	0	0
Hawaii	0	3	0	0	4	0	0	9	0	0
Idaho	0	1	0	0	4	0	0	4	0	0
Illinois	0	0	0	0	4	0	0	13	0	0
Indiana	0	2	0	0	79	0	0	111	0	0
Iowa	0	1	0	0	2	0	0	8	0	0
Kansas	0	4	0	0	4	0	0	6	0	0
Kentucky	0	0	0	0	8	0	0	12	0	0
Louisiana	0	4	0	0	9	0	0	13	0	0
Maine	0	0	0	0	2	0	0	2	0	0
Maryland	0	1	0	0	4	0	0	7	0	0
Massachusetts	0	3	0	0	8	0	0	11	0	0
Michigan	0	0	0	0	0	0	0	1	0	0
Minnesota	0	0	0	0	4	0	0	5	0	0
Mississippi	0	2	0	0	13	0	0	16	0	0
Missouri	0	2	0	0	12	0	0	17	0	0
Montana	0	1	0	0	8	0	0	10	0	0

Table 52. (Cont'd) Case 1, Total Number of Affected Bridges on IS, NHS and NN Highways Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Nebraska	0	2	0	0	11	0	0	15	0	0
Nevada	0	0	0	0	1	0	0	1	0	0
New Hampshire	0	1	0	0	1	0	0	1	0	0
New Jersey	0	2	0	0	7	0	0	8	0	0
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	0	0	0	1	0	0	6	0	0
North Carolina	0	1	0	0	4	0	0	5	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	0	2	0	0	294	0	0	379	0	0
Oklahoma	0	2	0	0	3	0	0	4	0	0
Oregon	0	9	0	0	17	0	0	22	1	0
Pennsylvania	0	5	0	0	19	0	0	31	0	0
Rhode Island	0	0	0	0	0	0	0	1	0	0
South Carolina	0	0	0	0	0	0	0	0	0	0
South Dakota	0	0	0	0	1	0	0	1	0	0
Tennessee	0	0	0	0	5	0	0	12	0	0
Texas	0	11	0	0	12	0	0	23	0	0
Utah	0	0	0	0	10	0	0	15	1	0
Vermont	0	0	0	0	0	0	0	0	0	0
Virginia	0	1	0	0	1	0	0	2	0	0
Washington	0	5	0	0	37	0	0	47	2	0
West Virginia	0	0	0	0	1	0	0	4	0	0
Wisconsin	0	1	0	0	5	0	0	6	0	0
Wyoming	0	0	0	0	1	0	0	1	0	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	1	0	0	1	0	0	1	0	0
Total	0	84	0	0	660	0	0	934	5	0

Table 53. Case 1, Total Number of Affected Bridges on IS, NHS and NN Highways Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Alabama	0	0	0	0	13	0	0	23	0	0
Alaska	0	0	0	0	0	0	0	1	0	0
Arizona	0	0	0	0	1	0	0	1	0	0
Arkansas	0	0	0	0	3	0	0	6	0	0
California	0	0	0	0	4	0	0	6	0	0
Colorado	0	0	0	0	4	0	0	7	1	1
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	2	0	0	3	0	0
DC	0	0	0	0	0	0	0	1	0	0
Florida	0	6	0	0	14	0	0	18	0	0
Georgia	0	1	0	0	4	0	0	5	0	0
Hawaii	0	0	0	0	0	0	0	1	0	0
Idaho	0	0	0	0	2	0	0	3	0	0
Illinois	0	0	0	0	2	0	0	7	0	0
Indiana	0	1	0	0	26	0	0	56	0	0
Iowa	0	1	0	0	2	0	0	3	0	0
Kansas	0	0	0	0	0	0	0	2	0	0
Kentucky	0	0	0	0	9	0	0	11	0	0
Louisiana	0	2	0	0	8	0	0	9	1	1
Maine	0	0	0	0	1	0	0	2	0	0
Maryland	0	0	0	0	4	0	0	6	0	0
Massachusetts	0	1	0	0	6	0	0	8	0	0
Michigan	0	0	0	0	0	0	0	1	0	0
Minnesota	0	0	0	0	3	0	0	4	0	0
Mississippi	0	0	0	0	7	0	0	10	0	0
Missouri	0	0	0	0	7	0	0	8	0	0
Montana	0	0	0	0	4	0	0	8	0	0

Table 53. (Cont'd) Case 1, Total Number of Affected Bridges on IS, NHS and NN Highways Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Nebraska	0	0	0	0	5	0	0	10	0	0
Nevada	0	0	0	0	0	0	0	1	0	0
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	0	1	0	0	5	0	0	6	0	0
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	0	0	0	1	0	0	4	0	0
North Carolina	0	0	0	0	2	0	0	2	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	0	1	0	0	79	0	0	150	0	0
Oklahoma	0	0	0	0	0	0	0	0	0	0
Oregon	0	0	0	0	9	0	0	11	1	1
Pennsylvania	0	2	0	0	17	0	0	26	0	0
Rhode Island	0	0	0	0	0	0	0	1	0	0
South Carolina	0	0	0	0	0	0	0	0	0	0
South Dakota	0	0	0	0	1	0	0	1	0	0
Tennessee	0	0	0	0	4	0	0	7	0	0
Texas	0	0	0	0	1	0	0	2	0	0
Utah	0	0	0	0	10	0	0	14	1	1
Vermont	0	0	0	0	0	0	0	0	0	0
Virginia	0	1	0	0	1	0	0	2	0	0
Washington	0	2	0	0	31	2	0	38	2	0
West Virginia	0	0	0	0	1	0	0	3	0	0
Wisconsin	0	0	0	0	2	0	0	3	0	0
Wyoming	0	0	0	0	0	0	0	1	0	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	0	0	0	0	0	0	0	0	0
Total	0	19	0	0	295	2	0	492	6	4

Table 54. Case 1, Total Number of Affected Bridges on IS, NHS and NN Highways for the Entire Country

Highway System	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
IS	0	0	0	0	60	1	0	109	2	0
NHS	0	3	0	0	145	1	0	264	3	0
NN	0	4	0	0	100	1	0	171	3	0
Total for the three systems	0	4	0	0	156	1	0	287	3	0

Table 54 (cont'd). Total Number of Affected Bridges on IS, NHS and NN Highways for the Entire Country

Highway System	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
IS	0	14	0	0	266	0	0	382	5	0
NHS	0	71	0	0	600	0	0	859	5	0
NN	0	46	0	0	405	0	0	565	4	0
Total for the three systems	0	84	0	0	660	0	0	934	5	0

Table 54 (cont'd). Total Number of Affected Bridges on IS, NHS and NN Highways for the Entire Country

Highway System	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
IS	0	3	0	0	120	2	0	205	5	3
NHS	0	18	0	0	270	2	0	453	6	4
NN	0	9	0	0	194	2	0	314	5	3
Total for the three systems	0	19	0	0	295	2	0	492	6	4

Table 55. Case 1, Total Number of Affected Bridges on IS, NHS and NN Highways for Indiana

Highway System	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
IS	0	1	0	0	35	0	0	53	0	0
NHS	0	1	0	0	53	0	0	82	0	0
NN	0	2	0	0	72	0	0	102	0	0
Total for the three systems	0	2	0	0	79	0	0	111	0	0

Table 55 (cont'd). Case 1, Total Number of Affected Bridges on IS, NHS and NN Highways for Indiana

Highway System	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
IS	0	1	0	0	10	0	0	27	0	0
NHS	0	1	0	0	17	0	0	45	0	0
NN	0	1	0	0	25	0	0	53	0	0
Total for the three systems	0	1	0	0	26	0	0	56	0	0

Table 56. Case 1, Total Number of Affected Bridges on IS, NHS and NN Highways for Ohio

Highway System	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
IS	0	2	0	0	134	0	0	169	0	0
NHS	0	2	0	0	291	0	0	372	0	0
NN	0	2	0	0	135	0	0	171	0	0
Total for the three systems	0	2	0	0	294	0	0	379	0	0

Table 56 (cont'd). Case 1, Total Number of Affected Bridges on IS, NHS and NN Highways for Ohio

Highway System	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
IS	0	0	0	0	32	0	0	62	0	0
NHS	0	1	0	0	79	0	0	146	0	0
NN	0	0	0	0	32	0	0	63	0	0
Total for the three systems	0	1	0	0	79	0	0	150	0	0

7.1.6 Number of Bridges That Could Potentially Be Affected Under Different Platoon Configurations and Assuming Case 2

The number of bridges that will potentially be affected by different platoon configurations per State for all platoon configurations was tabulated in the following tables:

- Table 57, Table 58, and Table 59 list the number of potentially affected bridges on the Interstate Highways (IS) per State for the Type 3-3, 3S2 and Type T truck platoons, respectively.
- Table 60, Table 61, and Table 62 list the number of potentially affected bridges on the National Highway System (NHS) per State for the Type 3-3, 3S2 and Type T truck platoons, respectively.
- Table 63, Table 64, and Table 65 list the number of potentially affected bridges on the National Network for Trucks (NN) per State for the Type 3-3, 3S2 and Type T truck platoons, respectively.
- Table 66, Table 67, and Table 68 list the total number of potentially affected bridges on the IS, NHS and NN combined per State for the Type 3-3, 3S2 and Type T truck platoons, respectively.
- Table 69 summarizes the total number of potentially affected bridges, assuming Case 2, for the entire country for the IS, NHS and NN separately and the combined number for the three highway systems. Notice that some routes are included in more than one of the three highway systems considered (SI, NHS and NN). This caused the total number of potentially affected bridges for the three systems combined to be less than the sum of the potentially affected bridges for the individual systems.

7.1.7 Number of Potentially Affected Bridges (Case 2)

The number of potentially affected bridges is significantly larger than those estimated under Case 1. The difference indicated bridges that currently have a rating factor between 1.00 and 1.20 for the operating rating under current rating loads and have a rating factor below 1.00 under the respective platoon configuration.

Under Case 2, the estimated number of potentially affected bridges under platoons with truck spacing of 70 ft. is larger than for Case 1, however, it is significantly smaller than those for platoons composed of the same type of truck having 50 ft. spacing.

Depending on the platoon configuration, steel girder bridges represented about 70 percent to 80 percent of the potentially affected bridges.

Table 57. Case 2, Number of Affected Bridges on the Interstate Highways Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Alabama	0	8	1	1	16	1	1	16	1	1
Alaska	0	0	0	0	0	0	0	0	0	0
Arizona	0	4	1	0	5	1	0	5	1	0
Arkansas	0	4	0	0	6	0	0	6	0	0
California	0	3	1	0	3	2	0	4	2	0
Colorado	0	26	8	0	31	8	0	32	8	0
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	0	0	0	0	0	0
DC	0	2	0	0	2	1	0	2	1	0
Florida	0	1	1	0	4	1	0	7	1	0
Georgia	0	32	10	1	33	12	1	33	12	1
Hawaii	0	1	0	0	1	0	0	1	0	0
Idaho	0	0	0	0	0	0	0	0	0	0
Illinois	0	5	0	0	5	3	0	6	3	0
Indiana	0	1	1	0	5	1	0	5	1	0
Iowa	0	1	0	0	4	1	0	4	1	0
Kansas	0	4	0	0	4	0	0	4	0	0
Kentucky	0	5	1	0	12	1	0	14	1	0
Louisiana	0	0	0	0	1	0	0	1	0	0
Maine	0	0	0	0	0	0	0	0	0	0
Maryland	0	8	1	0	11	3	0	11	3	0
Massachusetts	0	6	1	0	7	2	0	7	2	0
Michigan	0	1	1	0	1	1	0	2	1	0
Minnesota	0	2	0	0	6	1	0	6	1	0
Mississippi	0	2	0	0	2	1	0	2	1	0
Missouri	0	2	2	0	6	2	0	6	2	0
Montana	0	21	19	0	23	20	0	23	20	0

Table 57. (Cont'd) Case 2, Number of Affected Bridges on the Interstate Highways Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Nebraska	0	0	0	0	0	0	0	0	0	0
Nevada	0	7	4	1	7	4	1	7	4	1
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	0	3	0	0	3	2	0	3	2	0
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	1	0	0	2	0	0	3	0	0
North Carolina	0	0	0	0	2	0	0	2	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	0	83	28	4	94	35	4	124	35	4
Oklahoma	0	1	0	0	1	0	0	1	0	0
Oregon	0	2	1	0	5	1	0	5	2	0
Pennsylvania	0	1	0	0	8	2	0	10	2	0
Rhode Island	0	0	0	0	0	0	0	0	0	0
South Carolina	0	1	0	0	1	0	0	1	0	0
South Dakota	0	3	0	0	4	0	0	4	0	0
Tennessee	0	5	0	0	11	1	0	12	1	0
Texas	0	19	13	0	20	14	0	20	14	0
Utah	0	5	2	0	10	4	0	13	4	0
Vermont	0	0	0	0	0	0	0	0	0	0
Virginia	0	2	1	0	4	2	0	5	2	0
Washington	0	5	2	0	13	5	0	14	5	0
West Virginia	0	1	0	0	3	0	0	4	0	0
Wisconsin	0	3	1	0	3	1	0	3	1	0
Wyoming	0	0	0	0	0	0	0	0	0	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	2	0	0	2	0	0	2	0	0
Total	0	283	100	7	381	133	7	430	134	7

Table 58. Case 2, Number of Affected Bridges on the Interstate Highways Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Alabama	0	17	2	1	36	2	1	46	2	1
Alaska	0	0	0	0	0	0	0	1	0	0
Arizona	0	4	1	1	5	1	1	5	1	1
Arkansas	0	4	0	0	7	3	0	9	3	0
California	0	5	0	0	8	2	0	8	2	0
Colorado	0	25	7	0	38	14	0	40	15	0
Connecticut	0	0	0	0	0	0	0	1	0	0
Delaware	0	0	0	0	0	0	0	2	0	0
DC	0	2	0	0	2	1	0	2	1	0
Florida	0	4	1	0	7	1	0	11	1	0
Georgia	0	41	12	3	53	14	3	53	14	3
Hawaii	0	0	0	0	1	0	0	5	0	0
Idaho	0	0	0	0	1	0	0	1	0	0
Illinois	0	6	0	0	10	3	0	15	3	0
Indiana	0	2	0	0	37	0	0	55	0	0
Iowa	0	1	0	0	4	2	0	5	2	0
Kansas	0	4	0	0	4	0	0	5	0	0
Kentucky	0	7	3	0	14	4	0	16	4	0
Louisiana	0	1	0	0	1	0	0	2	0	0
Maine	0	0	0	0	0	0	0	0	0	0
Maryland	0	8	2	0	11	5	0	11	6	0
Massachusetts	0	9	2	0	11	3	0	12	3	0
Michigan	0	1	0	0	1	1	1	2	1	1
Minnesota	0	4	0	0	7	1	0	7	1	0
Mississippi	0	2	0	0	2	1	0	2	1	0
Missouri	0	5	1	0	13	2	0	14	2	0
Montana	0	26	18	0	30	20	0	32	20	0

Table 58. (Cont'd) Case 2, Number of Affected Bridges on the Interstate Highways Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Nebraska	0	1	0	0	1	0	0	2	0	0
Nevada	0	6	4	0	8	5	0	8	5	0
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	0	0	0	0	5	2	1	6	2	1
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	0	0	0	1	0	0	3	0	0
North Carolina	0	2	0	0	3	0	0	3	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	0	110	63	19	247	68	21	282	68	21
Oklahoma	0	3	1	0	3	1	0	3	1	0
Oregon	0	4	0	0	9	0	0	12	1	0
Pennsylvania	0	3	0	0	15	2	0	17	2	0
Rhode Island	0	0	0	0	0	0	0	0	0	0
South Carolina	0	1	0	0	1	0	0	1	0	0
South Dakota	0	3	2	0	5	2	0	5	2	0
Tennessee	0	9	0	0	17	1	0	19	1	0
Texas	0	33	18	3	33	18	3	36	18	3
Utah	0	4	1	0	13	4	0	15	5	0
Vermont	0	0	0	0	0	0	0	0	0	0
Virginia	0	2	1	0	4	2	0	5	2	0
Washington	0	8	2	1	19	4	1	22	6	1
West Virginia	0	0	0	0	2	0	0	4	0	0
Wisconsin	0	9	0	0	10	1	0	10	1	0
Wyoming	0	0	0	0	0	0	0	0	0	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	2	0	0	2	0	0	2	0	0
Total	0	378	141	28	701	190	32	817	196	32

Table 59. Case 2, Number of Affected Bridges on the Interstate Highways Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Alabama	0	8	1	1	23	1	1	29	1	1
Alaska	0	0	0	0	0	0	0	1	0	0
Arizona	0	4	1	0	5	1	0	5	3	0
Arkansas	0	4	0	0	6	1	0	8	1	0
California	0	3	1	0	6	2	0	6	2	0
Colorado	0	24	8	0	31	13	0	33	20	1
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	0	0	0	1	0	0
DC	0	2	0	0	2	1	0	2	1	0
Florida	0	2	1	0	7	1	0	7	1	0
Georgia	0	39	12	3	45	13	3	45	13	3
Hawaii	0	1	0	0	1	0	0	1	0	0
Idaho	0	0	0	0	0	0	0	1	0	0
Illinois	0	3	0	0	3	3	0	4	3	0
Indiana	0	2	1	0	11	1	0	28	1	0
Iowa	0	2	0	0	4	2	0	5	2	0
Kansas	0	4	0	0	4	0	0	5	0	0
Kentucky	0	7	1	0	14	2	0	16	2	0
Louisiana	0	0	0	0	1	0	0	1	0	0
Maine	0	0	0	0	0	0	0	0	0	0
Maryland	0	8	1	0	11	5	0	11	5	0
Massachusetts	0	5	1	0	7	2	0	8	2	0
Michigan	0	1	1	0	1	1	1	2	1	1
Minnesota	0	3	0	0	6	1	0	6	1	0
Mississippi	0	2	0	0	2	1	0	2	1	0
Missouri	0	2	2	0	7	2	0	7	2	0
Montana	0	25	19	5	27	20	6	30	20	6

Table 59. (Cont'd) Case 2, Number of Affected Bridges on the Interstate Highways Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Nebraska	0	0	0	0	0	0	0	1	0	0
Nevada	0	6	4	2	6	5	2	7	5	2
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	0	3	0	0	5	2	2	6	2	2
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	1	0	0	2	0	0	3	0	0
North Carolina	0	2	0	0	3	0	0	3	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	0	87	31	19	120	35	21	150	35	21
Oklahoma	0	1	0	0	1	0	0	1	0	0
Oregon	0	1	1	0	5	1	0	6	2	1
Pennsylvania	0	2	0	0	12	2	0	14	2	0
Rhode Island	0	0	0	0	0	0	0	0	0	0
South Carolina	0	1	0	0	1	0	0	1	0	0
South Dakota	0	3	0	0	4	0	0	4	0	0
Tennessee	0	5	0	0	11	1	0	13	1	0
Texas	0	27	13	0	27	14	0	27	14	0
Utah	0	5	2	0	13	4	0	15	5	1
Vermont	0	0	0	0	0	0	0	0	0	0
Virginia	0	2	1	0	4	2	0	5	2	0
Washington	0	9	2	0	19	6	0	21	6	0
West Virginia	0	1	0	0	3	0	0	4	0	0
Wisconsin	0	3	1	0	3	1	1	3	1	1
Wyoming	0	0	0	0	0	0	0	0	0	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	1	0	0	1	0	0	1	0	0
Total	0	311	105	30	464	146	37	549	157	40

Table 60. Case 2, Number of Affected Bridges on the National Highway System Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Alabama	0	19	3	1	37	9	1	37	9	1
Alaska	0	1	1	0	1	1	0	1	1	0
Arizona	0	6	1	0	9	1	0	9	1	0
Arkansas	0	6	0	0	11	1	0	13	1	0
California	0	15	5	1	16	8	1	18	8	1
Colorado	0	48	12	0	58	16	0	60	17	0
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	2	0	0	2	0	0
DC	0	3	0	0	3	1	0	3	1	0
Florida	0	7	2	0	13	2	0	19	3	0
Georgia	0	123	52	1	133	59	1	133	59	1
Hawaii	0	2	0	0	2	0	0	3	0	0
Idaho	0	2	1	0	3	1	0	3	1	0
Illinois	0	10	3	0	19	8	0	23	8	0
Indiana	0	4	1	0	10	1	0	11	1	0
Iowa	0	21	5	0	28	10	0	28	11	0
Kansas	0	7	0	0	11	3	0	11	3	0
Kentucky	0	9	2	0	22	6	0	26	6	0
Louisiana	0	4	2	0	10	3	0	11	4	0
Maine	0	0	0	0	1	0	0	1	0	0
Maryland	0	17	8	0	24	11	0	25	11	0
Massachusetts	0	13	4	0	19	4	0	19	4	0
Michigan	0	2	1	0	2	1	0	3	1	0
Minnesota	0	6	3	0	13	5	0	14	5	0
Mississippi	0	17	6	0	30	12	0	32	12	0
Missouri	0	17	4	0	29	8	0	29	8	0
Montana	0	53	42	0	55	48	0	55	48	0

Table 60. (Cont'd) Case 2, Number of Affected Bridges on the National Highway System Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Nebraska	0	10	3	0	12	4	0	14	4	0
Nevada	0	15	11	1	15	12	1	15	12	1
New Hampshire	0	2	0	0	2	0	0	2	0	0
New Jersey	0	8	2	0	11	5	0	11	5	0
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	5	0	0	6	1	0	9	1	0
North Carolina	0	1	0	0	3	0	0	3	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	0	185	59	12	226	84	12	291	85	12
Oklahoma	0	2	0	0	6	2	0	6	2	0
Oregon	0	15	3	0	22	3	0	23	4	0
Pennsylvania	0	9	4	0	28	8	0	35	8	0
Rhode Island	0	0	0	0	0	0	0	0	0	0
South Carolina	0	4	0	0	4	1	0	4	1	0
South Dakota	0	4	1	0	6	1	0	6	1	0
Tennessee	0	18	3	0	33	5	0	34	5	0
Texas	0	88	50	0	95	62	0	96	62	0
Utah	0	7	3	0	13	6	0	18	6	0
Vermont	0	1	0	0	1	0	0	1	0	0
Virginia	0	9	5	0	12	6	0	13	6	0
Washington	0	26	12	0	53	21	0	56	21	0
West Virginia	0	5	2	0	7	2	0	8	2	0
Wisconsin	0	6	3	0	7	3	0	8	3	0
Wyoming	0	0	0	0	0	0	0	0	0	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	8	0	0	8	0	0	8	0	0
Total	0	840	319	16	1131	445	16	1250	451	16

Table 61. Case 2, Number of Affected Bridges on the National Highway System Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Alabama	0	37	3	1	73	10	1	88	11	1
Alaska	0	1	1	0	1	1	0	2	1	0
Arizona	0	7	1	1	10	2	1	10	2	1
Arkansas	0	7	0	0	15	5	0	18	5	0
California	0	21	6	1	29	10	1	30	10	1
Colorado	0	56	14	0	75	24	0	79	26	0
Connecticut	0	0	0	0	0	0	0	1	0	0
Delaware	0	0	0	0	2	0	0	4	0	0
DC	0	4	0	0	5	1	0	5	1	0
Florida	0	20	2	0	27	2	0	37	2	0
Georgia	0	153	62	10	192	68	10	194	68	10
Hawaii	0	5	0	0	7	0	0	12	0	0
Idaho	0	3	1	0	7	1	0	7	1	0
Illinois	0	12	2	0	26	9	1	35	10	1
Indiana	0	4	0	0	61	2	0	90	2	0
Iowa	0	23	6	1	32	12	1	38	12	1
Kansas	0	14	1	0	19	4	0	21	4	0
Kentucky	0	11	3	0	25	9	0	29	10	0
Louisiana	0	6	1	0	13	3	0	16	3	0
Maine	0	0	0	0	2	0	0	2	0	0
Maryland	0	18	9	1	25	14	1	28	15	1
Massachusetts	0	21	3	0	28	6	0	31	7	0
Michigan	0	2	0	0	2	1	1	3	1	1
Minnesota	0	8	3	1	15	6	1	16	6	1
Mississippi	0	20	5	0	41	11	0	43	11	0
Missouri	0	53	3	0	77	8	0	82	8	0
Montana	0	79	47	2	85	49	2	87	49	2

Table 61. (Cont'd) Case 2, Number of Affected Bridges on the National Highway System Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Nebraska	0	17	3	1	21	5	1	25	5	1
Nevada	0	15	12	1	17	13	1	17	13	1
New Hampshire	0	3	0	0	3	0	0	3	0	0
New Jersey	0	8	1	0	16	4	1	17	5	1
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	7	0	0	10	1	0	15	1	0
North Carolina	0	3	0	0	6	0	0	7	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	0	246	123	36	544	138	38	625	138	38
Oklahoma	0	8	1	0	13	4	0	14	4	0
Oregon	0	27	3	0	39	4	0	44	5	0
Pennsylvania	0	15	2	0	39	8	0	51	9	0
Rhode Island	0	0	0	0	0	0	0	1	0	0
South Carolina	0	5	0	0	5	3	0	5	3	0
South Dakota	0	7	3	0	9	3	0	9	3	0
Tennessee	0	39	5	0	56	7	0	62	7	0
Texas	0	169	68	4	181	72	4	192	72	4
Utah	0	9	3	0	20	6	0	25	7	0
Vermont	0	1	0	0	1	0	0	1	0	0
Virginia	0	12	6	1	16	8	1	17	8	1
Washington	0	31	13	2	75	22	2	82	24	2
West Virginia	0	4	1	0	7	2	0	10	2	0
Wisconsin	0	13	2	1	17	3	1	18	3	1
Wyoming	0	0	0	0	1	0	0	1	0	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	15	1	0	16	1	0	16	1	0
Total	0	1239	420	64	2006	562	69	2265	575	69

Table 62. Case 2, Number of Affected Bridges on the National Highway System Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Alabama	0	20	4	1	42	10	1	52	11	1
Alaska	0	1	1	0	1	1	0	2	1	0
Arizona	0	6	1	0	9	2	0	9	4	0
Arkansas	0	6	0	0	13	3	0	15	4	0
California	0	15	6	1	20	9	1	22	9	1
Colorado	0	50	12	0	60	22	0	63	29	1
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	2	0	0	3	0	0
DC	0	3	0	0	3	1	0	4	1	0
Florida	0	15	3	1	24	3	1	28	3	1
Georgia	0	145	58	10	163	62	10	164	62	10
Hawaii	0	2	0	0	2	0	0	3	0	0
Idaho	0	2	1	0	5	1	0	6	1	0
Illinois	0	9	3	0	18	9	1	23	9	1
Indiana	0	4	1	0	23	2	0	51	2	0
Iowa	0	21	4	0	26	11	1	27	11	1
Kansas	0	5	0	0	9	3	0	11	3	0
Kentucky	0	11	2	0	26	7	1	28	7	1
Louisiana	0	4	2	0	11	3	1	12	4	2
Maine	0	0	0	0	1	0	0	2	0	0
Maryland	0	17	9	1	25	14	1	27	14	1
Massachusetts	0	15	4	0	23	5	1	25	5	1
Michigan	0	2	1	0	2	1	1	3	1	1
Minnesota	0	7	3	0	13	5	0	14	5	0
Mississippi	0	17	7	0	32	12	1	34	12	1
Missouri	0	18	4	0	36	8	0	37	8	0
Montana	0	76	42	10	78	48	11	82	48	11

Table 62. (Cont'd) Case 2, Number of Affected Bridges on the National Highway System Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Nebraska	0	9	4	0	13	4	0	15	4	0
Nevada	0	14	11	2	14	13	2	15	13	2
New Hampshire	0	2	0	0	2	0	0	2	0	0
New Jersey	0	10	2	0	14	5	2	15	5	2
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	7	0	0	8	1	1	11	1	1
North Carolina	0	3	0	0	5	0	0	5	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	0	193	70	35	275	85	37	342	85	37
Oklahoma	0	1	0	0	5	2	0	5	2	0
Oregon	0	11	4	0	21	4	0	23	5	1
Pennsylvania	0	12	4	0	35	8	1	44	8	1
Rhode Island	0	0	0	0	0	0	0	1	0	0
South Carolina	0	5	0	0	5	1	0	5	1	0
South Dakota	0	5	1	0	6	1	0	6	1	0
Tennessee	0	24	3	0	33	5	0	35	5	0
Texas	0	125	50	2	135	62	3	136	62	3
Utah	0	8	4	0	18	6	0	22	7	1
Vermont	0	1	0	0	1	0	0	1	0	0
Virginia	0	10	6	0	14	7	0	15	7	0
Washington	0	30	12	0	64	23	1	69	23	1
West Virginia	0	5	2	0	7	2	0	9	3	0
Wisconsin	0	6	2	0	8	2	1	9	2	1
Wyoming	0	0	0	0	0	0	0	1	0	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	8	0	0	8	0	0	8	0	0
Total	0	960	343	63	1358	473	80	1541	488	84

Table 63. Case 2, Number of Affected Bridges on the National Network for Trucks Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Alabama	0	11	2	1	23	5	1	23	5	1
Alaska	0	0	0	0	0	0	0	0	0	0
Arizona	0	5	2	0	7	2	0	7	2	0
Arkansas	0	6	0	0	11	1	0	14	1	0
California	0	3	1	0	3	2	0	4	2	0
Colorado	0	44	13	0	55	18	0	57	18	0
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	0	0	0	0	0	0
DC	0	0	0	0	0	0	0	0	0	0
Florida	0	1	0	0	3	0	0	6	0	0
Georgia	0	40	13	1	44	15	1	44	15	1
Hawaii	0	0	0	0	0	0	0	0	0	0
Idaho	0	1	1	0	1	1	0	1	1	0
Illinois	0	5	0	0	5	3	0	6	3	0
Indiana	0	7	3	0	15	3	0	17	3	0
Iowa	0	21	5	0	28	10	0	28	11	0
Kansas	0	14	4	0	18	6	0	18	6	0
Kentucky	0	9	1	0	20	3	0	23	3	0
Louisiana	0	4	2	0	10	3	0	11	4	0
Maine	0	0	0	0	0	0	0	0	0	0
Maryland	0	10	3	0	16	5	0	16	5	0
Massachusetts	0	3	1	0	5	2	0	5	2	0
Michigan	0	1	1	0	1	1	0	2	1	0
Minnesota	0	4	1	0	8	2	0	8	2	0
Mississippi	0	24	8	0	41	14	0	44	14	0
Missouri	0	15	3	0	25	7	0	25	7	0
Montana	0	75	58	0	78	65	0	79	65	0

Table 63. (Cont'd) Case 2, Number of Affected Bridges on the National Network for Trucks Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Nebraska	0	14	2	0	18	4	0	20	4	0
Nevada	0	16	12	1	16	13	1	16	13	1
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	0	3	0	0	3	2	0	3	2	0
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	2	0	0	3	0	0	4	0	0
North Carolina	0	3	0	0	6	0	0	6	0	0
North Dakota	0	0	0	0	1	0	0	1	0	0
Ohio	0	83	28	4	94	35	4	125	35	4
Oklahoma	0	1	0	0	2	0	0	2	0	0
Oregon	0	10	3	0	15	3	0	15	4	0
Pennsylvania	0	2	0	0	9	2	0	12	2	0
Rhode Island	0	0	0	0	0	0	0	0	0	0
South Carolina	0	4	0	0	4	1	0	4	1	0
South Dakota	0	22	5	0	24	6	0	24	6	0
Tennessee	0	11	3	0	19	4	0	21	4	0
Texas	0	28	16	0	30	20	0	30	20	0
Utah	0	8	3	0	13	6	0	17	6	0
Vermont	0	0	0	0	0	0	0	0	0	0
Virginia	0	1	0	0	2	1	0	3	1	0
Washington	0	36	11	0	67	21	0	71	21	0
West Virginia	0	2	0	0	4	0	0	5	0	0
Wisconsin	0	4	2	0	4	2	0	5	2	0
Wyoming	0	2	0	0	2	1	0	2	1	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	4	0	0	4	0	0	4	0	0
Total	0	559	207	7	757	289	7	828	292	7

Table 64. Case 2, Number of Affected Bridges on the National Network for Trucks Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Alabama	0	22	2	1	48	6	1	60	7	1
Alaska	0	0	0	0	0	0	0	1	0	0
Arizona	0	6	2	1	8	2	1	8	2	1
Arkansas	0	7	0	0	15	5	0	19	5	0
California	0	5	0	0	8	2	0	8	2	0
Colorado	0	49	14	0	69	25	0	73	26	0
Connecticut	0	0	0	0	0	0	0	1	0	0
Delaware	0	0	0	0	0	0	0	2	0	0
DC	0	0	0	0	0	0	0	0	0	0
Florida	0	3	0	0	7	0	0	11	0	0
Georgia	0	53	15	5	69	17	5	69	17	5
Hawaii	0	0	0	0	0	0	0	0	0	0
Idaho	0	1	1	0	3	1	0	3	1	0
Illinois	0	6	0	0	10	3	0	15	3	0
Indiana	0	15	2	0	90	4	0	120	4	0
Iowa	0	23	6	1	32	12	1	38	12	1
Kansas	0	31	5	0	37	7	0	39	7	0
Kentucky	0	9	4	0	23	9	0	25	9	0
Louisiana	0	6	1	0	12	4	0	15	4	0
Maine	0	0	0	0	1	0	0	1	0	0
Maryland	0	10	4	1	15	7	1	17	8	1
Massachusetts	0	5	1	0	7	2	0	8	2	0
Michigan	0	1	0	0	1	1	1	2	1	1
Minnesota	0	6	2	1	9	3	1	9	3	1
Mississippi	0	29	7	0	57	13	0	60	13	0
Missouri	0	53	2	0	74	8	0	77	8	0
Montana	0	118	64	4	128	68	4	130	68	4

Table 64. (Cont'd) Case 2, Number of Affected Bridges on the National Network for Trucks Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Nebraska	0	22	5	0	34	6	0	37	6	0
Nevada	0	16	13	1	18	14	1	18	14	1
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	0	2	0	0	5	2	1	6	2	1
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	2	0	0	4	0	0	6	0	0
North Carolina	0	6	0	0	9	0	0	10	0	0
North Dakota	0	0	0	0	1	0	0	1	0	0
Ohio	0	111	63	19	249	68	21	285	68	21
Oklahoma	0	3	1	0	4	1	0	4	1	0
Oregon	0	22	4	0	30	4	0	33	5	0
Pennsylvania	0	4	0	0	16	2	0	19	2	0
Rhode Island	0	0	0	0	0	0	0	0	0	0
South Carolina	0	4	0	0	4	3	0	4	3	0
South Dakota	0	57	17	2	58	17	2	58	17	2
Tennessee	0	21	3	0	33	4	0	36	4	0
Texas	0	50	24	3	51	25	3	55	25	3
Utah	0	8	3	0	17	6	0	20	6	0
Vermont	0	0	0	0	0	0	0	0	0	0
Virginia	0	2	0	0	4	1	0	5	1	0
Washington	0	43	13	1	92	23	1	101	25	1
West Virginia	0	1	0	0	3	0	0	5	0	0
Wisconsin	0	11	0	0	15	1	0	16	1	0
Wyoming	0	1	0	0	3	1	0	3	1	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	9	0	0	9	0	0	9	0	0
Total	0	853	278	40	1382	377	44	1542	383	44

Table 65. Case 2, Number of Affected Bridges on the National Network for Trucks Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Alabama	0	12	2	1	28	6	1	35	7	1
Alaska	0	0	0	0	0	0	0	1	0	0
Arizona	0	5	2	0	7	2	0	7	4	0
Arkansas	0	6	0	0	13	3	0	16	4	0
California	0	3	1	0	6	2	0	6	2	0
Colorado	0	45	13	0	56	23	0	59	30	1
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	0	0	0	1	0	0
DC	0	0	0	0	0	0	0	0	0	0
Florida	0	1	0	0	6	0	0	6	0	0
Georgia	0	50	15	5	59	16	5	59	16	5
Hawaii	0	0	0	0	0	0	0	0	0	0
Idaho	0	1	1	0	2	1	0	3	1	0
Illinois	0	3	0	0	3	3	0	4	3	0
Indiana	0	7	3	0	34	4	0	62	4	0
Iowa	0	21	4	0	26	11	1	27	11	1
Kansas	0	14	4	0	17	6	0	19	6	0
Kentucky	0	10	1	0	23	5	0	25	5	0
Louisiana	0	4	2	0	11	4	1	11	5	2
Maine	0	0	0	0	0	0	0	1	0	0
Maryland	0	10	3	0	16	7	0	17	7	0
Massachusetts	0	2	1	0	4	2	0	5	2	0
Michigan	0	1	1	0	1	1	1	2	1	1
Minnesota	0	5	1	0	8	2	0	8	2	0
Mississippi	0	24	9	0	45	14	1	48	14	1
Missouri	0	17	3	0	33	7	0	34	7	0
Montana	0	114	58	15	118	66	16	122	66	16

Table 65. (Cont'd) Case 2, Number of Affected Bridges on the National Network for Trucks Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Nebraska	0	12	3	0	20	4	0	24	4	0
Nevada	0	15	12	2	15	14	2	16	14	2
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	0	3	0	0	4	2	2	5	2	2
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	3	0	0	4	0	0	5	0	0
North Carolina	0	5	0	0	8	0	0	8	0	0
North Dakota	0	0	0	0	1	0	0	1	0	0
Ohio	0	87	31	19	120	35	21	151	35	21
Oklahoma	0	1	0	0	2	0	0	2	0	0
Oregon	0	7	4	0	13	4	0	14	5	1
Pennsylvania	0	3	0	0	13	2	0	16	2	0
Rhode Island	0	0	0	0	0	0	0	0	0	0
South Carolina	0	4	0	0	4	1	0	4	1	0
South Dakota	0	32	5	0	33	6	0	33	6	0
Tennessee	0	11	3	0	19	4	0	22	4	0
Texas	0	36	16	1	38	20	1	38	20	1
Utah	0	8	4	0	16	6	0	19	6	0
Vermont	0	0	0	0	0	0	0	0	0	0
Virginia	0	2	0	0	3	1	0	4	1	0
Washington	0	39	11	0	79	22	1	85	22	1
West Virginia	0	2	0	0	4	0	0	5	0	0
Wisconsin	0	4	1	0	5	1	1	6	1	1
Wyoming	0	2	0	0	2	1	0	3	1	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	4	0	0	4	0	0	4	0	0
Total	0	635	214	43	923	308	54	1043	321	57

Table 66. Case 2, Total Number of Affected Bridges on IS, NHS and NN Highways Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Alabama	0	19	3	1	37	9	1	37	9	1
Alaska	0	1	1	0	1	1	0	1	1	0
Arizona	0	7	2	0	10	2	0	10	2	0
Arkansas	0	6	0	0	11	1	0	14	1	0
California	0	15	5	1	16	8	1	18	8	1
Colorado	0	51	13	0	62	18	0	64	19	0
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	2	0	0	2	0	0
DC	0	3	0	0	3	1	0	3	1	0
Florida	0	7	2	0	13	2	0	19	3	0
Georgia	0	123	52	1	133	59	1	133	59	1
Hawaii	0	2	0	0	2	0	0	3	0	0
Idaho	0	2	1	0	3	1	0	3	1	0
Illinois	0	10	3	0	19	8	0	23	8	0
Indiana	0	7	3	0	15	3	0	18	3	0
Iowa	0	21	5	0	28	10	0	28	11	0
Kansas	0	15	4	0	20	7	0	20	7	0
Kentucky	0	11	2	0	25	6	0	30	6	0
Louisiana	0	5	3	0	14	4	0	15	5	0
Maine	0	0	0	0	1	0	0	1	0	0
Maryland	0	17	8	0	24	11	0	25	11	0
Massachusetts	0	16	4	0	23	5	0	23	5	0
Michigan	0	2	1	0	2	1	0	3	1	0
Minnesota	0	6	3	0	13	5	0	14	5	0
Mississippi	0	27	9	0	44	15	0	47	15	0
Missouri	0	18	4	0	30	8	0	30	8	0
Montana	0	79	62	0	82	69	0	83	69	0

Table 66. (Cont'd) Case 2, Total Number of Affected Bridges on IS, NHS and NN Highways Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Nebraska	0	17	4	0	21	6	0	23	6	0
Nevada	0	17	12	1	17	14	1	17	14	1
New Hampshire	0	2	0	0	2	0	0	2	0	0
New Jersey	0	8	2	0	11	5	0	11	5	0
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	5	0	0	6	1	0	9	1	0
North Carolina	0	3	0	0	6	0	0	6	0	0
North Dakota	0	0	0	0	1	0	0	1	0	0
Ohio	0	186	59	12	227	84	12	296	85	12
Oklahoma	0	2	0	0	6	2	0	6	2	0
Oregon	0	21	4	0	28	4	0	29	5	0
Pennsylvania	0	9	4	0	28	8	0	35	8	0
Rhode Island	0	0	0	0	0	0	0	0	0	0
South Carolina	0	4	0	0	4	1	0	4	1	0
South Dakota	0	25	5	0	27	6	0	27	6	0
Tennessee	0	19	4	0	34	6	0	36	6	0
Texas	0	103	56	0	111	71	0	112	71	0
Utah	0	8	3	0	14	6	0	19	6	0
Vermont	0	1	0	0	1	0	0	1	0	0
Virginia	0	9	5	0	12	6	0	13	6	0
Washington	0	40	14	0	74	25	0	78	25	0
West Virginia	0	5	2	0	7	2	0	8	2	0
Wisconsin	0	6	3	0	7	3	0	8	3	0
Wyoming	0	2	0	0	2	1	0	2	1	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	8	0	0	8	0	0	8	0	0
Total	0	970	367	16	1287	505	16	1418	511	16

Table 67. Case 2, Total Number of Affected Bridges on IS, NHS and NN Highways Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Alabama	0	38	3	1	74	10	1	90	11	1
Alaska	0	1	1	0	1	1	0	2	1	0
Arizona	0	9	2	1	12	3	1	12	3	1
Arkansas	0	7	0	0	15	5	0	19	5	0
California	0	21	6	1	29	10	1	30	10	1
Colorado	0	58	15	0	79	26	0	83	28	0
Connecticut	0	0	0	0	0	0	0	1	0	0
Delaware	0	0	0	0	2	0	0	4	0	0
DC	0	4	0	0	5	1	0	5	1	0
Florida	0	20	2	0	27	2	0	37	2	0
Georgia	0	153	62	10	192	68	10	194	68	10
Hawaii	0	5	0	0	7	0	0	12	0	0
Idaho	0	3	1	0	7	1	0	7	1	0
Illinois	0	12	2	0	26	9	1	35	10	1
Indiana	0	15	2	0	97	4	0	129	4	0
Iowa	0	23	6	1	32	12	1	38	12	1
Kansas	0	33	5	0	40	8	0	42	8	0
Kentucky	0	12	4	0	29	12	0	33	13	0
Louisiana	0	7	2	0	16	5	0	20	5	0
Maine	0	0	0	0	2	0	0	2	0	0
Maryland	0	18	9	1	25	14	1	28	15	1
Massachusetts	0	25	4	0	33	8	0	36	9	0
Michigan	0	2	0	0	2	1	1	3	1	1
Minnesota	0	8	3	1	15	6	1	16	6	1
Mississippi	0	31	9	0	60	15	0	63	15	0
Missouri	0	61	3	0	86	9	0	91	9	0
Montana	0	123	68	4	133	72	4	135	72	4

Table 67. (Cont'd) Case 2, Total Number of Affected Bridges on IS, NHS and NN Highways Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Nebraska	0	27	7	1	39	9	1	43	9	1
Nevada	0	17	14	1	19	15	1	19	15	1
New Hampshire	0	3	0	0	3	0	0	3	0	0
New Jersey	0	9	1	0	18	4	1	19	5	1
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	8	0	0	11	1	0	16	1	0
North Carolina	0	6	0	0	10	0	0	11	0	0
North Dakota	0	0	0	0	1	0	0	1	0	0
Ohio	0	248	124	36	549	139	38	634	139	38
Oklahoma	0	8	1	0	13	4	0	14	4	0
Oregon	0	38	6	0	51	7	0	56	8	0
Pennsylvania	0	15	2	0	39	8	0	51	9	0
Rhode Island	0	0	0	0	0	0	0	1	0	0
South Carolina	0	5	0	0	5	3	0	5	3	0
South Dakota	0	59	19	2	61	19	2	61	19	2
Tennessee	0	41	6	0	58	8	0	65	8	0
Texas	0	190	79	6	203	84	6	214	84	6
Utah	0	10	3	0	21	6	0	26	7	0
Vermont	0	1	0	0	1	0	0	1	0	0
Virginia	0	12	6	1	16	8	1	17	8	1
Washington	0	49	16	2	101	28	2	111	30	2
West Virginia	0	4	1	0	7	2	0	10	2	0
Wisconsin	0	13	2	1	18	3	1	19	3	1
Wyoming	0	1	0	0	3	1	0	3	1	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	15	1	0	16	1	0	16	1	0
Total	0	1468	497	70	2309	652	75	2583	665	75

Table 68. Case 2, Total Number of Affected Bridges on IS, NHS and NN Highways Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Alabama	0	20	4	1	42	10	1	52	11	1
Alaska	0	1	1	0	1	1	0	2	1	0
Arizona	0	7	2	0	10	3	0	10	5	0
Arkansas	0	6	0	0	13	3	0	16	4	0
California	0	15	6	1	20	9	1	22	9	1
Colorado	0	52	13	0	63	24	0	66	31	1
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	2	0	0	3	0	0
DC	0	3	0	0	3	1	0	4	1	0
Florida	0	15	3	1	24	3	1	28	3	1
Georgia	0	145	58	10	163	62	10	164	62	10
Hawaii	0	2	0	0	2	0	0	3	0	0
Idaho	0	2	1	0	5	1	0	6	1	0
Illinois	0	9	3	0	18	9	1	23	9	1
Indiana	0	7	3	0	35	4	0	65	4	0
Iowa	0	21	4	0	26	11	1	27	11	1
Kansas	0	14	4	0	18	7	0	20	7	0
Kentucky	0	13	2	0	30	8	1	32	8	1
Louisiana	0	5	3	0	15	5	1	16	6	2
Maine	0	0	0	0	1	0	0	2	0	0
Maryland	0	17	9	1	25	14	1	27	14	1
Massachusetts	0	18	4	0	27	6	1	29	6	1
Michigan	0	2	1	0	2	1	1	3	1	1
Minnesota	0	7	3	0	13	5	0	14	5	0
Mississippi	0	27	10	0	48	15	1	51	15	1
Missouri	0	20	4	0	39	8	0	40	8	0
Montana	0	119	62	15	123	70	16	127	70	16

Table 68. (Cont'd) Case 2, Total Number of Affected Bridges on IS, NHS and NN Highways Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Nebraska	0	16	5	0	24	6	0	29	6	0
Nevada	0	16	12	2	16	15	2	17	15	2
New Hampshire	0	2	0	0	2	0	0	2	0	0
New Jersey	0	10	2	0	15	5	2	16	5	2
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	0	8	0	0	9	1	1	12	1	1
North Carolina	0	5	0	0	8	0	0	8	0	0
North Dakota	0	0	0	0	1	0	0	1	0	0
Ohio	0	194	70	35	276	85	37	347	85	37
Oklahoma	0	1	0	0	5	2	0	5	2	0
Oregon	0	15	6	0	25	6	0	27	7	1
Pennsylvania	0	12	4	0	35	8	1	44	8	1
Rhode Island	0	0	0	0	0	0	0	1	0	0
South Carolina	0	5	0	0	5	1	0	5	1	0
South Dakota	0	35	5	0	36	6	0	36	6	0
Tennessee	0	25	4	0	34	6	0	37	6	0
Texas	0	140	56	2	152	71	3	153	71	3
Utah	0	9	4	0	19	6	0	23	7	1
Vermont	0	1	0	0	1	0	0	1	0	0
Virginia	0	10	6	0	14	7	0	15	7	0
Washington	0	44	14	0	86	27	1	93	27	1
West Virginia	0	5	2	0	7	2	0	9	3	0
Wisconsin	0	6	2	0	8	2	1	9	2	1
Wyoming	0	2	0	0	2	1	0	3	1	0
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	0	8	0	0	8	0	0	8	0	0
Total	0	1116	392	68	1556	537	85	1753	552	89

Table 69. Case 2, Total Number of Affected Bridges on IS, NHS and NN Highways for the Entire Country

Highway System	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
IS	0	283	100	7	381	133	7	430	134	7
NHS	0	840	319	16	1131	445	16	1250	451	16
NN	0	559	207	7	757	289	7	828	292	7
Total for the three systems	0	970	367	16	1287	505	16	1418	511	16

Table 69 (cont'd). Case 2, Total Number of Affected Bridges on IS, NHS and NN Highways for the Entire Country

Highway System	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
IS	0	378	141	28	701	190	32	817	196	32
NHS	0	1239	420	64	2006	562	69	2265	575	69
NN	0	853	278	40	1382	377	44	1542	383	44
Total for the three systems	0	1468	497	70	2309	652	75	2583	665	75

Table 69 (cont'd). Case 2, Total Number of Affected Bridges on IS, NHS and NN Highways for the Entire Country

Highway System	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
IS	0	311	105	30	464	146	37	549	157	40
NHS	0	960	343	63	1358	473	80	1541	488	84
NN	0	635	214	43	923	308	54	1043	321	57
Total for the three systems	0	1116	392	68	1556	537	85	1753	552	89

7.1.8 Number of Bridges with Rating Factor Below 1.00 Under Different Platoon Configurations

The number of potentially affected bridges presented in the previous sections represents the number of bridges that currently considered to have adequate load capacity at the operating rating level (rating factor >1.00) under standard rating loads but do not have adequate load capacity to support the platoon configuration being considered. Table 70 through Table 82 show the number of bridges that have a rating factor <1.00 under different platoon configurations per State regardless of their current rating factor under standard rating loads at the operating level (Item 64 in the NBI database may be greater or less than 1.0).

- Table 70, Table 71, and Table 72 list the number of bridges on the Interstate Highways (IS) per State that are estimated to have an operating rating factor <1.00 for the Type 3-3, 3S2 and Type T truck platoons, respectively.

- Table 73, Table 74, and Table 75 list the number of bridges on the National Highway System (NHS) per State that are estimated to have an operating rating factor <1.00 for the Type 3-3, 3S2 and Type T truck platoons, respectively.

- Table 76, Table 77, and Table 78 list the number of bridges on the National Network for Trucks (NN) per State that are estimated to have an operating rating factor <1.00 for the Type 3-3, 3S2 and Type T truck platoons, respectively.

- Table 79, Table 80, and Table 81 list the total number of potentially affected bridges on the IS, NHS and NN combined per State for the Type 3-3, 3S2 and Type T truck platoons, respectively. Notice that some routes are considered part of more than one of the three systems. Therefore, the total number of affected bridges on the three systems combine is less than the sum of number of affected bridges on the three individual systems.

- Table 82 summarizes the total number of bridges that are estimated to have an operating rating factor <1.00 for the entire country for the IS, NHS and NN separately and the combined number for the three highway systems. As explained above, the total number of affected bridges on the three systems combine is less than the sum of number of affected bridges on the three individual systems

The number of bridges with an operating load rating factor less than 1.00 was larger than expected. The number also was significantly larger for some States than the trend set by most other States. Most notably among these States are Georgia, North Carolina, Ohio, Oregon, South Dakota, and, Washington State. The results for these States were carefully reviewed and were confirmed to be correct. As an example, Table 83 shows the numbers for the State of Georgia. It was concluded that:

- The numbers of bridges with an operating rating factors less than 1.00 for different platoons reflects the relatively large number of bridges with an operating rating factor less 1.00 under the current standard rating loads.

- The difference in number of bridges with operating rating factors less than 1.00 for two, three and four truck platoons of the same truck type and spacing is relatively small. This indicates that these bridges are relatively short such that the third and fourth trucks are likely to be outside the bridge when the first two trucks are positioned at the critical location on the bridge.

- Many bridges having operating rating factor less than 1.00 for the design load rating and under the single 3-3, 3S2 and T trucks. The number of bridges with rating factor less than 1.00 under the design load is significantly larger than those under single 3-3, 3S2 or the T trucks (the ratio of the number of bridges is 2.5 for the 3-3 truck, 3.14 for the 3S2 truck and 2.68 for the T truck). Considering that none of the three trucks is lighter in total weight than the design HS 20 truck, the only other factor that can make the design truck more detrimental is the compactness of the design truck. This factor has a more significant effect on shorter spans. This led to the conclusion that most of the bridges comprising the difference between single trucks and the design loads are short spans. Following the same trend, it was concluded that the bridges with rating factor below 1.00 under the 3-3, 3S2 and T single trucks are also likely to be short spans that are most affected by the heavy 32 kips axles of the design HS 20 truck.

One observation made regarding the results for South Dakota is that the number of bridges with operating rating factor less than 1.00 on the IS and the NHS is very small while the number of such bridges on the National Network for Trucks (NN) is extremely large even for the single 3-3, 3S2 and the T trucks. Further review of the NBI database for South Dakota indicated some irregularities as shown in Table 84. As shown in the table, the percentage of South Dakota bridges designated in the NBI as being on the Interstate and National Highway Systems is comparable to the percentage of bridges on these two highway systems for the entire country. However, the percentage of South Dakota bridges designated as being on the National Network for Trucks is 82.5 percent while this percentage is 16.7 for the entire country. This led to concluding that the irregularity in South Dakota results was caused by the unusually high percentage of bridges designated as being on the National Network for Trucks.

Table 70. Number of Bridges with Platoon Rating Factor less than 1.00 on the Interstate Highways Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Alabama	2	10	3	3	18	3	3	18	3	3
Alaska	0	0	0	0	0	0	0	0	0	0
Arizona	0	4	1	0	5	1	0	5	1	0
Arkansas	0	5	1	1	8	1	1	8	1	1
California	8	23	17	11	23	19	12	25	19	14
Colorado	5	34	14	6	39	14	6	40	14	6
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	0	0	0	0	0	0
DC	0	2	0	0	2	1	0	2	1	0
Florida	0	4	3	1	8	3	1	11	4	1
Georgia	14	51	27	17	52	29	17	52	29	17
Hawaii	0	1	0	0	1	0	0	1	0	0
Idaho	1	2	1	1	2	1	1	2	1	1
Illinois	1	7	2	1	7	5	2	8	5	2
Indiana	0	1	1	0	5	1	0	5	1	0
Iowa	1	4	3	2	7	4	3	7	4	3
Kansas	0	4	0	0	4	0	0	4	0	0
Kentucky	5	16	10	7	24	11	8	26	11	8
Louisiana	3	10	8	8	14	11	8	14	11	8
Maine	0	0	0	0	0	0	0	0	0	0
Maryland	0	8	1	0	11	3	0	11	3	0
Massachusetts	7	16	11	10	17	12	10	17	12	10
Michigan	15	16	16	15	16	16	15	17	16	15
Minnesota	0	2	0	0	6	1	0	6	1	0
Mississippi	2	11	3	2	11	5	2	11	5	3
Missouri	1	3	3	1	7	3	1	7	3	1
Montana	0	21	19	0	23	20	0	23	20	0

Table 70. (Cont'd) Number of Bridges with Platoon Rating Factor less than 1.00 on the Interstate Highways Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Nebraska	1	4	3	2	5	4	3	5	4	3
Nevada	0	7	4	1	7	4	1	7	4	1
New Hampshire	4	4	4	4	4	4	4	4	4	4
New Jersey	19	38	28	24	40	32	26	40	32	26
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	1	3	2	2	4	2	2	5	2	2
North Carolina	13	13	13	13	15	13	13	15	13	13
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	25	114	56	29	125	63	29	155	63	29
Oklahoma	0	1	0	0	1	0	0	1	0	0
Oregon	72	119	92	81	126	101	83	129	103	83
Pennsylvania	0	1	0	0	8	2	0	10	2	0
Rhode Island	3	5	5	5	6	5	5	7	5	5
South Carolina	0	1	0	0	1	0	0	1	0	0
South Dakota	0	3	0	0	4	0	0	4	0	0
Tennessee	0	6	0	0	12	1	0	13	1	0
Texas	1	26	14	1	27	15	1	27	15	1
Utah	4	11	8	5	16	10	5	19	10	5
Vermont	1	1	1	1	1	1	1	1	1	1
Virginia	1	4	2	1	6	3	1	7	3	1
Washington	38	65	53	48	77	57	48	78	57	49
West Virginia	0	1	0	0	3	0	0	4	0	0
Wisconsin	3	6	4	3	6	4	3	6	4	3
Wyoming	1	1	1	1	1	1	1	1	1	1
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	5	7	5	5	7	5	5	7	5	5
Total	257	696	439	312	812	491	321	866	494	325

Table 71. Number of Bridges with Platoon Rating Factor less than 1.00 on the Interstate Highways Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Alabama	4	21	6	5	40	6	5	50	6	5
Alaska	0	0	0	0	0	0	0	1	0	0
Arizona	0	4	1	1	5	1	1	5	1	1
Arkansas	0	5	1	0	9	4	1	11	4	1
California	8	34	15	11	39	20	13	39	20	13
Colorado	4	34	14	5	47	21	5	49	22	5
Connecticut	0	0	0	0	0	0	0	1	0	0
Delaware	0	0	0	0	0	0	0	2	0	0
DC	0	2	0	0	2	1	0	2	1	0
Florida	0	8	4	0	12	4	1	17	5	1
Georgia	13	62	30	19	74	32	19	74	32	19
Hawaii	0	0	0	0	1	0	0	5	0	0
Idaho	1	2	2	1	3	2	1	3	2	1
Illinois	0	9	0	0	13	4	1	18	4	1
Indiana	0	2	0	0	37	0	0	55	0	0
Iowa	1	4	2	2	7	5	3	8	5	3
Kansas	0	5	0	0	5	0	0	6	0	0
Kentucky	5	18	13	6	26	15	8	28	15	8
Louisiana	3	11	9	7	14	12	7	15	12	7
Maine	0	0	0	0	0	0	0	0	0	0
Maryland	0	8	2	0	11	5	0	11	6	0
Massachusetts	7	19	12	10	21	13	10	22	13	10
Michigan	15	16	15	15	16	16	16	17	16	16
Minnesota	0	4	0	0	8	1	0	8	1	0
Mississippi	2	16	3	2	17	5	2	17	5	3
Missouri	1	6	2	1	14	3	1	15	3	1
Montana	0	26	18	0	30	20	0	32	20	0

Table 71. (Cont'd) Number of Bridges with Platoon Rating Factor less than 1.00 on the Interstate Highways Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Nebraska	1	5	3	2	6	4	3	7	4	3
Nevada	0	6	4	0	8	5	0	8	5	0
New Hampshire	4	4	4	4	4	4	4	4	4	4
New Jersey	17	36	31	24	44	34	27	45	34	27
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	1	2	2	2	3	2	2	5	2	2
North Carolina	13	15	13	13	16	13	13	16	13	13
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	21	145	93	43	282	98	46	317	98	46
Oklahoma	0	3	1	0	3	1	0	3	1	0
Oregon	67	129	98	83	142	105	85	148	109	85
Pennsylvania	0	3	0	0	15	2	0	17	2	0
Rhode Island	3	6	5	5	7	5	5	7	5	5
South Carolina	0	1	0	0	1	0	0	1	0	0
South Dakota	0	3	2	0	5	2	0	5	2	0
Tennessee	0	11	0	0	19	1	0	21	1	0
Texas	1	40	25	4	40	25	4	43	25	4
Utah	4	10	7	6	19	10	6	21	11	6
Vermont	1	1	1	1	1	1	1	1	1	1
Virginia	0	4	2	1	6	3	1	7	3	1
Washington	35	74	50	43	90	55	44	93	57	45
West Virginia	0	0	0	0	2	0	0	4	0	0
Wisconsin	2	21	3	3	22	4	3	22	4	3
Wyoming	1	1	1	1	1	1	1	1	1	1
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	6	8	6	6	8	6	6	8	6	6
Total	241	844	500	326	1195	571	345	1315	581	347

Table 72. Number of Bridges with Platoon Rating Factor less than 1.00 on the Interstate Highways Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Alabama	4	12	5	5	27	5	5	33	5	5
Alaska	0	0	0	0	0	0	0	1	0	0
Arizona	0	4	1	0	5	1	0	5	3	0
Arkansas	0	5	1	1	8	2	1	10	2	1
California	14	27	22	17	31	24	20	32	24	22
Colorado	6	32	15	7	39	20	7	41	27	8
Connecticut	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	0	0	0	1	0	0
DC	0	2	0	0	2	1	0	2	1	0
Florida	0	5	3	1	11	3	1	12	4	2
Georgia	16	60	31	21	66	32	21	66	32	21
Hawaii	0	1	0	0	1	0	0	1	0	0
Idaho	1	2	1	1	2	1	1	3	1	1
Illinois	2	6	3	2	6	6	3	7	6	3
Indiana	0	2	1	0	11	1	0	28	1	0
Iowa	1	5	3	2	7	5	3	8	5	3
Kansas	1	5	1	1	5	1	1	6	1	1
Kentucky	5	19	10	7	26	12	9	28	12	10
Louisiana	3	10	9	8	14	12	8	14	12	12
Maine	0	0	0	0	0	0	0	0	0	0
Maryland	0	8	1	0	11	5	0	11	5	0
Massachusetts	6	15	10	9	17	11	9	18	11	9
Michigan	15	16	16	15	16	16	16	17	16	16
Minnesota	0	3	0	0	6	1	0	6	1	0
Mississippi	2	11	2	2	11	4	2	11	4	3
Missouri	1	3	3	1	8	3	1	8	3	1
Montana	0	25	19	5	27	20	6	30	20	6

Table 72. (Cont'd) Number of Bridges with Platoon Rating Factor less than 1.00 on the Interstate Highways Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Nebraska	1	4	3	2	5	4	3	6	4	4
Nevada	0	6	4	2	6	5	2	7	5	2
New Hampshire	4	4	4	4	4	4	4	4	4	4
New Jersey	19	40	28	25	42	32	29	43	32	30
New Mexico	0	0	0	0	0	0	0	0	0	0
New York	1	3	2	2	4	2	2	5	2	2
North Carolina	13	15	13	13	16	13	13	16	13	13
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	30	122	64	50	155	68	52	185	68	52
Oklahoma	0	1	0	0	1	0	0	1	0	0
Oregon	76	125	99	86	135	107	87	137	110	105
Pennsylvania	0	2	0	0	12	2	0	14	2	0
Rhode Island	3	6	5	5	7	5	5	7	5	5
South Carolina	0	1	0	0	1	0	0	1	0	0
South Dakota	0	3	0	0	4	0	0	4	0	0
Tennessee	1	7	1	1	13	2	1	15	2	1
Texas	1	34	14	1	34	15	1	34	15	1
Utah	4	11	8	6	19	10	6	21	11	7
Vermont	1	1	1	1	1	1	1	1	1	1
Virginia	1	4	2	1	6	3	1	7	3	1
Washington	38	75	55	48	86	62	48	88	62	56
West Virginia	0	1	0	0	3	0	0	4	0	0
Wisconsin	12	15	13	12	15	13	13	15	13	13
Wyoming	1	1	1	1	1	1	1	1	1	1
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	4	6	5	4	6	5	4	6	5	4
Total	287	765	479	369	933	540	387	1021	554	426

Table 73. Number of Bridges with Platoon Rating Factor less than 1.00 on the National Highway System Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Alabama	4	23	7	5	41	13	5	41	13	5
Alaska	0	1	1	0	1	1	0	1	1	0
Arizona	0	6	1	0	9	1	0	9	1	0
Arkansas	3	13	6	6	19	7	6	21	7	6
California	33	71	51	39	72	55	40	75	55	42
Colorado	13	68	28	15	78	32	15	80	33	15
Connecticut	1	3	3	2	3	3	2	3	3	2
Delaware	0	0	0	0	3	0	0	3	0	0
DC	1	5	1	1	5	2	1	5	2	1
Florida	1	13	6	3	23	8	3	29	10	4
Georgia	101	274	180	114	284	187	114	284	187	114
Hawaii	1	5	3	3	5	3	3	7	3	3
Idaho	3	5	4	3	6	4	3	6	4	3
Illinois	16	36	26	21	45	32	24	49	32	24
Indiana	0	4	1	0	10	1	0	11	1	0
Iowa	6	38	18	10	45	23	11	45	24	11
Kansas	9	17	10	9	21	13	9	21	13	9
Kentucky	9	26	17	13	40	22	14	44	22	14
Louisiana	9	24	19	16	34	25	17	35	26	18
Maine	2	6	5	4	7	6	4	7	6	4
Maryland	5	23	13	5	30	16	5	31	16	5
Massachusetts	28	49	39	35	55	39	35	55	39	35
Michigan	23	25	24	23	25	24	23	26	24	23
Minnesota	1	7	4	1	14	6	1	15	6	1
Mississippi	16	40	23	16	53	30	16	55	30	17
Missouri	6	27	13	8	39	17	8	39	17	8
Montana	4	59	48	6	61	54	6	61	54	6

Table 73. (Cont'd) Number of Bridges with Platoon Rating Factor less than 1.00 on the National Highway System Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Nebraska	7	24	14	9	27	16	10	29	16	10
Nevada	0	15	11	1	15	12	1	15	12	1
New Hampshire	12	14	12	12	14	12	12	14	12	12
New Jersey	28	64	48	38	69	54	41	69	54	41
New Mexico	1	2	2	2	2	2	2	2	2	2
New York	25	32	27	27	33	28	27	36	28	27
North Carolina	65	67	66	66	69	66	66	69	66	66
North Dakota	0	0	0	0	0	0	0	0	0	0
Ohio	59	261	128	77	302	153	77	367	154	77
Oklahoma	1	5	1	1	9	3	1	9	3	1
Oregon	170	298	222	201	317	233	205	321	235	205
Pennsylvania	9	18	13	9	37	17	9	44	17	9
Rhode Island	11	18	17	13	20	18	14	21	18	14
South Carolina	2	7	3	3	7	4	3	7	4	3
South Dakota	2	6	3	2	8	3	2	8	3	2
Tennessee	1	23	4	1	38	6	1	39	6	1
Texas	5	101	56	6	108	68	6	109	68	6
Utah	6	16	12	8	22	15	8	27	15	8
Vermont	2	3	2	2	3	2	2	3	2	2
Virginia	6	17	11	6	21	12	6	22	12	6
Washington	96	158	132	111	191	142	114	194	142	115
West Virginia	2	7	4	2	9	4	2	10	4	2
Wisconsin	5	12	8	5	13	8	5	14	8	5
Wyoming	1	2	1	1	2	1	1	2	1	1
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	21	36	22	22	36	22	22	36	22	22
Total	832	2074	1370	983	2400	1525	1002	2525	1533	1008

Table 74. Number of Bridges with Platoon Rating Factor less than 1.00 on the National Highway System Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Alabama	7	44	10	8	80	17	8	95	18	8
Alaska	0	1	1	0	1	1	0	2	1	0
Arizona	2	9	3	3	12	4	3	12	4	3
Arkansas	6	18	10	8	27	15	9	30	15	9
California	50	113	71	58	124	78	60	125	78	60
Colorado	12	77	32	13	96	42	14	100	44	14
Connecticut	1	3	2	1	3	2	2	4	2	2
Delaware	0	0	0	0	3	0	0	5	0	0
DC	1	6	1	1	7	2	1	7	2	1
Florida	1	27	7	2	38	9	3	49	10	4
Georgia	86	311	206	120	350	212	120	352	212	120
Hawaii	7	15	9	9	18	9	9	23	9	9
Idaho	2	6	3	2	10	3	2	10	3	2
Illinois	15	41	24	21	56	34	26	65	35	26
Indiana	0	4	0	0	61	2	0	90	2	0
Iowa	7	43	22	11	52	29	12	58	29	12
Kansas	10	30	12	10	35	15	10	37	15	10
Kentucky	9	28	19	12	43	26	14	47	27	14
Louisiana	12	28	21	18	40	29	19	43	29	20
Maine	3	6	6	5	10	7	6	11	7	6
Maryland	4	24	15	6	31	20	6	34	21	6
Massachusetts	29	58	39	33	65	42	36	68	43	36
Michigan	23	25	23	23	25	24	24	26	24	24
Minnesota	2	11	6	4	19	9	4	20	9	4
Mississippi	16	48	22	16	70	29	16	72	29	17
Missouri	3	63	12	6	87	17	8	92	17	8
Montana	3	85	53	8	91	55	8	93	55	8

Table 74. (Cont'd) Number of Bridges with Platoon Rating Factor less than 1.00 on the National Highway System Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Nebraska	12	39	20	15	44	23	16	48	23	16
Nevada	0	15	12	1	17	13	1	17	13	1
New Hampshire	12	15	12	12	15	12	12	15	12	12
New Jersey	27	70	53	40	82	60	45	83	61	45
New Mexico	0	2	2	2	2	2	2	2	2	2
New York	24	34	27	27	37	28	27	42	28	27
North Carolina	65	69	66	66	72	66	66	73	66	66
North Dakota	1	1	1	1	1	1	1	1	1	1
Ohio	63	338	203	108	636	218	112	717	218	112
Oklahoma	0	11	4	1	16	7	1	17	7	1
Oregon	162	346	241	204	373	255	211	381	259	211
Pennsylvania	11	27	14	12	51	20	12	63	21	12
Rhode Island	11	22	16	14	25	18	15	26	18	15
South Carolina	2	9	4	4	9	7	4	9	7	4
South Dakota	1	9	5	2	11	5	2	11	5	2
Tennessee	1	46	8	1	63	10	1	69	10	1
Texas	4	183	81	10	195	85	10	206	85	10
Utah	6	18	12	9	29	15	9	34	16	9
Vermont	2	3	2	2	3	2	2	3	2	2
Virginia	5	21	12	7	25	14	7	26	14	7
Washington	89	174	129	104	228	143	109	235	145	110
West Virginia	2	6	3	2	9	4	2	12	4	2
Wisconsin	4	30	9	8	34	10	8	35	10	8
Wyoming	1	2	2	1	3	2	1	3	2	1
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	27	49	32	28	50	32	28	50	32	28
Total	843	2663	1599	1079	3484	1784	1124	3748	1801	1128

Table 75. Number of Bridges with Platoon Rating Factor less than 1.00 on the National Highway System Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Alabama	8	28	12	9	50	18	9	60	19	9
Alaska	0	1	1	0	1	1	0	2	1	0
Arizona	1	7	2	1	10	3	1	10	5	1
Arkansas	6	15	9	9	23	12	9	25	13	9
California	61	98	79	68	105	83	71	108	83	74
Colorado	14	70	29	16	80	39	16	83	46	17
Connecticut	1	3	3	2	3	3	2	3	3	3
Delaware	0	1	0	0	3	0	0	4	0	0
DC	1	5	1	1	5	2	1	6	2	1
Florida	1	22	7	4	34	9	4	39	10	6
Georgia	109	302	194	131	320	198	131	321	198	131
Hawaii	9	13	11	11	14	11	11	15	11	11
Idaho	3	5	4	3	8	4	3	9	4	3
Illinois	20	39	32	26	48	38	30	53	38	30
Indiana	0	4	1	0	23	2	0	51	2	0
Iowa	9	40	20	13	45	27	15	46	27	15
Kansas	15	21	16	15	25	19	15	27	19	15
Kentucky	9	29	17	13	44	23	16	46	23	17
Louisiana	12	27	23	19	38	29	21	39	30	27
Maine	4	8	7	6	10	8	7	12	8	7
Maryland	3	23	14	4	31	19	4	33	19	4
Massachusetts	29	53	40	36	61	41	37	63	41	37
Michigan	23	25	24	23	25	24	24	26	24	24
Minnesota	1	8	4	1	14	6	1	15	6	1
Mississippi	16	40	23	16	55	29	17	57	29	18
Missouri	5	28	14	9	46	18	9	47	18	9
Montana	4	82	48	16	84	54	17	88	54	17

Table 75. (Cont'd) Number of Bridges with Platoon Rating Factor less than 1.00 on the National Highway System Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Nebraska	16	31	24	18	36	25	19	38	25	20
Nevada	0	14	11	2	14	13	2	15	13	2
New Hampshire	12	14	12	12	14	12	12	14	12	12
New Jersey	31	71	52	44	75	58	49	76	58	51
New Mexico	1	2	2	2	2	2	2	2	2	2
New York	25	34	27	27	35	28	28	38	28	28
North Carolina	65	69	66	66	71	66	66	71	66	66
North Dakota	1	1	1	1	1	1	1	1	1	1
Ohio	79	284	159	121	366	174	123	433	174	123
Oklahoma	0	4	1	1	8	3	1	8	3	1
Oregon	191	317	247	224	337	259	227	342	262	250
Pennsylvania	12	24	16	12	47	20	13	56	20	13
Rhode Island	12	21	16	14	23	17	15	24	18	18
South Carolina	2	8	3	3	8	4	3	8	4	3
South Dakota	2	7	3	2	8	3	2	8	3	2
Tennessee	4	31	7	4	40	9	4	42	9	4
Texas	6	139	58	9	149	70	10	150	70	10
Utah	6	17	13	9	27	15	9	31	16	10
Vermont	2	3	2	2	3	2	2	3	2	2
Virginia	6	18	12	6	23	13	6	24	13	6
Washington	96	173	136	111	211	150	115	217	150	125
West Virginia	2	7	4	2	9	4	2	11	5	2
Wisconsin	17	23	19	17	25	19	18	26	19	18
Wyoming	1	2	1	1	2	1	1	3	1	1
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	27	40	29	28	40	29	28	40	29	28
Total	980	2351	1556	1190	2779	1717	1229	2969	1736	1284

Table 76. Number of Bridges with Platoon Rating Factor less than 1.00 on the National Network for Trucks Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Alabama	3	14	5	4	26	8	4	26	8	4
Alaska	0	0	0	0	0	0	0	0	0	0
Arizona	0	5	2	0	7	2	0	7	2	0
Arkansas	2	12	6	6	18	7	6	21	7	6
California	10	26	20	14	26	22	15	28	22	17
Colorado	14	64	29	15	75	34	15	77	34	15
Connecticut	1	1	1	1	1	1	1	1	1	1
Delaware	0	0	0	0	0	0	0	0	0	0
DC	0	0	0	0	0	0	0	0	0	0
Florida	1	6	4	3	10	4	3	13	5	3
Georgia	29	81	49	33	85	51	33	85	51	33
Hawaii	0	1	1	1	1	1	1	1	1	1
Idaho	2	4	4	3	4	4	3	4	4	3
Illinois	1	7	2	1	7	5	2	8	5	2
Indiana	1	9	4	1	17	4	1	19	4	1
Iowa	6	38	18	10	45	23	11	45	24	11
Kansas	11	33	17	11	37	19	11	37	19	11
Kentucky	5	23	13	10	35	16	11	38	16	11
Louisiana	12	27	22	19	38	28	20	39	29	21
Maine	0	1	1	1	1	1	1	1	1	1
Maryland	0	10	3	0	16	5	0	16	5	0
Massachusetts	4	12	10	9	14	11	9	14	11	9
Michigan	22	23	23	22	23	23	22	24	23	22
Minnesota	0	4	1	0	8	2	0	8	2	0
Mississippi	30	63	40	31	80	47	31	83	47	32
Missouri	4	24	10	6	34	14	6	34	14	6
Montana	9	86	69	11	89	76	11	90	76	11

Table 76. (Cont'd) Number of Bridges with Platoon Rating Factor less than 1.00 on the National Network for Trucks Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Nebraska	13	39	22	17	44	25	18	46	25	18
Nevada	0	16	12	1	16	13	1	16	13	1
New Hampshire	7	7	7	7	7	7	7	7	7	7
New Jersey	3	14	8	6	16	11	8	16	11	8
New Mexico	1	1	1	1	1	1	1	1	1	1
New York	2	5	3	3	6	3	3	7	3	3
North Carolina	111	115	112	112	118	112	112	118	112	112
North Dakota	0	0	0	0	1	0	0	1	0	0
Ohio	25	114	56	29	125	63	29	156	63	29
Oklahoma	0	1	0	0	2	0	0	2	0	0
Oregon	143	238	184	167	252	194	171	253	196	171
Pennsylvania	1	3	1	1	10	3	1	13	3	1
Rhode Island	3	5	5	5	6	5	5	7	5	5
South Carolina	0	4	0	0	4	1	0	4	1	0
South Dakota	622	652	628	622	654	629	622	654	629	622
Tennessee	1	15	5	2	23	6	2	25	6	2
Texas	3	37	19	3	39	23	3	39	23	3
Utah	5	16	11	7	21	14	7	25	14	7
Vermont	1	1	1	1	1	1	1	1	1	1
Virginia	2	4	2	2	5	3	2	6	3	2
Washington	78	157	116	96	195	127	99	199	127	100
West Virginia	0	2	0	0	4	0	0	5	0	0
Wisconsin	3	8	5	3	8	5	3	9	5	3
Wyoming	1	4	1	1	4	2	1	4	2	1
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	9	18	9	9	18	9	9	18	9	9
Total	1201	2050	1562	1307	2277	1665	1322	2351	1670	1327

Table 77. Number of Bridges with Platoon Rating Factor less than 1.00 on the National Network for Trucks Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Alabama	5	27	7	6	53	11	6	65	12	6
Alaska	0	0	0	0	0	0	0	1	0	0
Arizona	0	6	2	1	8	2	1	8	2	1
Arkansas	4	16	9	5	25	14	6	29	14	6
California	9	43	17	13	48	22	15	48	22	15
Colorado	14	71	33	15	91	44	15	95	45	15
Connecticut	1	1	1	1	1	1	1	2	1	1
Delaware	0	0	0	0	0	0	0	2	0	0
DC	0	0	0	0	0	0	0	0	0	0
Florida	1	10	5	2	15	5	3	19	6	3
Georgia	26	97	55	38	113	57	38	113	57	38
Hawaii	0	1	1	1	1	1	1	1	1	1
Idaho	2	4	4	3	6	4	3	6	4	3
Illinois	0	9	0	0	13	4	1	18	4	1
Indiana	1	17	3	1	92	5	1	122	5	1
Iowa	7	43	22	11	52	29	12	58	29	12
Kansas	12	57	23	13	63	25	13	65	25	13
Kentucky	5	23	17	9	38	23	11	40	23	11
Louisiana	20	37	29	26	49	38	27	52	38	28
Maine	0	1	1	1	2	1	1	3	1	1
Maryland	0	10	4	1	15	7	1	17	8	1
Massachusetts	4	14	10	7	16	11	9	17	11	9
Michigan	22	23	22	22	23	23	23	24	23	23
Minnesota	0	6	2	1	10	3	1	10	3	1
Mississippi	30	73	40	31	102	47	31	105	47	32
Missouri	4	62	10	6	83	16	6	86	16	6
Montana	8	131	76	16	142	80	16	144	80	16

Table 77. (Cont'd) Number of Bridges with Platoon Rating Factor less than 1.00 on the National Network for Trucks Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Nebraska	28	64	41	32	77	43	33	80	43	33
Nevada	0	16	13	1	18	14	1	18	14	1
New Hampshire	8	8	8	8	8	8	8	8	8	8
New Jersey	4	15	9	6	21	13	9	22	13	9
New Mexico	0	1	1	1	1	1	1	1	1	1
New York	2	5	3	3	7	3	3	9	3	3
North Carolina	113	120	114	114	123	114	114	124	114	114
North Dakota	0	0	0	0	1	0	0	1	0	0
Ohio	21	146	93	43	284	98	46	320	98	46
Oklahoma	0	3	1	0	4	1	0	4	1	0
Oregon	140	281	210	174	299	219	180	304	224	180
Pennsylvania	1	5	1	1	17	3	1	20	3	1
Rhode Island	3	7	5	5	8	5	5	8	5	5
South Carolina	0	4	0	0	4	3	0	4	3	0
South Dakota	745	816	767	749	817	767	749	817	767	749
Tennessee	1	26	6	2	38	7	2	41	7	2
Texas	2	59	33	6	60	34	6	64	34	6
Utah	5	16	11	8	25	14	8	28	14	8
Vermont	1	1	1	1	1	1	1	1	1	1
Virginia	1	5	2	2	7	3	2	8	3	2
Washington	75	180	118	91	238	133	97	247	135	98
West Virginia	0	1	0	0	3	0	0	5	0	0
Wisconsin	3	25	5	4	29	6	4	30	6	4
Wyoming	1	3	2	1	5	3	1	5	3	1
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	11	25	14	11	25	14	11	25	14	11
Total	1340	2614	1851	1493	3181	1980	1524	3344	1991	1527

Table 78. Number of Bridges with Platoon Rating Factor less than 1.00 on the National Network for Trucks Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Alabama	6	18	8	7	34	12	7	41	13	7
Alaska	0	0	0	0	0	0	0	1	0	0
Arizona	0	5	2	0	7	2	0	7	4	0
Arkansas	3	13	7	7	21	10	7	24	11	7
California	19	34	28	23	38	30	26	39	30	28
Colorado	16	66	31	17	77	41	17	80	48	18
Connecticut	1	1	1	1	1	1	1	1	1	1
Delaware	0	0	0	0	0	0	0	1	0	0
DC	0	0	0	0	0	0	0	0	0	0
Florida	1	7	4	3	13	4	3	13	5	4
Georgia	31	93	53	39	102	54	39	102	54	39
Hawaii	0	1	1	1	1	1	1	1	1	1
Idaho	2	4	4	3	5	4	3	6	4	3
Illinois	2	6	3	2	6	6	3	7	6	3
Indiana	2	9	5	2	36	6	2	64	6	2
Iowa	9	40	20	13	45	27	15	46	27	15
Kansas	19	41	25	20	44	27	20	46	27	20
Kentucky	5	25	13	10	38	18	12	40	18	13
Louisiana	21	36	32	28	48	39	30	48	40	36
Maine	0	1	1	1	1	1	1	3	1	1
Maryland	0	10	3	0	16	7	0	17	7	0
Massachusetts	4	11	10	9	13	11	9	14	11	9
Michigan	22	23	23	22	23	23	23	24	23	23
Minnesota	0	5	1	0	8	2	0	8	2	0
Mississippi	30	63	40	31	84	46	32	87	46	33
Missouri	6	27	12	8	43	16	8	44	16	8
Montana	15	131	75	32	135	83	33	139	83	33

Table 78. (Cont'd) Number of Bridges with Platoon Rating Factor less than 1.00 on the National Network for Trucks Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Nebraska	26	47	36	31	56	38	32	60	38	33
Nevada	0	15	12	2	15	14	2	16	14	2
New Hampshire	8	8	8	8	8	8	8	8	8	8
New Jersey	4	17	9	7	18	13	11	19	13	12
New Mexico	1	1	1	1	1	1	1	1	1	1
New York	2	6	3	3	7	3	3	8	3	3
North Carolina	113	119	114	114	122	114	114	122	114	114
North Dakota	0	0	0	0	1	0	0	1	0	0
Ohio	30	122	64	50	155	68	52	186	68	52
Oklahoma	0	1	0	0	2	0	0	2	0	0
Oregon	158	253	206	183	266	215	186	268	218	206
Pennsylvania	1	4	1	1	14	3	1	17	3	1
Rhode Island	3	6	5	5	7	5	5	7	5	5
South Carolina	0	4	0	0	4	1	0	4	1	0
South Dakota	798	835	804	798	836	805	798	836	805	798
Tennessee	2	16	6	3	24	7	3	27	7	3
Texas	3	45	19	4	47	23	4	47	23	4
Utah	6	17	13	9	25	15	9	28	15	9
Vermont	1	1	1	1	1	1	1	1	1	1
Virginia	2	5	2	2	6	3	2	7	3	2
Washington	81	172	122	99	216	136	103	222	136	113
West Virginia	0	2	0	0	4	0	0	5	0	0
Wisconsin	13	18	14	13	19	14	14	20	14	14
Wyoming	1	4	1	1	4	2	1	5	2	1
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	11	19	12	11	19	12	11	19	12	11
Total	1478	2407	1855	1625	2716	1972	1653	2839	1988	1697

Table 79. Total Number of Bridges with Platoon Rating Factor less than 1.00 on IS, NHS and NN Highways Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Alabama	5	24	8	6	42	14	6	42	14	6
Alaska	0	1	1	0	1	1	0	1	1	0
Arizona	0	7	2	0	10	2	0	10	2	0
Arkansas	3	15	8	8	21	9	8	24	9	8
California	33	72	52	40	73	56	41	76	56	43
Colorado	17	75	33	19	86	38	19	88	39	19
Connecticut	1	3	3	2	3	3	2	3	3	2
Delaware	0	0	0	0	3	0	0	3	0	0
DC	1	5	1	1	5	2	1	5	2	1
Florida	1	13	6	3	23	8	3	29	10	4
Georgia	102	275	181	115	285	188	115	285	188	115
Hawaii	1	5	3	3	5	3	3	7	3	3
Idaho	4	8	6	5	9	6	5	9	6	5
Illinois	16	36	26	21	45	32	24	49	32	24
Indiana	1	9	4	1	17	4	1	20	4	1
Iowa	6	38	18	10	45	23	11	45	24	11
Kansas	11	34	17	11	39	20	11	39	20	11
Kentucky	9	30	19	15	45	24	16	50	24	16
Louisiana	15	33	28	24	47	34	25	48	35	26
Maine	2	6	5	4	7	6	4	7	6	4
Maryland	5	23	13	5	30	16	5	31	16	5
Massachusetts	28	52	39	35	59	40	35	59	40	35
Michigan	25	27	26	25	27	26	25	28	26	25
Minnesota	1	7	4	1	14	6	1	15	6	1
Mississippi	38	74	49	39	91	56	39	94	56	40
Missouri	7	31	15	9	43	19	9	43	19	9
Montana	9	90	73	11	93	80	11	94	80	11

Table 79. (Cont'd) Total Number of Bridges with Platoon Rating Factor less than 1.00 on IS, NHS and NN Highways Per State. Type 3-3 Truck Platoons

State/District	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
Nebraska	13	42	24	17	47	27	18	49	27	18
Nevada	0	17	12	1	17	14	1	17	14	1
New Hampshire	13	15	13	13	15	13	13	15	13	13
New Jersey	28	64	48	38	69	54	41	69	54	41
New Mexico	1	2	2	2	2	2	2	2	2	2
New York	25	32	27	27	33	28	27	36	28	27
North Carolina	118	122	119	119	125	119	119	125	119	119
North Dakota	0	0	0	0	1	0	0	1	0	0
Ohio	59	262	128	77	303	153	77	372	154	77
Oklahoma	1	5	1	1	9	3	1	9	3	1
Oregon	190	338	247	225	358	261	229	363	263	229
Pennsylvania	10	19	14	10	38	18	10	45	18	10
Rhode Island	11	18	17	13	20	18	14	21	18	14
South Carolina	2	7	3	3	7	4	3	7	4	3
South Dakota	622	655	628	622	657	629	622	657	629	622
Tennessee	2	26	7	3	41	9	3	43	9	3
Texas	7	118	64	8	126	79	8	127	79	8
Utah	8	20	15	11	26	18	11	31	18	11
Vermont	2	3	2	2	3	2	2	3	2	2
Virginia	6	17	11	6	21	12	6	22	12	6
Washington	103	187	145	121	228	157	124	232	157	125
West Virginia	2	7	4	2	9	4	2	10	4	2
Wisconsin	5	13	8	5	14	8	5	15	8	5
Wyoming	1	4	1	1	4	2	1	4	2	1
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	22	37	23	23	37	23	23	37	23	23
Total	1592	3023	2203	1763	3378	2373	1782	3516	2381	1788

Table 80. Total Number of Bridges with Platoon Rating Factor less than 1.00 on IS, NHS and NN Highways Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Alabama	8	46	11	9	82	18	9	98	19	9
Alaska	0	1	1	0	1	1	0	2	1	0
Arizona	2	11	4	3	14	5	3	14	5	3
Arkansas	6	20	12	8	29	17	9	33	17	9
California	50	114	72	59	125	79	61	126	79	61
Colorado	17	84	38	18	105	49	19	109	51	19
Connecticut	1	3	2	1	3	2	2	4	2	2
Delaware	0	0	0	0	3	0	0	5	0	0
DC	1	6	1	1	7	2	1	7	2	1
Florida	1	27	7	2	38	9	3	49	10	4
Georgia	87	312	207	121	351	213	121	353	213	121
Hawaii	7	15	9	9	18	9	9	23	9	9
Idaho	3	9	6	4	13	6	4	13	6	4
Illinois	15	41	24	21	56	34	26	65	35	26
Indiana	1	17	3	1	99	5	1	131	5	1
Iowa	7	43	22	11	52	29	12	58	29	12
Kansas	12	60	23	13	67	26	13	69	26	13
Kentucky	9	31	22	14	49	31	16	53	32	16
Louisiana	24	44	36	32	59	45	33	63	45	34
Maine	3	6	6	5	10	7	6	11	7	6
Maryland	4	24	15	6	31	20	6	34	21	6
Massachusetts	29	62	40	33	70	44	36	73	45	36
Michigan	25	27	25	25	27	26	26	28	26	26
Minnesota	2	11	6	4	19	9	4	20	9	4
Mississippi	38	83	50	39	113	57	39	116	57	40
Missouri	4	74	15	7	99	21	9	104	21	9
Montana	8	136	80	16	147	84	16	149	84	16

Table 80. (Cont'd) Total Number of Bridges with Platoon Rating Factor less than 1.00 on IS, NHS and NN Highways Per State. Type 3S2 Truck Platoons

State/District	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
Nebraska	28	70	43	33	83	46	34	87	46	34
Nevada	0	17	14	1	19	15	1	19	15	1
New Hampshire	14	17	14	14	17	14	14	17	14	14
New Jersey	27	71	53	40	84	60	45	85	61	45
New Mexico	0	2	2	2	2	2	2	2	2	2
New York	24	35	27	27	38	28	27	43	28	27
North Carolina	120	127	121	121	131	121	121	132	121	121
North Dakota	1	1	1	1	2	1	1	2	1	1
Ohio	63	340	204	108	641	219	112	726	219	112
Oklahoma	0	11	4	1	16	7	1	17	7	1
Oregon	185	399	278	232	428	293	239	437	298	239
Pennsylvania	12	28	15	13	52	21	13	64	22	13
Rhode Island	11	22	16	14	25	18	15	26	18	15
South Carolina	2	9	4	4	9	7	4	9	7	4
South Dakota	745	818	769	749	820	769	749	820	769	749
Tennessee	2	50	11	3	67	13	3	74	13	3
Texas	6	206	94	14	219	99	14	230	99	14
Utah	8	22	15	12	33	18	12	38	19	12
Vermont	2	3	2	2	3	2	2	3	2	2
Virginia	5	21	12	7	25	14	7	26	14	7
Washington	98	212	147	116	275	164	122	285	166	123
West Virginia	2	6	3	2	9	4	2	12	4	2
Wisconsin	4	31	10	8	36	11	8	37	11	8
Wyoming	1	3	2	1	5	3	1	5	3	1
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	28	50	33	29	51	33	29	51	33	29
Total	1752	3878	2631	2016	4777	2830	2062	5057	2848	2066

Table 81. Total Number of Bridges with Platoon Rating Factor less than 1.00 on IS, NHS and NN Highways Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Alabama	9	29	13	10	51	19	10	61	20	10
Alaska	0	1	1	0	1	1	0	2	1	0
Arizona	1	8	3	1	11	4	1	11	6	1
Arkansas	6	17	11	11	25	14	11	28	15	11
California	61	99	80	69	106	84	72	109	84	75
Colorado	19	77	35	21	88	46	21	91	53	22
Connecticut	1	3	3	2	3	3	2	3	3	3
Delaware	0	1	0	0	3	0	0	4	0	0
DC	1	5	1	1	5	2	1	6	2	1
Florida	1	22	7	4	34	9	4	39	10	6
Georgia	110	303	195	132	321	199	132	322	199	132
Hawaii	9	13	11	11	14	11	11	15	11	11
Idaho	4	8	6	5	11	6	5	12	6	5
Illinois	20	39	32	26	48	38	30	53	38	30
Indiana	2	9	5	2	37	6	2	67	6	2
Iowa	9	40	20	13	45	27	15	46	27	15
Kansas	20	42	26	21	46	29	21	48	29	21
Kentucky	9	33	19	15	50	26	18	52	26	19
Louisiana	25	43	39	34	58	46	36	59	47	42
Maine	4	8	7	6	10	8	7	12	8	7
Maryland	3	23	14	4	31	19	4	33	19	4
Massachusetts	29	56	40	36	65	42	37	67	42	37
Michigan	25	27	26	25	27	26	26	28	26	26
Minnesota	1	8	4	1	14	6	1	15	6	1
Mississippi	38	74	49	39	95	55	40	98	55	41
Missouri	7	34	17	11	53	21	11	54	21	11
Montana	15	136	79	32	140	87	33	144	87	33

Table 81. (Cont'd) Total Number of Bridges with Platoon Rating Factor less than 1.00 on IS, NHS and NN Highways Per State. Type T Truck Platoons

State/District	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
Nebraska	27	52	39	32	61	41	33	66	41	34
Nevada	0	16	12	2	16	15	2	17	15	2
New Hampshire	14	16	14	14	16	14	14	16	14	14
New Jersey	31	71	52	44	76	58	49	77	58	51
New Mexico	1	2	2	2	2	2	2	2	2	2
New York	25	35	27	27	36	28	28	39	28	28
North Carolina	120	126	121	121	129	121	121	129	121	121
North Dakota	1	1	1	1	2	1	1	2	1	1
Ohio	79	285	159	121	367	174	123	438	174	123
Oklahoma	0	4	1	1	8	3	1	8	3	1
Oregon	213	359	277	250	380	290	253	385	293	279
Pennsylvania	13	25	17	13	48	21	14	57	21	14
Rhode Island	12	21	16	14	23	17	15	24	18	18
South Carolina	2	8	3	3	8	4	3	8	4	3
South Dakota	798	838	804	798	839	805	798	839	805	798
Tennessee	5	34	10	6	43	12	6	46	12	6
Texas	8	156	66	11	168	81	12	169	81	12
Utah	9	22	17	13	32	19	13	36	20	14
Vermont	2	3	2	2	3	2	2	3	2	2
Virginia	6	18	12	6	23	13	6	24	13	6
Washington	106	204	152	124	251	168	128	259	168	138
West Virginia	2	7	4	2	9	4	2	11	5	2
Wisconsin	17	24	19	17	26	19	18	27	19	18
Wyoming	1	4	1	1	4	2	1	5	2	1
Guam	0	0	0	0	0	0	0	0	0	0
Puerto Rico	28	41	30	29	41	30	29	41	30	29
Total	1949	3530	2601	2186	4003	2778	2225	4207	2797	2283

Table 82. Total Number of Bridges with Platoon Rating Factor less than 1.00 on IS, NHS and NN Highways for the Entire Country

Highway System	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
IS	257	696	439	312	812	491	321	866	494	325
NHS	832	2074	1370	983	2400	1525	1002	2525	1533	1008
NN	1201	2050	1562	1307	2277	1665	1322	2351	1670	1327
Total for the three systems	1592	3023	2203	1763	3378	2373	1782	3516	2381	1788

Table 82 (cont'd). Total Number of Bridges with Platoon Rating Factor less than 1.00 on IS, NHS and NN Highways for the Entire Country

Highway System	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
IS	241	844	500	326	1195	571	345	1315	581	347
NHS	843	2663	1599	1079	3484	1784	1124	3748	1801	1128
NN	1340	2614	1851	1493	3181	1980	1524	3344	1991	1527
Total for the three systems	1752	3878	2631	2016	4777	2830	2062	5057	2848	2066

Table 82 (cont'd). Total Number of Bridges with Platoon Rating Factor less than 1.00 on IS, NHS and NN Highways for the Entire Country

Highway System	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
IS	287	765	479	369	933	540	387	1021	554	426
NHS	980	2351	1556	1190	2779	1717	1229	2969	1736	1284
NN	1478	2407	1855	1625	2716	1972	1653	2839	1988	1697
Total for the three systems	1949	3530	2601	2186	4003	2778	2225	4207	2797	2283

Table 83. Number of Bridges with Operating Rating <1.00 on IS, NHS and NN Highways for Georgia

Highway System	AASHTO Rating Loads	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
IS	58	14	51	27	17	52	29	17	52	29	17
NHS	263	101	274	180	114	284	187	114	284	187	114
NN	100	29	81	49	33	85	51	33	85	51	33
Total for the three systems	265	102	275	181	115	285	188	115	285	188	115

Table 83 (cont'd). Number of Bridges with Operating Rating <1.00 on IS, NHS and NN Highways for Georgia

Highway System	AASHTO Rating Loads	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
IS	58	13	62	30	19	74	32	19	74	32	19
NHS	263	86	311	206	120	350	212	120	352	212	120
NN	100	26	97	55	38	113	57	38	113	57	38
Total for the three systems	265	87	312	207	121	351	213	121	353	213	121

Table 83 (cont'd). Number of Bridges with Operating Rating <1.00 on IS, NHS and NN Highways for Georgia

Highway System	AASHTO Rating Loads	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
IS	58	16	60	31	21	66	32	21	66	32	21
NHS	263	109	302	194	131	320	198	131	321	198	131
NN	100	31	93	53	39	102	54	39	102	54	39
Total for the three systems	265	110	303	195	132	321	199	132	322	199	132

Table 84. Analysis of Number of Bridges in South Dakota

Highway System	South Dakota		Entire Country	
	Number of Bridges	Percentage of Total	Number of Bridges	Percentage of Total
IS	476	9.1	57,640	9.4
NHS	969	18.6	145,190	23.6
NN	4301	82.5	102,707	16.7
Total number of bridges in the State	5216	-	615,531	-

8.0 DETAILED ANALYSIS OF A LIMITED BRIDGE SAMPLE

Two levels of analysis were utilized. Bridges included in a limited sample of bridges of different types were load rated for the specifications rating loads and for the truck platoons. The results of load rating these bridges were reviewed in detail. The bridges in the limited sample were selected from the bridges included in the NCHRP 12-78 database of bridges. In addition, all the bridges in this database were rated for the specifications rating loads and for the truck platoons and the results were screened to look for trends and to confirm the results of screening the NBI database.

The NCHRP 12-78database contains approximately 1,500 bridges of different types that represented a cross-section of the U.S. bridge inventory. Most AASHTOWare BrR input files for these bridges included two lines of girders, interior and exterior. The analysis excluded bridges of types that were not. included in this study, mainly culverts.

8.1 SAMPLING FOR THE LIMITED BRIDGE SAMPLE

In accordance with the project scope of work, the types of bridges that included in the limited sample are:

- Concrete girder bridges (NBI Item 43A=1,2,5,6 AND Item 43B=2,4)
- Steel girder bridges (NBI Item 43A=3,4 AND Item 43B=2)
- Concrete slab bridges (NBI Item 43A=1,2,5,6 AND Item 43B=1)

The original process for selecting the limited sample of bridges was as follows:

- Using the bridge database developed in the NCHRP 12-78 project, identify the bridges in the database in each of the three above categories.
- For each bridge type, use the random number function in Excel to randomly order the bridges in each category.
- After selecting the number of bridges required, run AASHTO BrR to determine the load effects and operating rating factors for the design loads (HL-93 and HS 20) and the platoons.
- Compare the results from the bridge sample with the results from Tier 1 analysis. Differences in the results will be reconciled and, if needed, the analysis of the NBI database conducted earlier would be refined and/or updated.

After completing this process, it was noticed that the bridges at the top of the randomly reordered bridges for each bridge type did not necessarily cover different bridge characteristics of span length, girder spacing, age, composite/noncomposite, etc. To provide a more representative sample, the process was revised by inserting the following two steps after the second bullet above:

- Select bridges starting from the top. If a bridge had characteristics similar to a bridge that was already selected, ignore that bridge.

- Continue until the selected bridges for each type covered different characteristics.

Table 85 shows the number of bridges in the limited sample.

Table 85. Number of Bridges in the Limited Sample of Different Bridge Types

Bridge Type	Number of Bridges
RC/Slab Bridges (Simple Spans)	3
RC/Slab Bridges (Continuous Spans)	4
RC T Beam	2
P/S Box Beams	11
P/S I Beams (Simple Spans)	9
P/S I Beams (Continuous Spans)	17
Steel Plate Girders (Simple Spans)	10
Steel Plate Girders (Continuous Spans)	20
Steel Rolled Shape (Simple Spans)	8
Steel Rolled Shape (Continuous Spans)	13
Total	97

The characteristics of the selected bridges are summarized in Appendix D.

8.2 VALIDATION OF THE ANALYSIS OF THE NBI DATABASE USING THE RATING OF THE LIMITED BRIDGE SAMPLE

The selected bridges were rated using AASHTOWare BrR computer program. They were rated using both the LFR and LRFR rating methods using the AASHTO rating loads and the 14 platoon configurations considered in this task of the project. The computer output was sorted using software written specifically for this project, which allowed extraction of the top five most controlling rating factors for flexure and for shear under each load scenario. This process produced large amounts of data that were reviewed to identify any common trends. The following observations were made:

- For continuous spans where the length of the platoon is longer than about one-and-a-half times the span length, it is likely that the platoon negative moment at interior supports controls the flexural rating. For single trucks and platoons that are short relative to the span length, the positive moment at the middle of the span is more likely to produce a more controlling rating than the negative moment. For design loads, either the positive moment or negative moment controlled the rating depending on the flexural reserve capacity at different locations.

- The location of the controlling rating factor for shear continued to be at the supports as expected.

- Although the current design loads operating rating factor for relatively few bridges was less than 1.00 for LRFR and 1.20 for LFR, the majority of bridges currently have a controlling operating rating factor higher than 1.7.

- No bridge satisfied the two criteria described above for impact by a truck platoon (i.e., no bridge exhibited):

    - An existing operating rating factor greater than 1.00 for HL-93 with LRFR or 1.20 for HS 20 with LFR and less than 1.00 for the platoons considered to be routine commercial traffic (legal loads) for Case 1, or;

    - An operating rating factor greater than 1.00 for HL-93 with LRFR or HS 20 with LFR and less than 1.00 for the platoons considered to be routine commercial traffic (legal loads) for Case 2.

To validate the conclusions of the parametric study of the load effects of the platoons, the maximum and minimum ratio between the platoon operating rating factors and the HS 20 with LFR and HL-93 with LRFR operating rating factors were determined for the sample bridge set for each platoon configuration. Table 86 presents a summary for these ratios.

The ratios between the load effects from the AASHTO rating loads and the platoon load effects are within the ranges observed in the parametric study.

Table 86. Comparison of AASHTO LFR and LRFR Critical Operating Rating Factors to those for the Platoons Considered for the 97 Sample Bridges

(a) Maximum Ratios

Comparison Criteria	3S2-1-00	3S2-2-30	3S2-2-50	3S2-3-30	3S2-3-50	3S2-4-30	3S2-4-50
Platoon Operating Rating Factor / HS 20 Operating Rating Factor	2.35	1.64	1.75	1.51	1.51	1.51	1.51
Platoon Operating Rating Factor / HL-93 Operating Rating Factor	3.27	2.29	2.45	1.81	1.85	1.81	1.85

Comparison Criteria	T-1-00	T-2-30	T-2-50	T-3-30	T-3-50	T-4-30	T-4-50
Platoon Operating Rating / HS 20 Operating Rating Factor	2.23	1.60	1.52	1.42	1.42	1.42	1.42
Platoon Operating Rating / HL-93 Operating Rating Factor	3.10	2.24	2.12	1.82	1.82	1.82	1.82

(b) Minimum Ratios

Comparison Criteria	3S2-1-00	3S2-2-30	3S2-2-50	3S2-3-30	3S2-3-50	3S2-4-30	3S2-4-50
Platoon Operating Rating Factor / HS 20 Operating Rating Factor	1.00	0.80	0.83	0.75	0.83	0.75	0.83
Platoon Operating Rating Factor / HL-93 Operating Rating Factor	1.33	1.11	1.19	0.97	1.13	0.88	0.98

Comparison Criteria	T-1-00	T-2-30	T-2-50	T-3-30	T-3-50	T-4-30	T-4-50
Platoon Operating Rating / HS 20 Operating Rating Factor	0.99	0.77	0.84	0.77	0.84	0.77	0.84
Platoon Operating Rating / HL-93 Operating Rating Factor	1.31	1.08	1.16	0.99	1.06	0.84	0.96

9.0 RESULTS OF RATING OF ALL BRIDGES IN THE NCHRP 12-78 DATABASE

All bridges in the NCHRP 12-78 database of various bridge types included in the analysis were load rated using the LFR and the LRFR methods for the specifications rating loads and the 14 platoon configurations considered in this task of the project. Only the critical operating rating factors were included, and typically, an interior girder and an exterior girder were analyzed for each girder bridge. For bridges where interior girders were not all identical, more than one interior girder was analyzed. For slab bridges, one run was performed for each bridge under each load. The number of runs for each bridge type is listed in Table 87.

Table 87. Number of Rated Bridges of Different Types from the NCHRP 12-78 Database

Bridge Type	Number of Runs
RC/Slab Bridges (Simple Spans)	98
RC/Slab Bridges (Continuous Spans)	105
RC T Beam	292
P/S Box Beams	357
P/S I Beams (Simple Spans)	453
P/S I Beams (Continuous Spans)	235
Steel Plate Girders (Simple Spans)	150
Steel Plate Girders (Continuous Spans)	226
Steel Rolled Shape (Simple Spans)	837
Steel Rolled Shape (Continuous Spans)	188
Total	2941

9.1 VALIDATION OF THE ANALYSIS OF THE NBI DATABASE USING THE RATING OF THE NCHRP 12-78 DATABASE

The bridges were rated using the AASHTOWare BrR computer program. Similar to the limited sample bridges, these bridges were rated using both the LFR and LRFR rating methods using the design load rating loads and the 14 platoon configurations considered. Each run included the analysis for the HS 20, HL-93, and the 14 platoon configurations considered with each platoon analysis made for LFR and LRFR. This resulted in 30 different loadings (HS 20, HL-93, 14 platoons for LFR, 14 platoons for LRFR) and 88,230 different girder outputs (2941 x 30). The controlling operating rating factor for each load was extracted and tabulated. For any truck platoon, the ratio between the rating factor for the design load operating rating to the rating factor for the truck platoon depended on the bridge configuration and the method of rating (LFR or LRFR). In some cases, the platoons produced a more critical rating factor than the design the design load, and in other cases they produced a more favorable rating factor. The section and the type of check (moment, shear, …) that resulted in the critical rating factor for the same girder was not necessarily the same for different loadings:

- Using Case 1 in determining whether a girder is impacted by a certain platoon configuration (i.e., a bridge is considered to be impacted by a certain platoon configuration when the operating rating factor is less than 1.00 for the platoon rating while it exceeded 1.00 for the HL-93 using the LRFR HL-93or 1.20 for the HS 20 using the LFR): No bridges satisfied the criteria when the LRFR rating method was used. In other words, no girder produced a rating factor below 1.0 for any of the platoons when this girder produced a rating factor >1.00 for the HL-93 loading using the LRFR rating method.

- Only two girders satisfied the above criteria and would be impacted by some of the platoons when the rating was performed using the LFR rating method:
    - One bridge was a 140 ft. long simple span plate girder that produced a rating factor of 1.24 for the LFR (HS 20) load and a rating factor of 0.998 for the 3S2-2-30, 3S2-3-30, 3S2-4-30, and
    - The other bridge was a four-span steel plate girder (76.73-201.71-201.71-76.73 ft. spans) that produced a rating factor of 1.28 for the LFR (HS 20) load and a rating factor of 0.96 for the 3S2-4-30 and T-4-30.

The analysis was repeated using Case 2 (see Section 5.2) for determining the potentially impacted girders. In this case, a bridge would be impacted by a certain platoon configuration when the operating rating factor is less than 1.00 for the platoon rating while it exceeded 1.00 for either of the LRFR operating rating using the HL-93 or the LFR operating rating using the HS 20 loading. Considering Case 2:

- No girders satisfied Case 2 criterion when the ratings were performed using the LRFR method.

- For ratings performed using the LFR method, the number of potentially impacted girders increased but was still small relative to the total number of girders analyzed. The number and types of bridges satisfying Case 2 criterion are shown in Table 88. All bridges satisfying the stated criterion are steel plate girders and rolled shapes.

The number of bridges discussed under the two cases represents the girders that have adequate capacity under the design loads at the operating level but will not have sufficient load capacity to support the respective platoon loadings. It does not include the girders that are currently deficient under the design loads and will continue to have a rating factor <1.0 under the platoon loadings. Table 89 and Table 90 show the number of bridges in the database with an operating rating factor less than 1.00 under different platoon configurations for both LFR and LRFR ratings, respectively. The number of girders shown in these tables includes all girders with an operating rating factor below 1.00 for platoon operating ratings regardless of the value of the operating rating factor under the design loads, i.e., whether or not the value of the operating rating factor for the HS 20 or HL-93 loadings is above 1.0.

The number of bridges with a platoon operating loading factor <1.00 is relatively high as shown in Table 89 and Table 90. Several factors contributed to this higher percentage:

- The bridges in the database are a cross-section of all bridges on the highway system. It includes many bridges on smaller highways that are more likely to have a lower rating.

It also includes many older bridges that were designed for lower loads than the HS 20 or HL-93 loadings.

- The percentage of bridges with rating factor <1.00 is higher for bridge types that are likely to be older bridges (e.g., reinforced concrete T-beams).

- The number of bridges with a rating factor <1.00 is higher for the HS 20 and HL-93 loadings than for the platoon loadings. This reflects the relatively short spans of many bridges in the database where the compactness of the design truck makes it more critical than the 3S2 or the T trucks. The additional trucks in the platoon are likely to be positioned outside the bridge or at locations of the girder where they produce small load effects, or, for continuous spans, may reduce the load effects, at the critical sections.

Table 88. Number of Girders with Current LFR Operating Rating Factor >1.00 for HS 20 Rating and Operating Rating Factor < 1.00 for Platoon Loading

Bridge Type	Total Number of Bridges	3S2-1-00	3S2-2-30	3S2-2-50	3S2-3-30	3S2-3-50	3S2-4-30	3S2-4-50
RC/Slab Bridges (Simple Spans)	98	0	0	0	0	0	0	0
RC/Slab Bridges (Continuous Spans)	105	0	0	0	0	0	0	0
RC T Beam	292	0	0	0	0	0	0	0
P/S Box Beams	357	0	0	0	0	0	0	0
P/S I Beams (Simple Spans)	453	0	0	0	0	0	0	0
P/S I Beams (Continuous Spans)	235	0	0	0	0	0	0	0
Steel Plate Girders (Simple Spans)	150	0	1	0	1	0	1	0
Steel Plate Girders (Continuous Spans)	226	0	1	0	6	2	8	2
Steel Rolled Shape (Simple Spans)	837	0	0	0	0	0	0	0
Steel Rolled Shape (Continuous Spans)	188	0	6	1	6	0	6	0
Total	2941	0	8	1	13	2	15	2

Table 88 (cont'd). Number of Girders with Current LFR Operating Rating Factor >1.00 for HS 20 Rating and Operating Rating Factor < 1.00 for Platoon Loading

Bridge Type	Total Number of Bridges	T-1-00	T-2-30	T-2-50	T-3-30	T-3-50	T-4-30	T-4-50
RC/Slab Bridges (Simple Spans)	98	0	0	0	0	0	0	0
RC/Slab Bridges (Continuous Spans)	105	0	0	0	0	0	0	0
RC T Beam	292	0	0	0	0	0	0	0
P/S Box Beams	357	0	0	0	0	0	0	0
P/S I Beams (Simple Spans)	453	0	0	0	0	0	0	0
P/S I Beams (Continuous Spans)	235	0	0	0	0	0	0	0
Steel Plate Girders (Simple Spans)	150	0	0	0	0	0	0	0
Steel Plate Girders (Continuous Spans)	226	0	1	0	5	2	6	2
Steel Rolled Shape (Simple Spans)	837	0	0	0	0	0	0	0
Steel Rolled Shape (Continuous Spans)	188	0	1	1	1	0	1	0
Total	2941	0	2	1	6	2	7	2

Table 89. Number of Girders with Loading Factor < 1.00 for LFR Operating Rating

Bridge Type	Total Number of Bridges	HS 20 Loading	3S2-1-00	3S2-2-30	3S2-2-50	3S2-3-30	3S2-3-50	3S2-4-30	3S2-4-50
RC/Slab Bridges (Simple Spans)	98	3	1	1	1	1	1	1	1
RC/Slab Bridges (Continuous Spans)	105	15	11	11	11	11	11	11	11
RC T Beam	292	58	25	25	25	25	25	25	25
P/S Box Beams	357	53	47	48	47	48	47	48	47
P/S I Beams (Simple Spans)	453	2	1	1	1	1	1	1	1
P/S I Beams (Continuous Spans)	235	3	3	3	3	3	3	3	3
Steel Plate Girders (Simple Spans)	150	1	1	2	1	2	1	2	1
Steel Plate Girders (Continuous Spans)	226	12	10	13	12	18	14	20	14
Steel Rolled Shape (Simple Spans)	837	0	0	0	0	0	0	0	0
Steel Rolled Shape (Continuous Spans)	188	14	3	18	10	17	8	17	8
Total	2941	161	102	122	111	126	111	128	111

Table 89 (cont'd). Number of Girders with Loading Factor < 1.00 for LFR Operating Rating

Bridge Type	Total Number of Bridges	HS 20 Loading	T-1-00	T-2-30	T-2-50	T-3-30	T-3-50	T-4-30	T-4-50
RC/Slab Bridges (Simple Spans)	98	3	1	1	1	1	1	1	1
RC/Slab Bridges (Continuous Spans)	105	15	11	11	11	11	11	11	11
RC T Beam	292	58	25	25	25	25	25	25	25
P/S Box Beams	357	53	47	48	47	48	47	48	47
P/S I Beams (Simple Spans)	453	2	1	1	1	1	1	1	1
P/S I Beams (Continuous Spans)	235	3	3	3	3	3	3	3	3
Steel Plate Girders (Simple Spans)	150	1	1	1	1	1	1	1	1
Steel Plate Girders (Continuous Spans)	226	12	10	13	12	17	14	18	14
Steel Rolled Shape (Simple Spans)	837	0	0	0	0	0	0	0	0
Steel Rolled Shape (Continuous Spans)	188	14	1	12	6	11	4	11	4
Total	2941	161	100	115	107	118	107	119	107

Table 90. Number of Girders with Loading Factor <1.00 for LRFR Operating Rating

Bridge Type	Total Number of Bridges	HL-93 Loading	3S2-1-00	3S2-2-30	3S2-2-50	3S2-3-30	3S2-3-50	3S2-4-30	3S2-4-50
RC/Slab Bridges (Simple Spans)	98	21	1	1	1	1	1	1	1
RC/Slab Bridges (Continuous Spans)	105	46	10	10	10	10	10	10	10
RC T Beam	292	115	16	16	16	16	16	16	16
P/S Box Beams	357	25	1	1	1	1	1	1	1
P/S I Beams (Simple Spans)	453	7	1	1	1	1	1	1	1
P/S I Beams (Continuous Spans)	235	7	0	1	0	1	0	1	0
Steel Plate Girders (Simple Spans)	150	0	0	2	1	2	1	2	1
Steel Plate Girders (Continuous Spans)	226	44	13	21	22	24	23	25	23
Steel Rolled Shape (Simple Spans)	837	0	0	0	0	0	0	0	0
Steel Rolled Shape (Continuous Spans)	188	45	11	26	23	26	23	26	23
Total	2941	310	53	79	75	82	76	83	76

Table 90 (cont'd). Number of Girders with Loading Factor <1.00 for LRFR Operating Rating

Bridge Type	Total Number of Bridges	HL-93 Loading	T-1-00	T-2-30	T-2-50	T-3-30	T-3-50	T-4-30	T-4-50
RC/Slab Bridges (Simple Spans)	98	21	2	2	2	2	2	2	2
RC/Slab Bridges (Continuous Spans)	105	46	11	11	11	11	11	11	11
RC T Beam	292	115	19	19	19	19	19	19	19
P/S Box Beams	357	25	1	1	1	1	1	1	1
P/S I Beams (Simple Spans)	453	7	1	1	1	1	1	1	1
P/S I Beams (Continuous Spans)	235	7	0	0	0	0	0	0	0
Steel Plate Girders (Simple Spans)	150	0	0	2	0	2	0	2	0
Steel Plate Girders (Continuous Spans)	226	44	13	23	22	24	22	24	22
Steel Rolled Shape (Simple Spans)	837	0	0	0	0	0	0	0	0
Steel Rolled Shape (Continuous Spans)	188	45	9	23	18	23	18	23	18
Total	2941	310	56	82	74	83	74	83	74

10.0 CONCLUSION ON RATING OF ACTUAL BRIDGES

The criteria used to identify potential impacts of a certain platoon configuration are based on determining that the bridge has an operating rating factor >1.0 under current rating loads (Item 64 in the NBI database) but will have a rating factor under the platoon. The parametric analysis in Chapter 7 predicted that a very small percentage of bridges will be impacted by the truck platoon configurations investigated, particularly when the NBI data from two States (data that did not follow the same trends as data from other States) are not included. The rating of the bridges in the NCHRP 12-78 database confirmed that conclusion, albeit showing a smaller percentage. Considering the limitations of the NBI database, such as the possibility of errors in the database, only listing the length of the largest span in a bridge, not listing the location of the section that controlled the rating or the type of the controlling load effect, missing data, etc., the conclusions of the parametric study of the load effects and the analysis of the NBI database are reasonable and supported by the results of rating of bridges in the NCHRP 12-78 database.

11.0 TRUCK PLATOON LOADS ON BRIDGES

In addition to live load gravity effects on bridges, live loads produce, or are subject to, three additional load components:

- Braking force
- Centrifugal force
- Wind load on live loads

Although the gravity effects of live loads are considered in the design of all components of the bridge structure, these other load components mainly affect the design of the bearings, substructures, and foundations.

The HS 20 design loads in AASHTO Standard Specifications (2002) first appeared in 1944. These design loads were meant to encompass the loads bridges were subjected to at the time of its development. It was another step in the continuous development of the design load that started earlier in the 20th century at the time motor vehicle development was advancing and was resulting in heavier loads on bridges.

The HL-93 design load was developed to produce load effects encompassing the load effects from heavy loads that were grandfathered at the time of the development of AASHTO LRFD. The load factors were developed to produce a reliability index of 3.5 at the strength limit state: the probability of the applied live load effects exceeding the factored resistance, assumed to be equal to the factored design live load effects, for a component over the 75 years design life of the bridge is one in 5,000.

11.1 PLATOON GRAVITY LOAD EFFECTS ON BRIDGE SUPERSTRUCTURES

The effect of gravity loads from truck platoons has been discussed in earlier sections of this report. The dynamic effects are discussed in this section.

Amplification in the load effects from live loads due to dynamic effects is termed “the dynamic load allowance” in AASHTO LRFD (2017) and as “Impact” in AASHTO Standard Specifications (2002). For this report, however, both are referred to as “impact.”

The impact is defined as:

$$\frac{load\ \ effects\ from\ live\ load\ \text{ including } dynamic\ \ effects - static\,load\ \ effects\ from\ live\ load}{static\,load\ \ effects\ from\ live\ load}$$

The value of the impact depends on many factors including the roughness of the riding surface; approach condition; vehicle speed; vehicle weight; bouncing cargo; the fundamental natural frequency of the structure; the stiffness of the vehicle suspension system; and surface defects such as bumps, potholes, and vertical misalignment of deck joints. The value of the impact in AASHTO LRFD (2017) is meant to generally produce conservative designs because it is higher than field-measured values.

Field testing indicated that the correlation between the span length and the impact is weak (McLean and Marsh, 1998). Interestingly, the impact empirical formula in AASHTO Standard Specifications (2002) has the span length as the only variable.

Field measurements in past research indicated that the impact decreased as the truck weight increased. The magnitude of the impact measured in different research projects varied:

- The impact did not exceed 15 percent for a single truck, weighing approximately 65 kips (Kim and Nowak, 1997).
- Impact below 10 percent was measured for very heavy trucks (Nassif and Nowak, 1996).
- Impact below 20 percent was measured for the heaviest loaded girders in a 5-girder bridge (Nassif and Nowak, 1995).

Numerical simulations concluded that the impact for two trucks side-by-side is lower than for a single truck (Hwang and Nowak, 1991). The interaction between trucks in the same lane also resulted in reducing the impact as a percentage of the weight of the two trucks compared to a single truck; other researchers reached a similar conclusion (McLean and Marsh, 1998). Furthermore, increasing the number of axles in a vehicle leads to a reduction in the impact (McLean and Marsh, 1998).

Some published measurements show impact values larger than those in the specifications. However, in these cases, the vehicles were cranes and special vehicles (Wekezer et al., 2008), not representative of common commercial trucks.

Table 91 shows the impact for the AASHTO Standard Specifications (2002) and the equivalent impact for AASHTO LRFD (2017). The latter is determined by dividing the portion of each load effect due to the dynamic effect (33 percent of the larger of the design truck or design tandem load effect) by the total load effect (sum of load effect from the uniform load and the larger of that from the design truck or design tandem). As the table shows, the equivalent dynamic load allowance for AASHTO LRFD (2017) decreases as the span length increases. The AASHTO LRFD (2017) equivalent impact follows the same trend as that for AASHTO Standard Specifications (2002). In addition, the difference in the impact from both specifications is small and insignificant.

Impact field measurements indicated an impact of no more than 20 percent for a single truck, and the presence of more than one truck in a platoon will result in further reducing impact. Therefore, using a lower impact than currently specified in the design specification is a rational approach to account for the difference in the behavior of the bridge under a single truck and under a truck platoon.

Table 91. Comparison of AASHTO LRFD (2017) Equivalent Impact to AASHTO Standard Specifications (2002) Impact Factor

Table 91a. Simple Spans Equivalent Dynamic Load Allowance

Load Effect	Span Length								
	30 ft	50 ft	70 ft	100 ft	130 ft	160 ft	200 ft	250 ft	300 ft
HL-93 midspan pos. moment	1.27	1.25	1.24	1.22	1.2	1.18	1.17	1.15	1.14
HL-93 end shear	1.28	1.26	1.24	1.22	1.2	1.19	1.17	1.15	1.14

Table 91b. Two-Span Continuous Equivalent Dynamic Load Allowance

Load Effect	Span Length								
	30 ft	50 ft	70 ft	100 ft	130 ft	160 ft	200 ft	250 ft	300 ft
HL-93 midspan 1 pos. moment	1.27	1.25	1.24	1.22	1.2	1.19	1.17	1.16	1.14
HL-93 support neg. moment	1.24	1.2	1.23	1.21	1.19	1.17	1.15	1.13	1.12
HL-93 end shear	1.28	1.26	1.25	1.23	1.21	1.2	1.18	1.16	1.15
HL-93 int. support Shear	1.27	1.25	1.23	1.21	1.19	1.17	1.15	1.14	1.12

Table 91c. Two-Span Continuous Equivalent Dynamic Load Allowance

Load Effect	Span Length								
	30 ft	50 ft	70 ft	100 ft	130 ft	160 ft	200 ft	250 ft	300 ft
HL-93 midspan 1 pos. moment	1.27	1.25	1.24	1.22	1.2	1.18	1.17	1.15	1.14
HL-93 midspan 2 pos. moment	1.27	1.25	1.24	1.22	1.21	1.19	1.18	1.16	1.15
HL-93 support neg. moment	1.24	1.21	1.22	1.21	1.19	1.17	1.15	1.14	1.12
HL-93 end shear	1.28	1.26	1.25	1.23	1.21	1.2	1.18	1.16	1.15
HL-93 left of support 2 Shear	1.27	1.25	1.23	1.21	1.19	1.17	1.16	1.14	1.12
HL-93 right of support 2 Shear	1.27	1.25	1.23	1.21	1.19	1.18	1.16	1.14	1.13

Table 91d. Average Equivalent Dynamic Load Allowance from Tables a, b and c

Load Effect	Span Length								
	30 ft	50 ft	70 ft	100 ft	130 ft	160 ft	200 ft	250 ft	300 ft
(Average total LRFD load effects including specifications dynamic load allowance applied to the truck or tandem) / (the total LRFD design load effects with no dynamic load allowance)	1.27	1.25	1.24	1.22	1.2	1.18	1.17	1.15	1.13
Average LRFD equivalent dynamic load allowance as a percentage of the total design load effects (uniform load plus design truck or tandem)	0.27	0.25	0.24	0.22	0.2	0.18	0.17	0.15	0.13
AASHTO Standard Specifications Impact Factor	0.3	0.29	0.26	0.22	0.2	0.18	0.15	0.13	0.12

Considering AASHTO LRFD and the LRFR method of rating, using an impact of 20 percent applied to the entire platoon still produces a conservative design load effect for the following reasons:

- The interaction between the trucks in the platoons will result in a smaller impact than for a single truck.
- Although the 20 percent may seem low for shorter spans, it really does not matter:
    - For spans longer than 130 feet, the maximum average equivalent impact is 20 percent or less. This equivalent impact is applied to both the truck and the uniform load that represents other vehicles on the structure.
    - For shorter spans where only one truck may fit on the structure, the existing design loads with the 33 percent impact applied to the truck will continue to control the design over the 20 percent for the platoon. (assuming platoons are of the configurations investigated in this research), i.e. the reduction in the impact for the platoons will not result in lower design load effects.

The same rationale may be used in justifying the use of a maximum of 20 percent impact applied to the entire platoons when AASHTO Standard Specifications (2002) and the ASD or LFD methods of rating are considered.

The commentary of the AASHTO MBE (2018) allows the reduction of the dynamic load allowance for bridges with riding surface and approach conditions that do not include bumps, sags, or other major surface deviations and discontinuities. The AASHTO MBE (2018) suggests the use of impact of 10 percent for bridges with smooth riding surface at approaches, bridge deck, and expansion joints and 20 percent for bridges with minor surface deviations or depressions. It is recommended that the values shown in Table 92 be considered for LRFR rating when it is desired to take advantage of favorable surface conditions.

Table 92. Reduced Impact Suggested by the AASHTO MBE and Values Suggested for Rating Truck Platoons

Riding Surface Conditions	Suggested impact for a single truck in the MBE	Suggested for Truck Platoons
Smooth riding surface at approaches, bridge deck, and expansion joints	10%	10%
Minor surface deviations or depressions	20%	15%

For LFR rating, the impact coefficient equation in AASHTO Standard Specifications (2002) can still be used for platoons but the impact may be limited to 20%. This equation yields an impact factor of less than 20% for spans longer than 125 ft.

11.2 BRAKING FORCE

Starting in the 1940s, the braking force in AASHTO Standard Specifications was taken as 5 percent of the live load in all lanes carrying traffic headed in the same direction. This force was called “the longitudinal force.” The load used to calculate this force was the lane load plus the concentrated load for moment. The force was applied horizontally at a point 6 feet above the roadway surface. The design article did not mention whether the impact should be included; however, the common practice was to ignore it. No significant changes to this force were incorporated in the AASHTO Standard Specifications until the last edition of the specifications was issued in 2002.

The first edition of AASHTO LRFD (1994) specified the braking force as 25 percent of the of the axle weights of the design truck or tandem per lane placed in all design lanes which are carrying traffic headed in the same direction. The direction and point of application of the force is the same as that for the AASHTO Standard Specifications. The fraction (25 percent) of the axle loads was determined using energy principles assuming uniform deceleration of a truck travelling at 55 mph and a stopping distance of 400 feet. This resulted in a significant increase in the braking force from the truck; however, it was recognized that improvements in truck braking capabilities between the 1940s and the 1990s warranted this increase.

The uniform live load of the HL-93 design load was not included in the calculation of the braking force. This load is considered to represent other vehicles in the same lane with the design truck and it was assumed that the braking forces from these vehicles are out-of-phase with that from the truck.

The new approach resulted in a significant increase in the braking force for shorter bridges; however, for longer bridges, it resulted in a reduction in the braking force.

The reduction in the braking force for longer spans raised concerns about the stability of bridges with large length between consecutive expansion joints when designed using the then-new provisions. Therefore, the braking force calculations were revised in the 2001 interim edition of the second edition of the AASHTO LRFD (2001). The braking force was defined as the greater of:

- 25 percent of the axle weights of the design truck or design tandem, or
- 5 percent of the design truck plus lane load or 5 percent of the design tandem plus lane load

In all editions of AASHTO LRFD, it was explicitly specified that the impact was not to be applied to the braking force.

For truck platoons, it is expected that all trucks in a platoon will engage the brakes almost instantaneously. This means that the full braking force (25 percent of axle loads) will develop for all axles on the bridge at the time the trucks hit the brakes. For the following discussion, the “bridge” indicates a bridge length between two consecutive expansion joints.

Figure 37 through Figure 39 show the comparison between the braking force for the two-, three-, and four-truck platoons, respectively, and the AASHTO Standard Specifications (2002) and AASHTO LRFD (2017). All forces are calculated for one lane of traffic loaded with the respective load. For truck platoons, no other loads are assumed to exist in the same traffic lane with a truck platoon. In these comparisons, the braking force for the platoons is calculated assuming that the platoons are composed of type "T" trucks spaced at 30 feet between the rear axle of the preceding truck to the front axle of the trailing truck. The design truck platoons are assumed to consist of design trucks spaced at 50 feet and with the rear axle spacing of each truck taken as 30 feet. For all truck platoons, only the axle of the trucks that can fit on the bridge are considered in the calculations, and axles outside the bridge were ignored.

The braking forces were factored using 1.3 for AASHTO Standard Specifications, 1.75 for AASHTO LRFD, and 1.75 for the design truck platoons to reflect the design braking force factored for Loading Group III (AASHTO Standard Specifications) and the Strength I load combination (AASHTO LRFD). For the "T" truck platoons, considered to be routine commercial traffic or "Legal Loads" that will be considered in bridge load rating only, the braking force was factored by 1.45.

As shown in Figure 37 through Figure 39, the braking forces from the design truck platoons envelop those from the "T" truck platoons with the same number of trucks. This means that, for bridges on highways where truck platoons will be allowed, designing new bridges for braking force determined using platoons composed of design trucks spaced at 50 feet, having rear axle spacing of 30 feet and factored using a load factor of 1.75 will produce braking forces equal or higher than those from platoons composed of the most compact 80,000 lb. trucks satisfying Bridge Formula B (the "T" Trucks) spaced at 30 feet and factored using a load factor of 1.45 which corresponds to the highest load factor for routine commercial traffic.

The figures also show that the design braking forces from both the AASHTO LRFD (2017) and the AASHTO Standard Specifications are significantly lower than those from truck platoons for bridge lengths more than about 100 feet between expansion joints. Generally, the difference between the braking force determined using the design specifications and that from the truck platoons increases as the number of trucks in the platoon increases, assuming the bridge length can accommodate the full length of the platoon. However, the difference decreases as the bridge length increases for all truck platoons. For two-truck platoons, the braking force determined using the truck platoons is larger than that from the Standard Specifications for all bridge lengths considered (up to 1,200 feet) and for bridge lengths up to about 900 feet for AASHTO LRFD (2017). For three- and four-truck platoons, the braking force from the truck platoons exceeds that from both design specifications for all bridge lengths considered (up to about 1,200 feet).

Calculating the braking force for a platoon involves determining the axle loads that fit between two consecutive expansion joints and calculate the braking force using the sum of these axle loads. As a simplification, the braking force may be calculated using an equivalent uniform load of 1.0 k/foot applied to the length of the bridge between expansion joints or the total length of a truck platoon, whichever is smaller. The results for this equivalent uniform load are also shown in Figure 37 through Figure 39. The braking force for this load envelopes that from both the design truck platoons and the "T" truck platoons for two-, three-, and four-truck platoons. It becomes more conservative as the number of trucks in a platoon increased.

Comparisons like those in Figure 37 through Figure 39 were made for "T" truck platoons with 50 foot and 70 foot truck spacing and the corresponding design truck platoons with 70 foot and 90 foot truck spacing, respectively. Similar trends as shown in Figure 37 through Figure 39 were observed. The only difference was that the sloping part of the curves for the platoons was flatter. The equivalent uniform loads that can be used for these cases are 0.9 k/foot and 0.8 k/foot, respectively.

The team proposes discussing this equivalent load in the commentary rather than in the specification.

The sloping part of the braking force curve from the T-truck platoons and the design truck platoons is not a straight line. Rather it consists of sudden increase at bridge length when an additional axle is accommodated on the bridge followed by a horizontal part up to the point where the next axle can be accommodated. When fractions of trucks exist on the length of the bridge between consecutive expansion joints, there may be some cases where the weight of axles from the "T" truck platoons on the bridge exceeds the weight of the design truck axles on the same length. In these cases, the braking force from the T-truck platoons will be slightly larger than that from the design truck platoons but within the acceptable limit for design. This is particularly so when considering that, in cases while the braking trucks are still in motion, some axles of the truck will move out of the bridge while others come on the bridge causing the weight of axles on the bridge and the corresponding braking force to vary with time.

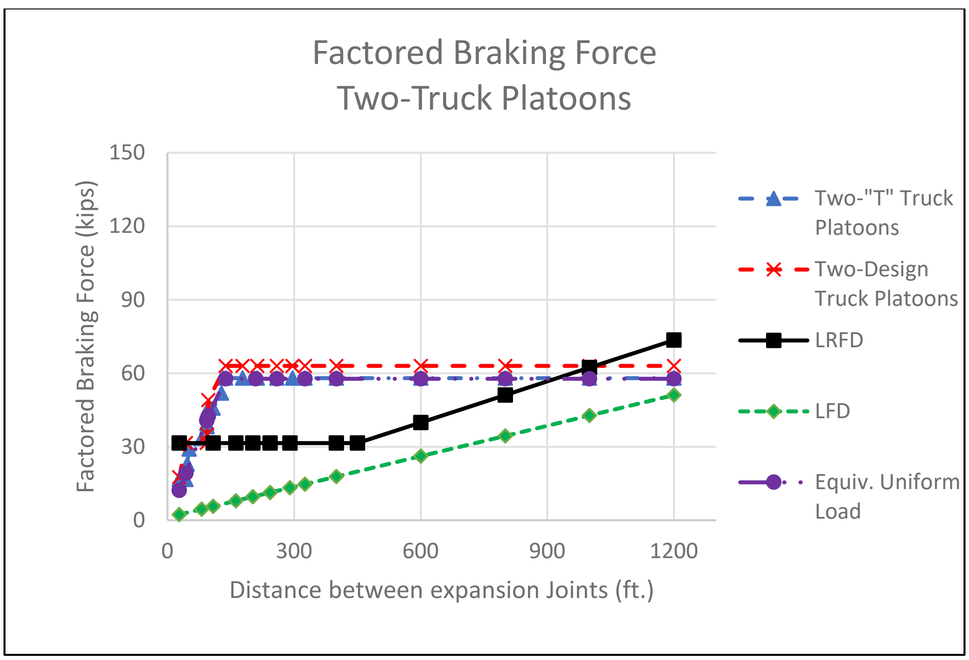


Figure 37. Comparison Between the Braking Force from the Design Specifications and Two-Truck Platoons

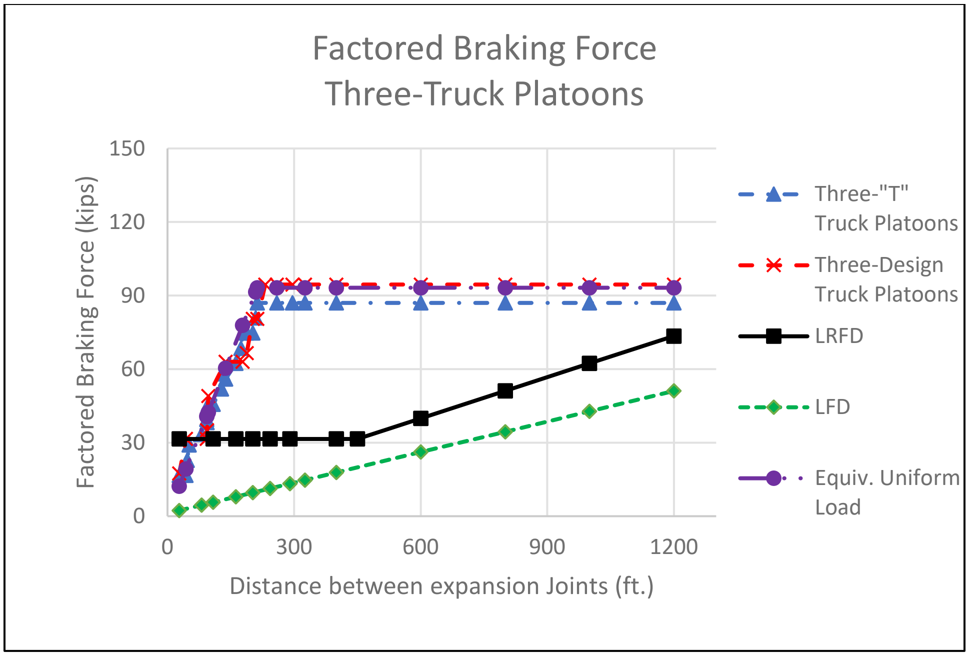


Figure 38. Comparison Between the Braking Force from the Design Specifications and Three-Truck Platoons

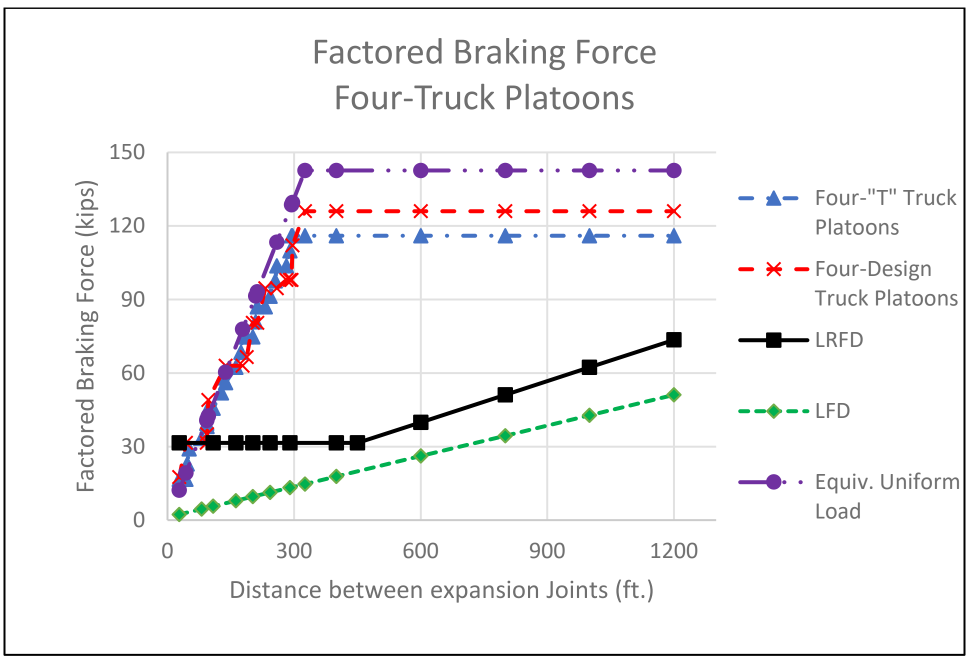


Figure 39. Comparison Between the Braking Force from the Design Specifications and Four-Truck Platoons

Figure 37 through Figure 39 indicate that bridge components designed for current and past design specifications and having load effects from braking forces that represent a significant portion of the design load effects will possibly be overstressed when the braking force from the platoons is applied, even at the operating level regardless of the specifications used to calculate the braking force used in the design. These components are the fixed bearings, bearing anchor bolts, substructures, and foundations.

The significance of the increase in the braking force varies with the configuration of the structure. For example, two identical bridges that only differ in the height of the piers will have the same forces transmitted from the superstructure to the substructure; however, the load effects from the braking force on pier columns and foundations will be greater for the bridge with the taller piers, and the load effects from the gravity effects of live loads will be identical in the case of a wall pier or very similar in the case of multi-column pier. This varying ratio between the vertical force load effects and the load effects from the horizontal breaking force makes it impossible to make a general conclusion of the magnitude of the effect of the increased braking force on the design of new bridges and on the rating of existing bridges; if the bridge owner chooses to load rate the substructure.

11.3 CENTRIFUGAL FORCE

The centrifugal force equation in both the AASHTO Standard Specifications and in AASHTO LRFD (2017) is based on the dynamics of a body traveling on a curve at a constant speed. The two specifications yield the same force, although the presentation of the formula is different. The formula appears in AASHTO LRFD (2017) in this form:

$CE = C\ W$

For which $C = f\ (v^2/gR)$

where:

- CE = the centrifugal force from an axle or a group of axle of total weight W (kips)
- C = a factor represents the fraction of the horizontal centrifugal force to the gravity load of the truck or tandem axles
- v = highway design speed (ft/s)
- f = 4/3 for load combinations other than fatigue and 1.0 for fatigue
- g = gravitational acceleration: 32.2 (ft/s^2)
- R = radius of curvature of traffic lane (ft)

The factor 4/3 is meant to increase the force to correspond to a group of heavier trucks that were grandfathered at the time the specifications was developed.

The calculation of the centrifugal force is based on basic dynamics and is applicable to all travelling vehicles be them travelling as a single vehicle or in a platoon. AASHTO LRFD does not specify applying the centrifugal force to the design uniform load. The assumption is that the spacing of vehicles at high speed becomes large resulting in a low density of vehicles following and/or preceding the design truck. This assumption is not applicable to the same extent to truck platoons where the vehicles are expected to be travel tightly spaced and the spacing may increase relatively slightly with the increase in travelling speed.

With both the centrifugal force and the braking force are taken as a fraction of the weight of the axles, the trends shown in Figure 37 through Figure 39 for the braking forces of the "T" truck platoons, design truck platoons and the equivalent uniform loads will hold true for the centrifugal force. The only difference will be that the scale of the force on the vertical axis will be different. Furthermore, the scale of force on the vertical axis will also vary with the highway design speed and the radius of the curve.

This means that using platoons of the design trucks with 30 ft. rear axle spacing and 50 ft. truck spacing for the Strength I load combination during the design of new bridges will result in a centrifugal force slightly higher than that calculated for the "T" truck platoons with 30 ft. truck spacing during the rating of a bridge assuming that the "T" truck platoons will be treated as routine commercial traffic (legal loads).

Other conclusions regarding other truck spacings in the platoons and the equivalent uniform loads made for the braking force also hold true for the centrifugal force.

To account for the larger braking force, the design specifications may be revised to include the above-described design truck platoons for the calculation of the centrifugal force in the design of new bridges on highways where truck platoons will be allowed. The 4/3 factor need not to be applied to truck platoons as it is expected that trucks allowed to form platoons will be restricted to 80,000 lbs GVW.

Article 6.1.5.2. of the AASHTO MBE (2018) specifies that the centrifugal force be considered in the rating of substructures when the owner deems such rating as necessary. Additional commentary to the design specifications may be considered to alert the owners that the centrifugal force from truck platoons are higher than single trucks and to consider this when making the decision of whether to rate the substructure and/or checking the bearings and bearing anchors.

11.4 WIND LOAD ON LIVE LOAD

For the strength limit state, the wind on live loads are included in load combination Strength V in the AASHTO LRFD (2017) and in Load Groups III and VI in AASHTO Standard Specifications. In both cases, a reduced wind speed is assumed compared to the basic strength case (Strength I in AASHTO LRFD (2017) and Load Group I in AASHTO Standard Specifications). The reduction is based on practical experience that trucks may overturn if they travel while the wind speed is higher than 80 mph, 3-second gusts, used in AASHTO LRFD (2017) (approximately equivalent to 55 mph fastest mile wind speed with a load factor of 1.4 as used in the Standard Specifications).

In both design specifications, the wind force on live loads is taken as 0.10 klf of the moving live load. The commentary of AASHTO LRFD (2017), Article 3.8.1.3, states that, historically, the 0.10 klf wind load has been assumed to represent the wind load on a long row of randomly sequenced passenger cars, commercial vans, and trucks exposed to the maximum wind speed that vehicles can safely travel.

Note that, even if single trucks can travel when the wind speed is as high as 80 mph, it is not expected that platoons will be travelling when the wind speed is as high out of fear of one truck overturning and causing the other trucks to crash, which will result in reducing the wind pressure on the trucks. Assuming that the wind speed at which trucks will be disconnected from a platoon and run individually is 70 mph, 3-second wind gusts (notice this is an arbitrary number), for the Strength V load combination, the wind pressure may be determined using the following equation:

The wind pressure, P_Z can be determined as:

$$P_Z = 2.56 \times 10^{-6} V^2 K_Z G C_D$$

Where:

> P_Z = design wind pressure (ksf)
>
> V = design 3-second gust wind speed = 70 mph for platoons and Strength V load combination
>
> K_Z = pressure exposure and elevation coefficient = 1.0 for Strength V load combination
>
> G = gust effect factor = 1.0 for Strength V load combination
>
> C_D = drag coefficient equals 1.3 (assuming the same drag coefficient specified for girder bridges)

This results in wind pressure of 0.0163 ksf.

Although maximum allowable truck height differs by State, for most States, the maximum vehicle height is 14 feet or less. Assuming:

- A truck height of 14 feet above the riding surface
- Height of traffic barrier of 3.0 feet above the riding surface
- Truck length between first and last axles is 51 feet (for the "T" truck). Assuming the sum of the length of truck body overhangs in front of first axle and behind the rear axle is 10 feet, the truck length blocking the wind is 61 feet.
- Truck spacing of 30, 50, and 70 feet between the rear axle of the leading truck to the front axle of the trailing truck. Accounting for the truck body overhangs, the clear spacing between trucks that does not block the wind is 20, 40, and 60 feet, respectively.
- The truck platoon is placed centered over an intermediate bent with two equal adjacent spans. Span lengths are equal to one-half of the platoon length, i.e., the entire platoon fits on the two adjacent spans.
- Half the wind load on the platoon is assumed to be transmitted to the intermediate bent at the center of the platoon while the remainder of the force is transmitted to the supports at the far ends of the two spans.

- The intermediate bent is assumed to have two columns, and the wind load on the bent is distributed equally among them.

Table 93 shows the estimated wind load calculated for different platoon and span scenarios. The procedure to calculate the load transmitted to each column is illustrated below for a 2-truck platoon with 30-feet truck spacing:

The traffic barrier will shield the lower 3 feet of the truck and the wind pressure may be applied to the top 11 feet only (14 foot truck height – 3 foot barrier height = 11 feet).

Average wind load on the platoon may be estimated as: 0.0163 x exposed height x total truck length blocking the wind/total platoon length = 0.0163 x 11 x (61 x 2)/(61 x 2+20) = 0.154 klf applied to the full length of the platoon.

Total wind load on the platoon = 0.154 x platoon length = 0.154 x (61x2+20) = 21.868 kips.

Estimated wind load on live load transmitted to the intermediate bent at the center of the platoon = 21.868/2 = 10.937 kips.

Applying the same assumptions to the specifications for wind load on live load of 0.1 klf applied to the entire length of the two adjacent spans, the estimated wind load on live load transmitted to the intermediate bent = 7.1 kips.

Difference in load = 10.937 – 7.1 = 3.834 kips.

Difference in load on each of the two columns in the bent = 3.834/2 = 1.917 kips.

The above procedure is approximate but is sufficient to conclude that the difference between the design wind load on live load from the specifications and the estimated wind load on the platoons will be insignificant and is not expected to cause any difference in the design of the substructures, bearings, or bearing anchors. The team proposes no revisions to the design provisions for wind on live loads in AASHTO LRFD (2017). Additional commentary may be added to clarify that existing provisions may be used for truck platoons and reference the final report of this project.

Table 93. Estimated Wind Load on Live Load from Different Platoon Configurations

Parameter	2-Truck Platoons			3-Truck Platoons			4-Truck Platoons		
Individual truck length between front and rear axles (ft.)	51	51	51	51	51	51	51	51	51
Individual truck length blocking the wind (ft.)	61	61	61	61	61	61	61	61	61
Truck spacing between front axle of a truck and rear axle of the preceding truck(ft.)	30	50	70	30	50	70	30	50	70
Clear truck spacing not blocking wind(ft.)	20	40	60	20	40	60	20	40	60
Total platoon length (ft.)	142	162	182	223	263	303	304	364	424
Total trucks length blocking wind (ft.)	122	122	122	183	183	183	244	244	244
Estimated wind pressure on trucks (psf)	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163
Equivalent wind load (klf)	0.154	0.135	0.12	0.147	0.125	0.108	0.144	0.12	0.103
Total wind load (kips)	21.868	21.870	21.840	32.781	32.875	32.724	43.776	43.680	43.672
Minimum span length to allow the entire platoon to fit on a two-span bridge (ft.)	71	81	91	111.5	131.5	151.5	152	182	212
Approximate Platoon wind load on the intermediate bent of a two-span bridge with span length equal to half platoon length (kips)	10.934	10.935	10.92	16.391	16.438	16.362	21.888	21.84	21.836
Specifications wind load based on 0.1 klf (kips)	14.2	16.2	18.2	22.3	26.3	30.3	30.4	36.4	42.4
Approximate wind load on the intermediate bent of a two-span bridge with span lengths equal to half platoon length (kips)	7.1	8.1	9.1	11.15	13.15	15.15	15.2	18.2	21.2
Difference in Load on intermediate bent (kips)	3.834	2.835	1.82	5.241	3.288	1.212	6.688	3.64	0.636
Additional lateral force per column (assuming two columns per bent) (kips)	1.917	1.42	0.91	2.62	1.64	0.61	3.34	1.82	0.32

For rating, Article 6.1.5.2 of the AASHTO MBE (2018) states that: "*Where deemed necessary by the Owner, load rating of substructure elements and checking stability of substructure components such as abutments, piers, and walls should be done using all permanent loads and loads due to braking and centrifugal forces but neglecting other transient loads such as wind or temperature", and, A*rticle 6A.2.3.5 states: *"Wind loads need not be considered unless special circumstances justify otherwise."*

The insignificant possible increase in wind load on live load when platoons are allowed should have negligible effect on bridge load rating, including for special structures such as movable bridges, suspension bridges, and other high-level structures. Revisions to the AASHTO MBE (2018) to account for the additional load were deemed unnecessary.

Although it is expected that no additional design provisions are needed to account for including truck platoons in the rating of superstructures designed using the AASHTO LRFD (2017) specifications, the increase in the braking force and centrifugal force necessitates revising the design provisions such that the bearings, substructures, and foundations of bridges designed using AASHTO LRFD (2017) will be adequate to accommodate truck platoons at the operating level.

12.0 EFFECT OF TRUCK PLATOONS ON SERVICE AND FATIGUE LIMIT STATES

The thrust of this research was the effect of truck platoons on the strength limit state. The following is a brief discussion of the possible effects of truck platoons on the service and fatigue limit states.

12.1 SERVICE LIMIT STATE

An earlier study of WIM data (Kulicki et al., 2015, Wassef et al., 2014)) indicated that load effects from then-current traffic on the highways sometimes exceed those from the design loads. The frequency of exceedance varies with the span length. The results of analyzing the moments in bridges with different spans under the data collected during a one-year period at 32 WIM sites across the United States were used to determine the frequency of the applied moment exceeding 1.3 of the HL-93 design moment (1.3 is the ratio between the 1.75 load factor for live load used in the design for the Strength I limit state to the 1.35 load factor used for the design load operating rating at the Strength II limit state). The frequency of exceedance varied from site to site. Because there have been no reports of current traffic causing sudden severe damage to existing bridges, the research team concluded that current frequency of such incidents of exceedance is acceptable. Considering that the ratio between load effects from the investigated truck platoons generally does not exceed that from HL-93 except in very small number of cases, and when they do not exceed the HL-93 load effects by more than 18 percent in some span lengths under tightly spaced platoons containing more than two trucks, it appears that the platoons do not produce higher load effects than the heavier vehicles currently run on the highways. This indicates that truck platoons are expected to have minimal to no implications for new bridges designed for AASHTO LRFD (2017).

However, for existing bridge designed for the AASHTO Standard Specifications, the load effects from truck platoons can be as high as 1.3 times those from the HS 20 design loads. In addition, some of the existing bridges have relatively low rating factors. The frequency of the higher load effects will depend on the number of platoons. Although quantifying the effect of the increase in the frequency is beyond the scope of this study, the research team for this study recommends that it be researched.

The components that are typically checked under the service limit states and the possible effect of truck platoons on these components are shown in Table 94.

Table 94. Anticipated Effect of Truck Platoons on the Service Limit State Design of Different Bridge Components

Component	Effect Anticipated (Yes/No)	Anticipated Significance of the Effect	Notes
Reinforced Concrete Decks	No	N/A	Decks are usually designed for the heavy axles of the design truck or, in the case of orthotropic decks, for the actual load of these axles. Axle loads from platoons are not expected to exceed the 32 kips design axle loads.
Reinforced Concrete Superstructure	Yes	Low	Reinforced concrete is checked for crack width under service loads. Reinforced concrete superstructures are typically short spans that will be controlled by the compact design truck rather than the longer typical trucks expected to be allowed for platooning.
Prestressed Concrete Superstructure	Yes	Variable	Prestressed concrete components are checked for stresses under service loads. With the ratio between the moment and shear from truck platoons and those from the design loads vary with the span length, number of trucks in a platoon and the truck spacing, most superstructures with typical span lengths will not be affected. Bridges with longer spans, small truck spacing and platoons with more than two trucks may be affected.
Steel Superstructures	Yes	Variable	Like prestressed concrete superstructures and for the same reasons, steel superstructures may be affected to varying degree.
Concrete Substructures	Yes	Variable	The vertical reactions from platoons may exceed those from the design loads for bridges with longer spans loaded with truck platoons containing more than two trucks with tight truck spacing. The braking force and the centrifugal force are expected to increase significantly. The increase becomes more significant as the number of trucks in a platoon increases.
Bearings and Bearing Anchors	Yes	Variable	The effect on these components is similar to that on the concrete substructures discussed above.

12.2 FATIGUE LIMIT STATE

The fatigue limit state is divided into two load combinations: Fatigue I and Fatigue II.

Fatigue I Load Combination: For this load combinations, the load factor is determined by analyzing the moment ranges using the traffic loads recorded in WIM data and determining the moment range that is only exceeded once in every 10,000 load cycles. The load factor for design is selected to make the moment range from the factored fatigue truck equal to that moment. If the moment range from the factored fatigue truck produces a stress range at a certain detail location less than the constant amplitude fatigue threshold (CAFT) for the fatigue category of the detail, the detail is considered to have an infinite fatigue life. On the other hand, if the moment range from the factored fatigue truck produces a stress range higher than the CAFT for the fatigue category of the detail, the detail is considered to have finite fatigue life that can be determined using the Fatigue II load combination. Typically, new bridges are proportioned and detailed to have infinite fatigue life for all details.

The load factor currently in the AASHTO LRFD (2017) for Fatigue I load combination is 1.75. As discussed above, although the heaviest trucks in current traffic produce load effects higher than those from the design loads, the number of incidents is small. The difference between the load effect from heaviest trucks to that from the design loads is in the same range of the difference between truck platoons and design loads. If truck platoons are added to the traffic, the number of incidents of traffic loads, including the platoons, producing load effects higher than factored Fatigue I design loads is expected to increase. The increase of the number of incidents will depend on the number of trucks in a platoon, the spacing of the trucks in a platoon, bridge span length, and the ratio between the average daily number of platoons to the ADTT. This increase will result in shifting the 1 in 10,000 stress range higher and will cause the load factor for Fatigue I to increase.

Fatigue II Load Combination: For this load combination, the load factor is determined by analyzing the equivalent moment ranges and the associated number of load cycles using the traffic loads recorded in WIM data. Typically, the rain flow method is used to convert the random cycles of loading into groups of stress cycles with approximately the same stress ranges followed by the application of Miner's rule to determine the equivalent magnitude of constant stress cycles with an associated number of cycles equal to the number of trucks in the WIM data. The load factor is selected to make the number of cycles equal to the number of trucks in the WIM data. The stress range from the factored design truck and the fatigue category of the detail are used to determine the fatigue life expressed as a number of cycles. The fatigue life of the detail in days can be determined by dividing the total life number of cycles by the ADTT. The number of days is then divided by 365 to determine the fatigue life in years.

The anticipated increase in the load factor for Fatigue I load combination is expected to cause some details currently classified as having infinite fatigue life to be reclassified as having finite fatigue life. This will limit the remaining life of such details affected.

For existing bridges, depending on the span length, the presence of the platoons may increase the number of the higher stress cycles albeit it will reduce the total number of load cycles as each platoon will replace more than one truck. Truck platoon effect on finite fatigue life (Fatigue II load combination) is a function of truck configurations, weight, and spacing; number of trucks in platoons; and the percentage of platoons in traffic. Because the load factor for Fatigue II is based on the accumulative fatigue damage and a single cycle of higher stress range can cause more fatigue damage than several cycles of smaller stress range (fatigue damage is proportional to the stress range raised to the third power), allowing the platoons may lead to an increase in the load factor for Fatigue II load combination.

12.2.1 Anticipated Effect of Truck Platoons on Fatigue Life

The anticipated effect of truck platoons on fatigue life varies depending on their current classification and the current stress range for the fatigue load combinations. Table 95 shows the anticipated effect.

Table 95. Anticipated Effect of Truck Platoons on Fatigue Life

Situation	Anticipated Effect on Fatigue Life
Details in new bridges	New bridges are typically designed for Fatigue I load combination (infinite fatigue life). Truck platoons are expected to result in a higher load factor for Fatigue I load combination. This may need increasing some sections to keep factored design stress range below the CAFT.
Details in existing bridges that currently are classified as having infinite fatigue life	If the stress range calculated using the Fatigue I load factor including the effect of truck platoons result in: a) a stress range below the CAFT: the detail will continue to have infinite fatigue life and allowing the platoons will have no effect on such a detail. a) a stress range above the CAFT: the detail will be reclassified as having a finite life and the total and remaining fatigue life may be determined using the calculated stress range. This case has the potential to have substantial impacts for fatigue life.
Details in existing bridges that are currently classified as having finite fatigue life	Depending on whether the load factor for Fatigue II load combination is larger than current load factor of 0.8, the fatigue life of such details may be reduced. The reduction will depend on the difference between the current and new load factors.

The effect of platoons on both the service and fatigue limit states is the subject of future research.

13.0 CONCLUSIONS AND NEEDED FUTURE RESEARCH

13.1 CONCLUSIONS

Many assumptions were made during this study. The main assumptions are:

- Truck platoons will mainly run on the main highway systems including the Interstate System (IS), the National Highway System (NHS) and the National Network for Trucks (NN). Only bridges on these highway systems are covered by the conclusions regarding existing bridges.
- The evaluation of existing bridges under truck platoons assumed the truck platoons to be treated as legal loads
- Only the strength limit state was considered in the evaluation.
- Truck platoons will be limited to the truck configurations considered

The following conclusions are drawn from the results of this work:

- Truck platoons of the configurations considered may produce load effects higher than those from the standard design loads. The degree the load effects from truck platoons exceeding those from the design loads depending on the configuration of the platooned trucks, the spacing between the trucks in a platoon, the number of trucks in a platoon and the bridge span length.
- The smaller the spacing between trucks in a platoon the higher the load effects from this platoon. The exception is the negative moment at interior supports of continuous spans where larger truck spacing can result in positioning the trucks at areas of the spans that can result in higher negative moments at the interior supports.
- For bridge spans long enough to accommodate the full, or most, of the length of a platoon, the increase of the number of trucks in a platoon increases the ratio between the platoon load effects and those from the design loads.
- For shorter spans, the standard design loads will continue to control the design because a portion of the truck platoon lies outside the span.
- Existing bridges having a current inventory rating factor (Item 64 in the NBI database) >1.0 for HL-93 design loading and all new bridges designed for AASTO LRFD (2017) (the latter will automatically have an inventory rating >1.0 for HL-93 design loading) will be able to safely support all truck platoons considered.
- Existing bridges having a current operating rating factor (Item 64 in the NBI database) >1.0 for HL-93 design loading will be able to safely support all truck platoons considered except for spans longer than 200 ft. under three- and four-truck platoons with truck spacing of 30 ft.

- Existing bridges having a current inventory rating factor (Item 64 in the NBI database) >1.0 for HS 20 design loading will be able to support all truck platoons considered safely.

- Existing bridges having a current operating rating factor (Item 64 in the NBI database) >1.20 for HS 20 design loading are expected to be able to support all truck platoons with truck spacing of 50 and 70 ft. These bridges are also expected to have adequate load capacity to support two-truck platoons with truck spacing of 30 ft. except for the end shear of simple span for a limited number of cases. Some of these bridges are expected to be affected by the three- and four-truck platoons with truck spacing of 30 ft. The span lengths to be affected vary for different load effects but they are not less than 130 ft in any case.

  Some existing bridges having a current operating rating factor (item 64 in the NBI database) >1.00 for HS 20 design loading are expected to be affected by two-, three- and four-truck platoons with truck spacing of 30, 50 and 70 ft. The span lengths affected vary with the type, number and spacing of the trucks in a platoon and also vary for different load effects. Truck platoon negative moments at interior supports of continuous spans exceeded those from the HS 20 loading for spans as short as 70 ft. For other load effects, no span less than 100 ft. was negatively affected.

13.2 NEEDED FUTURE RESEARCH

Based on the work done in this research, there are some knowledge gaps that should be covered in future research. These are:

- Statistical live load analysis to determine the probability of truck platoons existing in adjacent lanes and the appropriate load factor to be used for the platoons. The effect of tighter control over truck platoon vehicle weights should be considered in such statistical analysis.

- Determining the appropriate dynamic load allowance for use with truck platoons taking into account the effect of the presence of more than one closely spaced trucks on the bridge simultaneously

- Determining the effect of truck platoons on the fatigue life of bridges

- Determining the effect of truck platoons on the design of bridge components for the service limit state

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APPENDIX A

LITERATURE REVIEW

BACKGROUND

The ability of vehicles to operate jointly and communicate virtually for certain distances autonomously or to be led by a single driver is defined as vehicle "platooning." The technology was developed to increase the safety and capacity of highways and the driver's comfort, reduce fuel consumption and emissions, thereby increasing the efficiency of vehicle operations.

The scenario for vehicles equipped with the automated driving system was developed within the program of an Automated Highway System (AHS) supported by FHWA dating back to the early 1970s (Fenton 1976). The program was then closed due to the lack of investments, but in 1997 the model of the AHS restarted through the National Automated Highway System Consortium (NAHSC) project. The potential advantages of the developed intelligent highway system were demonstrated in San Diego (CA) in 1997 ("Public Roads - Demo '97: Proving AHS Works, July/August 1997 -" n.d.). Among the considered scenarios, such as automated vehicle operation, the ability of a group of vehicles (eight 1997 Buick LeSabres) to operate in a "platoon" was demonstrated. The vehicles, modified by Delco Electronics, General Motors, Hughes, and the University of California PATH, were moving in a single lane along I-15 controlled by a chain of magnets embedded in the road surface. The program was later terminated and replaced by onboard automated operating technology (AOT) (Table A-1) (Alam 2014; Auburn University 2017; Bergenheim et al. 2012; Bergenhem et al. 2012, 2010; Carbaugh et al. 1998; Englund et al. 2016; Michael et al. 1998; Scania Group n.d.; Tsugawa et al. 2011; Wille et al. 2014).

In Europe, the idea of vehicles operating jointly was first discussed in a Program for European Traffic with Highest Efficiency and Unprecedented Safety in 1988. The first developments towards truck "platooning" started in 2000 in the Netherlands (Janssen et al. 2015) with Langere en Zwaardere Vrachtautocombinatie (LZVs), 57-meter combination of two vehicles, 7 meters apart. The first tests were performed in 2006, and after six years of development, LZV was officially allowed to operate on Dutch roads.

PLATOONING TECHNOLOGY

The automated operation technology includes some already implemented (by Volvo, Mercedes, Volkswagen, BMW, etc.) systems, such as autonomous emergency braking (AEB), lane keeping assistant (LKA), adaptive cruise control (ACC), etc. The ability of the vehicle to recognize and join the "platoon" utilizes the abilities of the systems listed above as a part of Cooperative Adaptive Cruise Control (CACC) (Anderson et al. 2016; FHWA 2017). The CACC technology applies to all types of vehicles equipped with ACC, AEB, and LKA. However, the fuel savings due to the improved aerodynamics is substantial when the "platoon" is formed by heavy vehicles such as tractor-trailer trucks. Therefore, the "platooning" event commonly refers to "truck platooning."

The existing intelligent transportation systems provide two types of communication: driver-to-driver (V2V) and driver to the environment (V2I) (Bergenheim et al. 2012). Drivers can receive information about the trucks that are available to follow, the route, speed, final destination, roadworks, accidents, traffic jams, etc.

- **DATP** (Driver Assistive Truck Platooning) system was developed by Peloton Technology based on Cooperative Adaptive Cruise Control (CACC) within the FHWA-sponsored project "Heavy Truck Cooperative Adaptive Cruise Control: Evaluation, Testing, and Stakeholder Engagement for Near Term Deployment" (Auburn University 2017). **DAPT** enables the following vehicle/vehicles to trail the leading truck automatically but the driver remains fully controlling and maneuvering the vehicle, leaving or re-joining the fleet.

- **PATH** automated system initially developed for lightweight cars by California Partners for Advanced Transportation Technology (PATH) at University of California (Berkeley) within a project by the NAHSC (Carbaugh et al. 1998; Michael et al. 1998; "Public Roads - Demo '97: Proving AHS Works , July/August 1997 -" n.d.). The technology called to optimize the traffic flow by allowing up to 10 cars to operate jointly under control in transverse and longitudinal direction within an AHS (patterned with reference markers recognized by onboard car sensors). Currently, California PATH is deeply involved in developing and testing heavy truck platooning system.

- **SARTRE** (Safe Road Trains for the Environment) is the automated operating system developed by a team of companies chaired by Ricardo UK and co-sponsored by European Commission FP7 (Bergenhem et al. 2010). The application includes cameras, laser sensors, and onboard communication system for vehicles operating in "platoons." This allows the equipped vehicles, both passenger cars and trucks, to connect and disconnect from the platoon. The V2V communication is critical in platoons operated with SARTRE because only the leading truck controls the travel.

- **KONVOI is** the product developed at RWTH University Aachen (Germany) to provide the effective coupling of vehicles in the traffic stream (Wille et al. 2014). The system is equipped with the V2V communication interface to provide the effective operation, coupling, uncoupling, and maneuvering of up to five vehicles in the platoon.

- **GCDC** (The Grand Cooperative Driving Challenge) aimed to reduce the traffic congestion by safely reducing the minimum spacing between in-lane traffic participants. The system utilizes both V2V and V2I systems to provide safe operation of mixed platoons (cars and trucks) at a minimum distance (Englund et al. 2016).

- **Energy ITS** development started in 2008 and is sponsored by Japanese Ministry of Economy, Trade, and Industry. The technology is based on the concept of Intelligent Transportation System (ITS) where the roadway or selected lane is upgraded with the markers recognized by onboard truck sensors. This allows truck platoons to operate safely on minimum distance 32.81 ft (10m).

- **SCANIA** is the automated operating system developed by Scania Group and KTH (The Swedish Royal Institute of Technology) as a tool to reduce the truck fuel consumption (Alam 2014; Scania Group n.d.). Vehicles in the platoon are automatically operated in the longitudinal direction while the following vehicle drivers remain in charge of operation of their trucks. Vehicles able to form a platoon are to be equipped with cameras, radars, and V2V communication system to communicate in between the fleet members effectively.

Table A-1. Operating systems for truck platooning

Type of the system	Features	Producer	Reference
DATP	• DATP is a type of Cooperative Adaptive Cruise Control (CACC) for two- or more truck platoons. • In DATP, the drivers of trucks in "platoon" are enabled to exchange the information and communicate. The system includes radar, DSRC-based communication system, satellite communication, interface panel for communication with the driver. • Controls longitudinal direction automatically, leaving the following vehicles entirely controlled by the drivers.	Peloton Technology	(Auburn University 2017)
PATH	• Originally developed to form the "platoons" of up to 10 passenger cars. • Currently applicable for both lightweight cars and heavy trucks. • Controls fully automated cars operating within AHS. • Controls transverse and longitudinal direction of travel.	California Partners for Advanced Transportation Technology (PATH) and Volvo Group	(Carbaugh et al. 1998; Michael et al. 1998)
SARTRE	• Developed to allow heavy trucks to form the "platoons" within traffic flow. • The leading truck is operated manually, while the following trucks are driven fully automatically. • No changes to the infrastructure needed; • Controls transverse and longitudinal direction of travel.	Ricardo UK, Robotiker-Tecnalia, Applus+ IDIADA, Institut für Kraftfahrwesen Aachen (IKA), SP Technical Research Institute of Sweden, Volvo Car Corporation and Volvo Technology	(Bergenhem et al. 2010)

KONVOI	• Connect up to 5 vehicles in "platoon. • The leading vehicle is operated manually. • Controls transverse and longitudinal direction of travel.	RWTH University Aachen (Germany)	(Wille et al. 2014)
GCDC	• Applicable for mixed traffic platoons. • "Platoons" are operated by vehicle leading the fleet which can change the role and become following. • Controls longitudinal direction of travel.	Halmstad University, AnnieWAY, Karlsruhe Institute of Technology, KTH Truck, KTH Royal Institute of Technology, Chalmers Car, Chalmers University of Technology, Chalmers Truck, Chalmers University of Technology, A-Team, Eindhoven University of Technology / Fontys University of Applied Sciences, Heudiasyc, Université de Technologie de Compiègne, Derivative, University of Alcalá, KTH Experimental Car, KTH Royal Institute of Technology, Latvia, University of Latvia	(Englund et al. 2016)
Energy-ITS	• Developed to allow heavy trucks to operate jointly within a dedicated lane. • Used road markers and onboard scanning sensor. • Controls transverse and longitudinal direction of travel.	Japanese Ministry of Economy, Trade, and Industry	(Tsugawa et al. 2011)
SCANIA	• Designed for heavy vehicles. • Controls longitudinal direction automatically, while lateral movement is controlled manually.	Scania Group and KTH (The Royal Institute of Technology)	(Alam 2014; Scania Group n.d.)

SCENARIOS FOR TRUCK PLATOONING FORMATION

Despite obvious advantages of the AOT, the disadvantages include the risk of system malfunction due to the technical fault or unauthorized access and drivers' actions in the situations that need human intelligence (road accident, route change or detours, interaction with the other traffic disjunction of trucks in "platoon," etc.). The challenges of introducing the "truck platoons" to the traffic planning are associated with the types of truck platoons or the scenario of truck "platoon" formation. (Bhoopalam et al. 2018), (Janssen et al. 2015), (Sokolov et al. 2017) and (Liang et al. 2014) define three possible scenarios of forming "truck platoons": **scheduled self-organized** "platooning," **real-time or en-route orchestrated** "platooning," and **opportunistic self-organized** "platooning." The scheduled platooning is the regular planned transportation of certain goods along the previously defined route. Because CACC technology enables vehicles to "communicate" and share the information, the truck platoons can be formed once the routes of independent truck drivers overlap. This is reasonable along busy transportation arteries where multiple trucks are driving along for long miles. Although the first two scenarios are implemented as events planned in advance or by the preliminary or real-time announcement, the opportunistic self-organized platooning can occur spontaneously. Therefore, any type/class (FHWA class) can potentially become a part of "platoon"(Liang et al. 2014). It involves consideration of extreme GVW and axle load combinations and their impact on transportation structures (instant and long-term effect).

Currently, while the platooning technology is not commonly used and the opportunistic self-organized platooning scenario is unlikely, the effect of it can be evaluated through simulation (Auburn University 2017; Liang et al. 2014). At Auburn University, the traffic simulation was utilized using ATRI (American Transportation Research Institute) traffic data to assess the possible frequency of truck "platooning" on the highways and estimate possible fuel savings. The database consisted of 876 trucks recorded at a 300-mile segment of I-94 in North Dakota. The results show the possibility of the truck to form a "platoon" was about 30-45 percent per database and remain in the "platoon" for 55-75 percent of the considered road segment. Traffic simulation using 1,800 heavy-duty vehicles and road mapping algorithms resulted in a truck "platooning" rate of 1.2 percent. According to Peter Appel Transport, the estimated distance vehicles can stay in "platoon" on a 123-km segment of the road from LDC Geldermalsen to RDC Zwolle (both in the Netherlands) is 70 percent (Janssen et al. 2015). The map-matching algorithm was utilized by (Liang et al. 2014 p.) to investigate the possibility and fuel-saving effect due to spontaneous "platoon" formation. The time stamps and relative speed of consecutive vehicle records were analyzed to investigate if trucks follow each other in real life on the same route. The changes in relative speed were tracked to distinguish possible spontaneous and coordinated (catch-up) platoons. The resultant rates for spontaneous and pre-planned cases were 1.2 percent and 6.97 percent (25-km route), respectively.

There are a number of studies focusing on the traffic mix, or what type of vehicles can form, within a platoon (Alam 2014; van de Hoef 2016; Larsson et al. 2015; Liang et al. 2014, 2016; Luo et al. 2018; Meisen et al. 2008; Sokolov et al. 2017; Zhang et al. 2017) and primarily it depends on the purpose of creating a platoon. There are two main objectives specified by the platooning service developers: fuel-savings and safety of truck operations (Bhoopalam et al. 2018). The first objective commonly associated with the maximizing the number of trucks within a platoon operating at a minimum possible distance. The latter, on the contrary, is associated with limiting the number of connected vehicles at a distance sufficient for safe deceleration.

Another obstacle indicated by (Berger 2016; Bhoopalam et al. 2018; Brizzolara 2016; Meisen et al. 2008) is incompatibility of the CACC systems installed on different types of trucks. Therefore, the first commercial deployment of the platooning technology is more possible to occur within the same brand truck or the same transportation company. (Meisen et al. 2008) emphasizes that, in case of transporting hazardous goods, the platoon pre-planning approach is reasonable. (Sokolov et al. 2017) pointed out the fuel saving effect reaches its maximum when the trucks remain in a platoon for most or all of their travel time. This is most probable to be controlled/pre-planned and centrally coordinated. The researchers compare the scenarios of coordinated and uncoordinated platooning regarding fuel-efficiency using transportation system simulator (POLARIS). The ratios of distance truck traveled within a platoon were compared for both scenarios. While the distance-in-platoon ratio was three times higher for the coordinated platooning case, the wait time difference was about 5 minutes (vs. opportunistic platooning wait-time=0). The highest effect regarding a distance-in-platoon ratio was achieved with the wait time =10 minutes.

The issue of liability/trust comes into play once vehicles from different fleets/companies in a platoon share the information about the trip planning. Regarding a truck platooning scenario, it is even more possible to pre-plan the platooning formation and operation for the entire route. (Janssen et al. 2015) considered limitations related to the allowable platoon length of 50 m so that not to create an obstacle to other traffic. This is also related to road planning because of existing turnarounds and merging lanes. The issue of V2V communication in case of long multi-truck platoons has been raised by (Chardaire et al. 2005; Tuson and Harrison 2005). The total fuel savings due to platooning is only significant (10-20 percent) when vehicles operate closely spaced (10-16m - (Bonnet and Fritz 2000)) and with high speed (60-80km/h). Therefore, in the United States, the most advantageous routes will be long stretches of the interstate highways.

TRUCK IN PLATOONING TESTING - VEHICLES AND CONFIGURATIONS

Technical abilities of the developed AOT for platooning were rapidly tested and demonstrated (Auburn University 2017; Bhoopalam et al. 2018; Browand et al. 2004; Janssen et al. 2015; McAuliffe et al. 2018; Roberts et al. 2016; “Truck Platooning | California PATH” n.d.; Yang et al. 2018). The details are summarized in Table A-2. The main objective of most of the field tests is to determine fuel consumption reduction due to the electronic coupling of the vehicles with regard to the following distance, speed, and weight of the trucks. The percentages of the fuel consumption reduction are summarized in Figure A-1 and Figure A-2

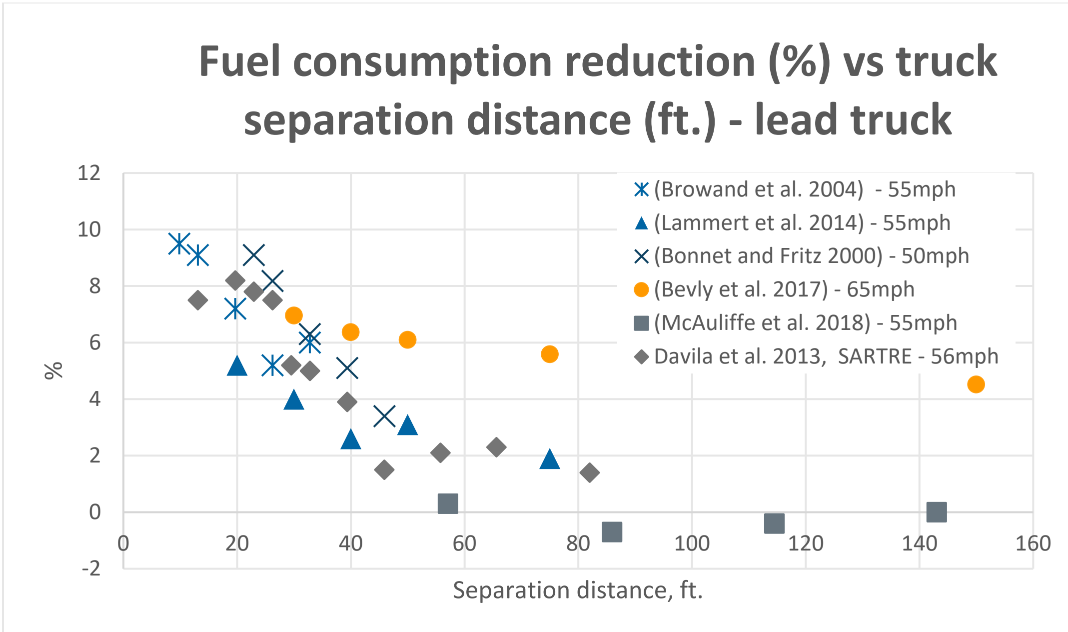

Figure A-1. Summary of the fuel consumption reduction for the lead truck vs. the following distance

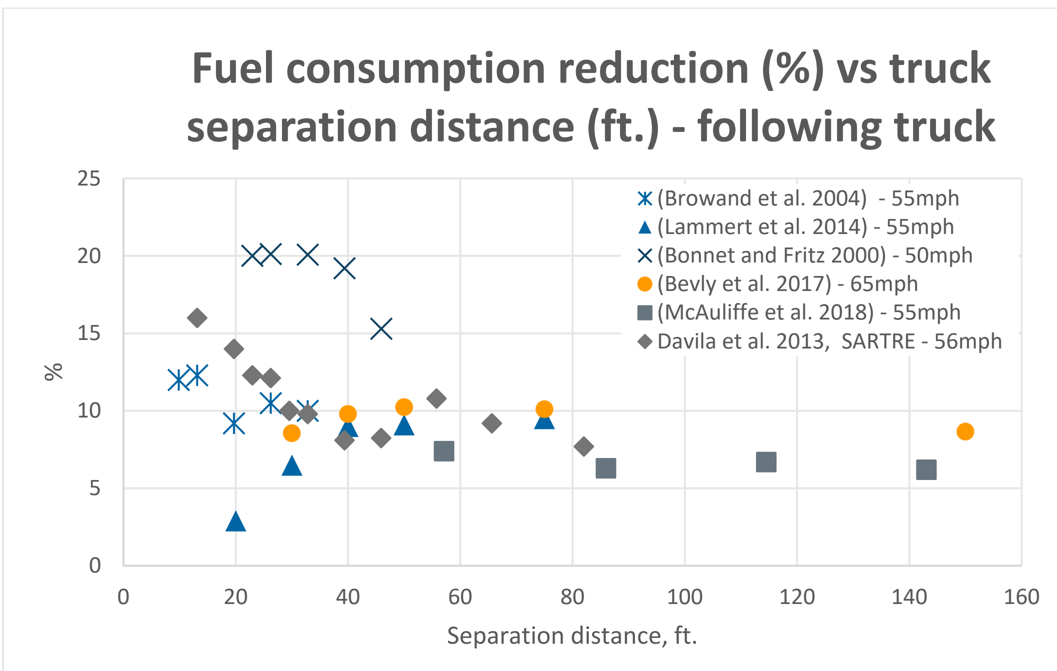

Figure A-2. Summary of the fuel consumption reduction for the trailing truck vs. the following distance

The fuel efficiency of heavy trucks moving jointly due to the improved aerodynamics of the fleet was mentioned in the chapter "Commercial vehicles" in "Aerodynamics of Road Vehicles"(1998) (Götz and Mayr 1998). Gotz and Mayr indicated a high rate of fuel savings (about 10 percent) even in the case of long distances (20-80m) between trucks weighing 40 metric tons (88kips). Bonnet and Fritz (Bonnet and Fritz 2000) in their test obtained even more promising results within European Commission PROMOTE-CHAUFFEUR project. The lead 62-kip truck showed 6 percent of fuel reduction, while the following truck reached 21 percent with the spacing of 10m between vehicles and speed of 50 mph.

California PATH and **Volvo Group** were deeply involved in the development of a cooperative cruise control system (Carbaugh et al. 1998; Michael et al. 1998) funded by FHWA and Caltrans. Recently the performance of CACC systems was demonstrated in San Jose, CA (2016), Port of Los Angeles (2017) and Washington DC (2017). The first trials of vehicles operating jointly on the short distance were conducted by PATH to demonstrate how the increase of the vehicle grading force can lead to the fuel efficiency/ savings (Michaelian and Browand 2001; "Public Roads - Demo '97: Proving Ahs Works, July/August 1997 -" n.d.). One of the first truck platooning testing was described by Bonnet and Fritz (Bonnet and Fritz 2000) where two 5-axle trucks were operated with a following distance of 7-14m with 50 mph speed. The reported fuel savings made up to 6 percent for the leading truck and over 20 percent for the trailing truck.

The fuel-efficiency of two trucks moving in a single platoon was investigated by **University of California** and partners (State of California Business, Transportation, and Housing Agency, Department of Transportation; and the United States Department of Transportation, FHWA) within the PATH program (Browand et al. 2004). The total fuel savings were measured at about 10 percent for a lead truck and 6 percent for the following one at a spacing of 10m. The shorter spacing (3-10m) cases resulted in higher fuel savings: 5-10 percent a lead truck and 10-12 percent for the following one (Figure A-3).

A series of tests and public demonstrations were conducted to assess the usability of a CACC system for the truck drivers. The system allows selection of the time-gap in between trucks: 0.6-1.18 sec which corresponds to 14.8 to 44.3m distance at a speed of 55mph. Three Volvo Class 8 empty trucks (3-4 axles single trailer vehicles) were utilized for the test. The drivers' experience of operating platoons via CACC system was evaluated through a questionnaire. Among other responses, the short time-gap (0.6-0.9s which correspond to 14.8-22.1m) was ranked the most comfortable for joint driving.

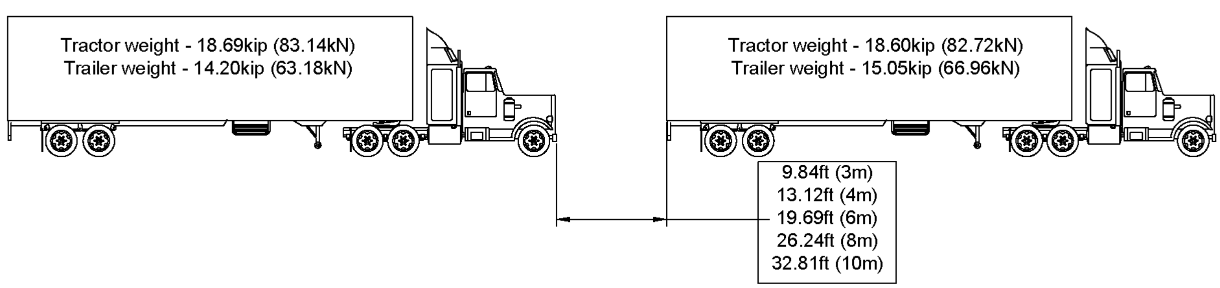

Figure A-3. Two 5-axle Freightliner trucks fuel-saving test at Crows Landing, California December 4, 2003. (Browand et al. 2004)

Two fuel-saving tests were conducted in Blainville, Quebec, in 2016 as part of the **FHWA Exploratory Advanced Research** Project in collaboration with **Transport Canada** and **California PATH** and Volvo Trucks (McAuliffe et al. 2018). The testing fleet consisted of four trucks: one 2013 International ProStar aerodynamic sleeper-cab + 53 ft. Utility model 4000D-X dry-van trailer (control vehicle) and three MY2015 Volvo model VNL 670 aerodynamic sleeper-cabs+53 ft Utility model 4000D-X dry-van trailers (test trucks). The vehicles were tested on the oval test track "Bravo." The impact of four parameters, such as spacing between trucks, GVW, speed, and truck configuration, on total fuel savings was investigated. The considered time gaps were 1.5 s, 1.2 s, 0.9 s, and 0.6 s, which corresponds to the spacing of 44m, 35m, 26m, and 17m for speed of 65mph and 0.71 s, which corresponds to 17m spacing with speed of 55mph (Auburn University 2017; Bhoopalam et al. 2018; Browand et al. 2004; Janssen et al. 2015; Roberts et al. 2016; "Truck Platooning | California PATH" 1997; Yang et al. 2018). The lead vehicle experienced the lowest fuel savings and it decreased with the increase of the spacing distance, while the following vehicles exceed 10 percent of the fuel saving at 17m gap (McAuliffe et al. 2018).

The **Auburn University** research team investigated the economic effect of platooning within FHWA's Exploratory Advanced Research (EAR) in cooperation with Peterbilt Truck, American Transportation Institute, Peloton Technology, and Meritor, Inc. A sponsored study was primarily focused on the analysis of commercial benefits and challenges of the truck "platooning" option and future perspective of this technology (Figure A-4). The evaluation of fuel efficiency of using the then-proposed DATP was the primary objective of the study. To demonstrate the performance of the newly developed DATP system (Peloton), two Peterbilt 579 tractors with Smartway 53ft trailers were tested. They were equipped with cameras, human-machine interface, computers, and DSRC radios for connecting the trucks. They were first tested on NCAT (National Center of Asphalt Technology) at Auburn University and further on the test track at the Transportation Research Center (TRC) in Ohio for SAE Type II Fuel Economy testing (Figure A-4). The total team fuel savings reached a maximum at 30ft spacing and 65 mph, while the following truck saved up to 10 percent at a spacing of 50ft. It was also noticed that the following truck achieved a fuel savings at 4.5 percent at the distance of 150ft even when there was no significant fuel efficiency for the lead truck.

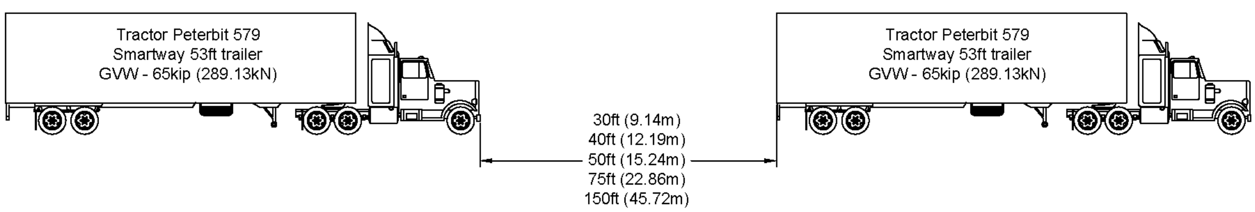

Figure A-4. Demonstration of DATP (Peloton) platooning technology(Auburn University 2017)

The aerodynamic modeling (a two-truck leader-follower platooning train) performed as a Computational Fluid Dynamics (CFD) model to investigate the economic effect due to a lead-vehicle drag reduction showed the reduction of fuel consumption of the following truck even with a following long distance (>100ft). Different distances between the lead and follower truck were considered ranging from 5-100ft. The modeling confirmed the results of the fuel consumption field testing performed by Lammert et al. (2014) that pointed out the reverse fuel saving effect once the trucks were travelling less than 50ft apart. The fuel economy testing performed using two 65kip 5-axle single trailer trucks confirmed the highest total fuel efficiency for a team of two jointly moving trucks at the distance of 30ft and highest fuel efficiency for the following truck only when the distance is 50ft. Therefore, the optimum headway distance for trucks operating in "platoons" controlled by DATP is recommended as a range from 50-75ft. The resultant total fuel saving per platoon exceeded 5 percent for most of the cases of time gaps and a speed of 65mph. This fuel savings was also demonstrated in the other field tests (Roeth 2013).

Returning to the field testing reported by Lammert (National Renewable Energy Laboratory) (Lammert et al. 2014) the two tandem 5-axle single trailer vehicles were tested moving in a platoon with speed of 70mph and distance of 20-75ft. The total team fuel savings ranged from 3.5 percent to 6.4 percent in case of 30ft vehicle spacing and 50mph speed in comparison to trucks operating singly. The test results show the peak fuel saving of the lead truck at the short spacing of 30ft, while the following truck demonstrated the increase of the fuel savings with the increased gap (75ft). The case with the shortest spacing between trucks of 20ft, however, reduced fuel savings (Lammert et al. 2014; Roberts et al. 2016).

The earlier developments of Cooperative Adaptive Cruise Control system by **Peloton** was tested in 2013 in Utah (Roeth 2013) under **North America Council for Freight Efficiency (NACFE)**. Two 5-axle single trailer trucks with 36ft spacing were employed to assess the fuel-saving effect due to a drag force. The test was performed following a modified SAE J1321 procedure. The resultant fuel savings were 4.5 percent and 10 percent for the lead and following vehicle, respectively.

A comprehensive study of the consequence of utilizing truck platooning technology was initiated by the Florida Department of Transportation (FDOT) and Florida Highway Patrol (FHP). Although in Florida it is still prohibited for heavy trucks to operate in a distance closer than 300ft for safety reasons, **DAPT** technology is being recognized as a mechanism allowing drivers to maintain a shorter distance safely (according to National Highway Traffic Safety Administration) and reduce fuel consumption in long distances (Crane et al. 2018).

In Europe, within **SARTRE (Safe Road Trains for the Environment)** project (Davila et al. 2013; "The SARTRE project" n.d.) the mixed traffic platooning test was conducted in both test tracks and as part of the highway. The lead truck driven manually was operating the mixed traffic platoon. The 4-15m spacings between vehicles (two 3-axle trucks and three lightweight cars) were maintained. The resultant fuel consumption reduction was in the range from 8 percent to 1 percent for a lead truck for spacing 4m and 15m, respectively. The highest fuel efficiency was recorded for the following (at 4m distance) truck 16 percent. This percent was gradually decreasing to 8 percent with the increase of the following distance (to 15m). The trail cars show a similar trend: up to 15 percent at the 8m distance and 6-11 percent for 15m distance. All tests proved the increase of the fuel efficiency of different vehicles operating jointly.

A similar study was performed by Alam within KTH Swedish Royal Institute of Technology in 2011 (Alam 2014). In this study, two 4-axles, 86 kip tractor-trailer vehicles operating with Scania (Scania Group n.d.) were tested on a dedicated section of a Swedish highway. The trucks were driven at a speed of 43 mph using various spacings. The maximum fuel reduction of 7.7 percent was recorded for the following truck while the leading truck showed just 4.7 percent when both vehicles had identical configuration and GVW.

Towards commercial deployment of truck platooning in the specified roads within 5-10 years **Texas DOT** funded a large scale demonstration of truck platooning operation (Kuhn et al. 2017). The fuel saving analysis was performed based on traffic simulation via Vissim simulation software. First, the traffic routes (segments I-35, I-45, I-40, and I-10) with the highest tonnage were determined as potential corridors for truck platooning. Then, the expected traffic mix model developed using the available traffic records databases. Truck platoons' formation was determined through the joining time gap equal to 10-20s with the speed 65 and 75 mph. The desired spacing between simulated vehicles in the platoon was selected as 17m and 32m (Nowakowski et al. 2015). The resultant fuel savings ranged from 0 to 12 percent.

Table A-2, Figure A-1 and Figure A-2 summarize the most desired time gaps/distances in between trucks in "platoon"; however, state laws prohibit vehicles moving at close distances for safety reasons (Perry and Ahn 2018).

Table A-2. Testing of automated operation technologies for truck platooning

Type of trucks	**# of Trucks in Platoon**	**Distance**	**Location**	**Details**	**Reference**
Two Mercedez-Benz heavy-duty ACTROS trucks in tandem	2	22.96ft (7m), 26.25ft (8m), 32.81ft (10m), 39.37ft (12m), 45.93ft (14m).	Papenburg, Northern Germany	Fuel-saving test; Lead truck(empty)= 31.97kip (14.5 tons) Following truck(loaded)= (61.73kip) 28 tons Speed=50mph (80km/h); =37.28mph (60km/h)	(Bonnet and Fritz 2000)
Peterbilt 579 tractors with Smartway 53ft trailers with Peloton prototype DATP	2	30ft (9.14m), 40ft (12.19m), 50ft (15.24m), 75ft (22.86m), 150ft (45.72m)	Transportation Research Center (TRC), (Ohio)	SAE Type II Fuel Economy testing; DATP system; GVW=65kips (29,483.5kg); Speed=65mph (104.607kmph); Number of axles =5; Number of trailers=1;	(Bevly et al. 2017)
Two Class 8 5-axle single trailer (Laden Trailers (65kips)	2	20ft (6.09m), 30ft (9.14m), 40ft (12.19m), 50ft (15.24m), 75ft (22.86m)	The Continental Tire Uvalde Proving Grounds track (Texas)	SAE Type II Fuel Economy testing Tractors=MY 2011 Aero Tractors Trailer=Laden Trailers (65kips (29,483.5kg)) GVWR=80kips (36,287.39kg) Speed=70mph (112.65kmph)	(Lammert et al. 2014)
Three Volvo Class 8 tractor-trailer trucks	2, 3	48.55ft (14.8m)-	From UC Berkeley Richmond	Testing of 5.9 GHz DSRC (Dedicated Short-Range	("Truck Platooning | California

Type of trucks	# of Trucks in Platoon	Distance	Location	Details	Reference
		145.34ft (44.3m)	Field Station (RFS) in Richmond, CA to Westley, CA (I-580, US-24, I- 680, I-580, I-5)	Communication) application within CACC; CACC system; Empty trailer; Speed=55mph (88.51kph)	PATH" n.d.; Yang et al. 2018)
Two identical 5-axle Freightliner tractors pulling 53-foot trailers	2	9.84 ft (3m), 13.12 ft (4m), 19.69 ft (6m), 26.24 ft (8m), 32.81 ft (10m)	Crows Landing, California	Fuel-saving testing of two tandem trucks depending on the distance. 1st trailer empty; 2nd contains Mobile Emissions 2 empty trailers Research Laboratory Speed=55 mph (88.51kph);	(Browand et al. 2004)
Langere en Zwaardere Vrachtautocombinatie (LZVs) - a 57m combination of two vehicles	2	22.96ft (7m)	Netherlands	Common European practice of trucks operating in "platoon." More than 164.04ft (50m) will create an obstacle for the other members of the traffic flow.	(Janssen et al. 2015)
Three tractor-trailer single trailer trucks	3	32.81ft (10m)	Japan	Energy-ITS truck platooning system testing within ITS project by Japanese Ministry of Economy, Trade, and Industry	(Tsugawa et al. 2011)
2013 International ProStar aerodynamic sleeper-cab (Control tractor), Three e MY2015 Volvo model VNL 670 aerodynamic sleeper-cabs (Test tractors) with 53 ft dry-van trailers,	1, 3, 4	55.17ft (17m), 85.30ft (26m), 114.83ft (35m), 144.36ft (44m),	Blainville, Québec	SAE J1321 Type II fuel consumption test; Control tractor mass= 18.77 kips (8,515 kg) Test tractor mass= 18.77 kips (8,515 kg); Trailer mass= 46.03 kips (20,880 kg); Total GVW= 64.8kips (29,395 kg)	(McAuliffe et al. 2018)

Type of trucks	# of Trucks in Platoon	Distance	Location	Details	Reference
Utility model 4000D-X				Speed=55mph (88.51kph), 65mph (104.61kph);	
Two tandem 3-axle single trailer vehicles	2	55.77ft (17m), 104.99 (32m)	Austin, Texas	Demonstration of truck platooning on specified roads in Texas - Simulation Experiment; Speed=65 mph(104.61kph) and 70 mph(120.70kph)	(Kuhn et al. 2017)
Two 5-axle single trailer vehicles	2	36ft (10.97m)	Utah	Peloton Technology Platooning Test - SAE J1321 consumption test; Tractors=MY 2011 Aero Tractors; Trailers=Laden Trailers Speed= 64 mph (102.99kmph);	(Roeth 2013)
Mixed Traffic: Two 3-axle trucks and three lightweight cars	5	13.12ft (4m), 19.68ft (6m), 22.96ft (7m), 26.24ft (8m), 29.53ft (9m), 32.82ft (10m), 39.37ft (12m), 45.93ft (15m)	Europe	Fuel consumption tests; Speed= 56 mph, (90.12km/h)	(Davila et al. 2013; "The SARTRE project" n.d.)

STATE REGULATION OF PLATOONING OPERATION

This technology is expected to be commercially utilized in EU and the United States in the nearest decade (Janssen et al. 2015) if the program is sufficiently supported, funded, and correctly introduced to the public. There is still a need for platooning technology to prove its safety and reliability. Perry and Ahn (2018) provides an overview of the state restrictions of electronically coupled vehicles on the public roads along 10-state Mid-America Association of Transportation Officials (MAASTO) traffic corridor. They indicate that the level of public acceptance and understanding of the truck platooning benefits is low. Most of the states do not have specific regulations for truck platooning (e.g., Illinois, Iowa, Minnesota, Missouri, Ohio, and Kansas. However, some of them, such as Indiana (§ 9-21-8-15), Iowa (§ 321.308), Florida (§ 316.0895), and Missouri (§ 304.044) restrict the minimum following distance in between heavy vehicles to 300ft (91.44m). The minimum following distance in between commercial motor vehicles (CMV) is restricted to 500ft (152.4m) in Minnesota (Perry and Ahn 2018). An exemption of maintaining the minimum following distance by commercial motor vehicles (CMV) appeared in Kentucky with a bill signed in March 2018. Similar exemption exists in Michigan along with regulations for truck platooning operation in different regimes. In Alabama, when the following truck in a platoon is equipped with an electronic brake system, this truck is allowed to violate the minimum following distance for trucks operating singly (Senate Bill #125). The minimum following distance in Arkansas is 200ft, but electronically coupled vehicles are exempt from this restriction (House Bill #1754). Similar exemptions exist in Georgia (House Bill #472), Nevada (Assembly Bill # 69), North Carolina (House Bill # 716), South Carolina (House Bill #3289), Utah (House Bill #373), and Tennessee (Senate Bill #676)

CONCLUSIONS:

The analysis of the available literature resulted in the following conclusions:

- Most available literature deals with the development of the technology (hardware and software), the investigation of safety issues, and fuel savings. No studies of the effect of platoons on bridges could be located.
- There are a variety of systems for platooning developed worldwide. These systems differ in the number of vehicles included in a platoon, the direction of control (lateral and/or longitudinal), and degree/level of human control (fully autonomous/partially operated by the driver), etc. However, the trucks need to be upgraded with assisting systems (ACC, AEB, LKA, etc.) to support adaptive cruise control technology (ACC).
- The common configuration of vehicles to form the platoon is 3-, 4-, or 5-axle trucks (FHWA Class 8: 3- or 4-axle single trailer, Class 7: 4- or more axle single unit, and Class 9: 5-axle single trailer).
- The fuel efficiency of jointly operating vehicles mostly depends on the spacing between trucks, number of vehicles in the platoon, vehicle configuration, speed, and the time vehicles are in the "platoon."
- The maximum fuel consumption reduction for a two-truck platoon corresponds to the spacing between vehicles (GVW of 60-80kips and speed 65mph) equal to 30-50ft. Peak fuel saving for the lead vehicle occurs at a 30ft spacing (4-6 percent), while trailing vehicles demonstrate the highest savings (10-15 percent) at 50ft spacing and maintain it for the longer spacing (100-150ft).

The optimum, most efficient, truck platoon configurations, however, contradict many state code regulations that limit spacing in between vehicles to a minimum following distance

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APPENDIX B

LOAD EFFECTS FOR HL-93 AND HS 20 DESIGN LOADS

AND

THE TRUCK PLATOONS INVESTIGATED

APPENDIX B

LOAD EFFECTS FOR HL-93 AND HS 20 DESIGN LOADS
AND
THE TRUCK PLATOONS INVESTIGATED
ON
SIMPLE SPANS AND TWO AND THREE EQUAL CONTINUOUS SPANS

Table B-1 through Table B-9 list the calculated load effects for different platoons along with different components of the HL-93 and HS 20 design loads (truck, tandem, and uniform load). For the HS 20 loading, the load effects due to the lane load include both the uniform load and the concentrated loads included in the definition of the lane load (18 kips concentrated load for moment calculations, 26 kips concentrated load for shear calculations and two concentrated loads of 18 kips each for the calculations of negative moments at intermediate supports of continuous spans).

All listed values do not include the dynamic load allowance (impact).

Table B-1 Maximum Unfactored Load Effects for 30 ft. Long Spans

Loading	Simple Span		Two-Span Continuous			
	M midspan (ft.k)	End shear (kips)	Pos. M span 1 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear at int. support (kips)
HL-93 Truck	282	50	229	-192	46	-53
HL-93 Tandem	325	47	267	-141	46	-48
HL-93 Lane	72	10	55	-71	8	-12
HL-93 Truck	-	-	-	-158	-	-
HS 20 Truck	282	50	229	-192	46	-53
HS 20 Tandem	312	45	256	-135	44	-46
HS 20 Lane	207	36	166	-175	34	-38
33-1-00	182	31	149	-152	27	-33
33-2-30	182	31	149	-152	27	-33
33-2-50	182	31	149	-152	27	-33
33-2-70	182	31	149	-152	27	-33
33-3-30	182	31	149	-152	27	-33
33-3-50	182	31	149	-152	27	-33
33-3-70	182	31	149	-152	27	-33
33-4-30	182	31	149	-152	27	-33
33-4-50	182	31	149	-152	27	-33
33-4-70	182	31	149	-152	27	-33
3S2-1-00	222	34	178	-185	32	-37
3S2-2-30	222	34	178	-185	32	-37
3S2-2-50	222	34	178	-185	32	-37
3S2-2-70	222	34	178	-185	32	-37
3S2-3-30	222	34	178	-185	32	-37
3S2-3-50	222	34	178	-185	32	-37
3S2-3-70	222	34	178	-185	32	-37
3S2-4-30	222	34	178	-185	32	-37
3S2-4-50	222	34	178	-185	32	-37
3S2-4-70	222	34	178	-185	32	-37
T-1-00	239	37	193	-172	36	-39
T-2-30	239	37	193	-172	36	-39
T-2-50	239	37	193	-172	36	-39
T-2-70	239	37	193	-172	36	-39
T-3-30	239	37	193	-172	36	-39
T-3-50	239	37	193	-172	36	-39
T-3-70	239	37	193	-172	36	-39
T-4-30	239	37	193	-172	36	-39
T-4-50	239	37	193	-172	36	-39
T-4-70	239	37	193	-172	36	-39

Table B-1 (cont'd.) Maximum Unfactored Load Effects for 30 ft. Long Spans

Loading	Three-Span Continuous					
	Pos. M span 1 (ft.k)	Pos. M span 2 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear left of 1st int. support (kips)	Shear right of 1st int. support (kips)
HL-93 Truck	226	181	-183	46	-53	50
HL-93 Tandem	263	217	-150	46	-48	47
HL-93 Lane	58	44	-67	9	-12	11
HL-93 Truck	-	-	-165	-	-	-
HS 20 Truck	226	177	-183	46	-53	50
HS 20 Tandem	252	208	-144	44	-46	45
HS 20 Lane	168	138	-165	35	-38	37
33-1-00	147	99	-144	27	-34	30
33-2-30	147	99	-144	28	-34	30
33-2-50	154	99	-144	27	-34	30
33-2-70	149	99	-144	27	-34	30
33-3-30	147	99	-144	28	-34	30
33-3-50	154	99	-144	27	-34	30
33-3-70	149	99	-144	27	-34	30
33-4-30	147	99	-144	28	-34	30
33-4-50	154	99	-144	27	-34	30
33-4-70	149	99	-144	27	-34	30
3S2-1-00	175	111	-176	32	-37	36
3S2-2-30	175	111	-176	32	-37	36
3S2-2-50	184	111	-176	33	-37	36
3S2-2-70	175	111	-176	33	-37	36
3S2-3-30	175	111	-176	32	-37	36
3S2-3-50	184	111	-176	33	-37	36
3S2-3-70	175	111	-176	33	-37	36
3S2-4-30	175	111	-176	32	-37	36
3S2-4-50	184	111	-176	33	-37	36
3S2-4-70	175	111	-176	33	-37	36
T-1-00	190	131	-157	36	-39	38
T-2-30	190	131	-157	36	-39	38
T-2-50	200	131	-157	36	-39	38
T-2-70	190	131	-157	36	-39	38
T-3-30	190	131	-157	36	-39	38
T-3-50	200	131	-157	36	-39	38
T-3-70	190	131	-157	36	-39	38
T-4-30	190	131	-157	36	-39	38
T-4-50	200	131	-157	36	-39	38
T-4-70	190	131	-157	36	-39	38

Table B-2 Maximum Unfactored Load Effects for 50 ft. Long Spans

Loading	Simple Span		Two-Span Continuous			
	M midspan (ft.k)	End shear (kips)	Pos. M span 1 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear at int. support (kips)
HL-93 Truck	620	59	501	-320	56	-62
HL-93 Tandem	575	48	472	-238	48	-49
HL-93 Lane	200	16	152	-198	14	-20
HL-93 Truck	-	-	-	-352	-	-
HS 20 Truck	620	59	501	-320	56	-62
HS 20 Tandem	552	46	453	-228	46	-47
HS 20 Lane	425	42	338	-371	40	-46
33-1-00	394	43	310	-313	39	-46
33-2-30	394	43	310	-346	39	-48
33-2-50	394	43	310	-313	39	-46
33-2-70	394	43	310	-313	39	-46
33-3-30	394	43	310	-346	39	-48
33-3-50	394	43	310	-313	39	-46
33-3-70	394	43	310	-313	39	-46
33-4-30	394	43	310	-346	39	-48
33-4-50	394	43	310	-313	39	-46
33-4-70	394	43	310	-313	39	-46
3S2-1-00	439	45	357	-301	41	-49
3S2-2-30	439	45	357	-376	41	-51
3S2-2-50	439	45	357	-301	41	-49
3S2-2-70	439	45	357	-301	41	-49
3S2-3-30	439	45	357	-376	41	-51
3S2-3-50	439	45	357	-301	41	-49
3S2-3-70	439	45	357	-301	41	-49
3S2-4-30	439	45	357	-376	41	-51
3S2-4-50	439	45	357	-301	41	-49
3S2-4-70	439	45	357	-301	41	-49
T-1-00	469	41	378	-363	40	-45
T-2-30	469	42	378	-365	40	-47
T-2-50	469	41	378	-363	40	-45
T-2-70	469	41	378	-363	40	-45
T-3-30	469	42	378	-365	40	-47
T-3-50	469	41	378	-363	40	-45
T-3-70	469	41	378	-363	40	-45
T-4-30	469	42	378	-365	40	-47
T-4-50	469	41	378	-363	40	-45
T-4-70	469	41	378	-363	40	-45

Table B-2 (cont'd.) Maximum Unfactored Load Effects for 50 ft. Long Spans

Loading	Three-Span Continuous					
	Pos. M span 1 (ft.k)	Pos. M span 2 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear left of 1st int. support (kips)	Shear right of 1st int. support (kips)
HL-93 Truck	493	398	-313	56	-62	59
HL-93 Tandem	466	391	-254	47	-49	48
HL-93 Lane	160	121	-185	14	-20	19
HL-93 Truck	-	-	-345	-	-	-
HS 20 Truck	493	398	-313	56	-62	59
HS 20 Tandem	448	375	-243	46	-47	47
HS 20 Lane	344	278	-349	40	-46	45
33-1-00	305	224	-301	39	-46	42
33-2-30	305	224	-301	39	-46	44
33-2-50	310	224	-301	40	-46	42
33-2-70	327	224	-301	39	-46	42
33-3-30	305	224	-301	39	-46	44
33-3-50	310	224	-301	40	-46	42
33-3-70	327	224	-301	39	-46	42
33-4-30	305	224	-301	39	-46	44
33-4-50	310	224	-301	40	-46	42
33-4-70	327	224	-301	39	-46	42
3S2-1-00	351	276	-296	41	-49	45
3S2-2-30	351	247	-343	41	-50	47
3S2-2-50	371	276	-296	41	-49	45
3S2-2-70	370	276	-296	42	-49	45
3S2-3-30	351	247	-343	41	-50	47
3S2-3-50	371	276	-296	41	-49	45
3S2-3-70	370	276	-296	42	-49	45
3S2-4-30	351	247	-343	41	-50	47
3S2-4-50	371	276	-296	41	-49	45
3S2-4-70	370	276	-296	42	-49	45
T-1-00	373	262	-352	40	-45	45
T-2-30	373	254	-352	40	-46	45
T-2-50	373	262	-352	40	-45	45
T-2-70	389	262	-352	40	-45	45
T-3-30	373	254	-352	40	-46	45
T-3-50	373	262	-352	40	-45	45
T-3-70	389	262	-352	40	-45	45
T-4-30	373	254	-352	40	-46	45
T-4-50	373	262	-352	40	-45	45
T-4-70	389	262	-352	40	-45	45

Table B-3 Maximum Unfactored Load Effects for 70 ft. Long Spans

Loading	Simple Span		Two-Span Continuous			
	M midspan (ft.k)	End shear (kips)	Pos. M span 1 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear at int. support (kips)
HL-93 Truck	980	62	791	-444	60	-65
HL-93 Tandem	825	49	679	-334	48	-49
HL-93 Lane	392	22	299	-388	20	-28
HL-93 Truck	-	-	-	-834	-	-
HS 20 Truck	980	62	791	-444	60	-65
HS 20 Tandem	792	47	651	-320	46	-47
HS 20 Lane	707	48	559	-630	46	-54
33-1-00	740	53	572	-403	48	-57
33-2-30	740	53	572	-698	48	-60
33-2-50	740	53	572	-581	48	-58
33-2-70	740	53	572	-430	48	-57
33-3-30	740	53	572	-698	48	-60
33-3-50	740	53	572	-581	48	-58
33-3-70	740	53	572	-430	48	-57
33-4-30	740	53	572	-698	48	-60
33-4-50	740	53	572	-581	48	-58
33-4-70	740	53	572	-430	48	-57
3S2-1-00	785	53	632	-383	49	-57
3S2-2-30	785	53	632	-760	49	-61
3S2-2-50	785	53	632	-645	49	-58
3S2-2-70	785	53	632	-482	49	-57
3S2-3-30	785	53	632	-760	49	-61
3S2-3-50	785	53	632	-645	49	-58
3S2-3-70	785	53	632	-482	49	-57
3S2-4-30	785	53	632	-760	49	-61
3S2-4-50	785	53	632	-645	49	-58
3S2-4-70	785	53	632	-482	49	-57
T-1-00	739	52	601	-464	48	-57
T-2-30	739	53	601	-683	48	-60
T-2-50	739	52	601	-589	48	-58
T-2-70	739	52	601	-468	48	-57
T-3-30	739	53	601	-683	48	-60
T-3-50	739	52	601	-589	48	-58
T-3-70	739	52	601	-468	48	-57
T-4-30	739	53	601	-683	48	-60
T-4-50	739	52	601	-589	48	-58
T-4-70	739	52	601	-468	48	-57

Table B-3 (cont'd.) Maximum Unfactored Load Effects for 70 ft. Long Spans

Loading	Three-Span Continuous					
	Pos. M span 1 (ft.k)	Pos. M span 2 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear left of 1st int. support (kips)	Shear right of 1st int. support (kips)
HL-93 Truck	780	636	-473	60	-66	64
HL-93 Tandem	670	566	-356	48	-49	49
HL-93 Lane	314	237	-362	20	-28	26
HL-93 Truck	-	-	-771	-	-	-
HS 20 Truck	780	636	-473	60	-66	64
HS 20 Tandem	644	543	-342	46	-47	47
HS 20 Lane	572	457	-592	46	-54	52
33-1-00	563	451	-407	48	-58	53
33-2-30	563	355	-647	48	-60	57
33-2-50	563	401	-519	48	-58	54
33-2-70	590	450	-407	48	-58	53
33-3-30	563	355	-647	48	-60	57
33-3-50	563	401	-519	48	-58	54
33-3-70	590	450	-407	48	-58	53
33-4-30	563	355	-647	48	-60	57
33-4-50	563	401	-519	48	-58	54
33-4-70	590	450	-407	48	-58	53
3S2-1-00	622	494	-409	49	-57	53
3S2-2-30	622	379	-709	49	-60	58
3S2-2-50	622	423	-597	49	-58	55
3S2-2-70	627	485	-422	49	-57	53
3S2-3-30	622	379	-709	49	-60	58
3S2-3-50	622	423	-597	49	-58	55
3S2-3-70	627	485	-422	49	-57	53
3S2-4-30	622	379	-709	49	-60	58
3S2-4-50	622	423	-597	49	-58	55
3S2-4-70	627	485	-422	49	-57	53
T-1-00	592	465	-460	48	-57	52
T-2-30	592	388	-639	48	-60	57
T-2-50	592	431	-539	48	-57	54
T-2-70	621	465	-460	48	-57	52
T-3-30	592	388	-639	48	-60	57
T-3-50	592	431	-539	48	-57	54
T-3-70	621	465	-460	48	-57	52
T-4-30	592	388	-639	48	-60	57
T-4-50	592	431	-539	48	-57	54
T-4-70	621	465	-460	48	-57	52

Table B-4 Maximum Unfactored Load Effects for 100 ft. Long Spans

Loading	Simple Span		Two-Span Continuous			
	M midspan (ft.k)	End shear (kips)	Pos. M span 1 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear at int. support (kips)
HL-93 Truck	1520	65	1234	-661	64	-68
HL-93 Tandem	1200	49	988	-478	49	-49
HL-93 Lane	800	32	610	-792	28	-40
HL-93 Truck	-	-	-	-1320	-	-
HS 20 Truck	1520	65	1234	-661	64	-68
HS 20 Tandem	1152	47	949	-459	47	-47
HS 20 Lane	1250	58	981	-1138	54	-66
33-1-00	1340	61	1048	-646	57	-66
33-2-30	1340	65	1048	-1277	57	-71
33-2-50	1340	61	1048	-1261	57	-69
33-2-70	1340	61	1048	-1129	57	-67
33-3-30	1340	65	1048	-1295	57	-76
33-3-50	1340	61	1048	-1261	57	-69
33-3-70	1340	61	1048	-1129	57	-67
33-4-30	1340	65	1048	-1295	57	-76
33-4-50	1340	61	1048	-1261	57	-69
33-4-70	1340	61	1048	-1129	57	-67
3S2-1-00	1322	59	1064	-617	56	-62
3S2-2-30	1389	67	1064	-1184	61	-74
3S2-2-50	1322	61	1064	-1234	56	-67
3S2-2-70	1322	59	1064	-1166	56	-64
3S2-3-30	1389	67	1064	-1282	61	-79
3S2-3-50	1322	61	1064	-1234	56	-69
3S2-3-70	1322	59	1064	-1166	56	-64
3S2-4-30	1389	67	1064	-1326	61	-79
3S2-4-50	1322	61	1064	-1234	56	-69
3S2-4-70	1322	59	1064	-1166	56	-64
T-1-00	1315	61	1064	-636	57	-65
T-2-30	1367	67	1064	-1248	61	-76
T-2-50	1315	61	1064	-1254	57	-69
T-2-70	1315	61	1064	-1141	57	-67
T-3-30	1367	67	1064	-1280	61	-79
T-3-50	1315	61	1064	-1254	57	-69
T-3-70	1315	61	1064	-1141	57	-67
T-4-30	1367	67	1064	-1280	61	-79
T-4-50	1315	61	1064	-1254	57	-69
T-4-70	1315	61	1064	-1141	57	-67

Table B-4 (cont'd.) Maximum Unfactored Load Effects for 100 ft. Long Spans

Loading	Three-Span Continuous					
	Pos. M span 1 (ft.k)	Pos. M span 2 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear left of 1st int. support (kips)	Shear right of 1st int. support (kips)
HL-93 Truck	1217	1006	-705	64	-68	66
HL-93 Tandem	977	828	-510	49	-49	49
HL-93 Lane	642	483	-739	29	-39	37
HL-93 Truck	-	-	-1253	-	-	-
HS 20 Truck	1217	1006	-705	64	-68	66
HS 20 Tandem	938	795	-489	47	-47	47
HS 20 Lane	1009	798	-1068	55	-65	63
33-1-00	1032	833	-689	57	-66	62
33-2-30	1032	651	-1207	57	-71	70
33-2-50	1032	617	-1174	57	-68	67
33-2-70	1032	678	-1042	57	-66	64
33-3-30	1032	625	-1219	57	-75	70
33-3-50	1032	617	-1174	57	-68	67
33-3-70	1032	678	-1042	57	-66	64
33-4-30	1032	625	-1219	57	-75	70
33-4-50	1032	617	-1174	57	-68	67
33-4-70	1032	678	-1042	57	-66	64
3S2-1-00	1048	847	-659	55	-63	60
3S2-2-30	1048	765	-1129	61	-74	68
3S2-2-50	1048	654	-1160	55	-66	65
3S2-2-70	1048	666	-1079	55	-64	62
3S2-3-30	1048	660	-1218	61	-79	75
3S2-3-50	1048	654	-1160	55	-69	65
3S2-3-70	1048	666	-1079	55	-64	62
3S2-4-30	1048	660	-1218	61	-79	75
3S2-4-50	1048	654	-1160	55	-69	65
3S2-4-70	1048	666	-1079	55	-64	62
T-1-00	1047	834	-678	56	-66	61
T-2-30	1047	704	-1177	61	-76	71
T-2-50	1047	647	-1170	56	-68	67
T-2-70	1047	702	-1053	56	-66	64
T-3-30	1047	649	-1193	61	-78	74
T-3-50	1047	647	-1170	56	-68	67
T-3-70	1047	702	-1053	56	-66	64
T-4-30	1047	649	-1201	61	-78	74
T-4-50	1047	647	-1170	56	-68	67
T-4-70	1047	702	-1053	56	-66	64

Table B-5 Maximum Unfactored Load Effects for 130 ft. Long Spans

Loading	Simple Span		Two-Span Continuous			
	M midspan (ft.k)	End shear (kips)	Pos. M span 1 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear at int. support (kips)
HL-93 Truck	2060	67	1676	-878	66	-69
HL-93 Tandem	1575	49	1298	-622	49	-50
HL-93 Lane	1352	42	1030	-1339	36	-52
HL-93 Truck	-	-	-	-1749	-	-
HS 20 Truck	2060	67	1676	-878	66	-69
HS 20 Tandem	1512	47	1246	-597	47	-48
HS 20 Lane	1937	68	1513	-1788	62	-78
33-1-00	1940	65	1534	-900	62	-70
33-2-30	2102	80	1590	-1665	72	-87
33-2-50	1940	71	1534	-1782	64	-77
33-2-70	1940	66	1534	-1789	62	-74
33-3-30	2102	80	1590	-1997	72	-94
33-3-50	1940	71	1534	-1797	64	-83
33-3-70	1940	66	1534	-1789	62	-75
33-4-30	2102	80	1590	-2065	72	-95
33-4-50	1940	71	1534	-1797	64	-83
33-4-70	1940	66	1534	-1789	62	-75
3S2-1-00	1862	62	1502	-840	59	-65
3S2-2-30	2190	84	1749	-1449	76	-92
3S2-2-50	1862	73	1502	-1622	67	-79
3S2-2-70	1862	66	1502	-1678	60	-70
3S2-3-30	2190	84	1749	-2010	76	-99
3S2-3-50	1862	73	1502	-1729	67	-85
3S2-3-70	1862	66	1502	-1678	60	-75
3S2-4-30	2190	84	1749	-2228	76	-100
3S2-4-50	1862	73	1502	-1759	67	-85
3S2-4-70	1862	66	1502	-1678	60	-75
T-1-00	1909	65	1544	-892	62	-69
T-2-30	2222	81	1697	-1621	73	-91
T-2-50	1909	72	1544	-1758	65	-78
T-2-70	1909	67	1544	-1777	62	-74
T-3-30	2222	81	1697	-2121	73	-96
T-3-50	1909	72	1544	-1789	65	-84
T-3-70	1909	67	1544	-1777	62	-76
T-4-30	2222	81	1697	-2139	73	-96
T-4-50	1909	72	1544	-1789	65	-84
T-4-70	1909	67	1544	-1777	62	-76

Table B-5 (cont'd.) Maximum Unfactored Load Effects for 130 ft. Long Spans

Loading	Three-Span Continuous					
	Pos. M span 1 (ft.k)	Pos. M span 2 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear left of 1st int. support (kips)	Shear right of 1st int. support (kips)
HL-93 Truck	1655	1377	-936	65	-69	68
HL-93 Tandem	1283	1091	-663	49	-50	49
HL-93 Lane	1084	817	-1249	37	-51	48
HL-93 Truck	-	-	-1662	-	-	-
HS 20 Truck	1655	1377	-936	65	-69	68
HS 20 Tandem	1232	1047	-637	47	-48	47
HS 20 Lane	1562	1226	-1676	63	-77	74
33-1-00	1512	1235	-960	62	-70	67
33-2-30	1558	1198	-1594	71	-88	79
33-2-50	1512	996	-1688	64	-77	75
33-2-70	1512	929	-1676	62	-73	72
33-3-30	1558	969	-1859	71	-93	88
33-3-50	1512	952	-1698	64	-82	77
33-3-70	1512	929	-1676	62	-74	72
33-4-30	1558	969	-1890	71	-93	89
33-4-50	1512	952	-1698	64	-82	77
33-4-70	1512	929	-1676	62	-74	72
3S2-1-00	1481	1210	-896	59	-65	63
3S2-2-30	1721	1318	-1402	75	-93	84
3S2-2-50	1481	1082	-1552	66	-80	73
3S2-2-70	1481	955	-1587	60	-70	69
3S2-3-30	1721	1149	-1900	75	-98	92
3S2-3-50	1481	948	-1644	66	-84	81
3S2-3-70	1481	955	-1587	60	-74	70
3S2-4-30	1721	1043	-2084	75	-99	94
3S2-4-50	1481	948	-1644	66	-84	81
3S2-4-70	1481	955	-1587	60	-74	70
T-1-00	1521	1228	-951	62	-70	66
T-2-30	1662	1261	-1553	73	-91	85
T-2-50	1521	1036	-1669	64	-79	75
T-2-70	1521	949	-1669	62	-73	72
T-3-30	1662	1032	-1986	73	-95	91
T-3-50	1521	958	-1688	64	-83	78
T-3-70	1521	949	-1669	62	-75	72
T-4-30	1662	1028	-1986	73	-95	91
T-4-50	1521	958	-1688	64	-83	78
T-4-70	1521	949	-1669	62	-75	72

Table B-6 Maximum Unfactored Load Effects for 160 ft. Long Spans

Loading	Simple Span		Two-Span Continuous			
	M midspan (ft.k)	End shear (kips)	Pos. M span 1 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear at int. support (kips)
HL-93 Truck	2600	68	2121	-1088	67	-70
HL-93 Tandem	1950	49	1607	-766	49	-50
HL-93 Lane	2048	51	1561	-2028	45	-64
HL-93 Truck	-	-	-	-2172	-	-
HS 20 Truck	2600	68	2121	-1088	67	-70
HS 20 Tandem	1872	47	1543	-735	47	-48
HS 20 Lane	2768	77	2155	-2581	71	-90
33-1-00	2540	68	2023	-1150	65	-72
33-2-30	3082	94	2452	-1934	85	-104
33-2-50	2612	84	2023	-2149	76	-92
33-2-70	2540	76	2023	-2266	69	-81
33-3-30	3082	94	2452	-2744	85	-111
33-3-50	2612	84	2023	-2426	76	-99
33-3-70	2540	76	2023	-2286	69	-87
33-4-30	3082	94	2452	-3167	85	-113
33-4-50	2612	84	2023	-2555	76	-99
33-4-70	2540	76	2023	-2286	69	-87
3S2-1-00	2402	64	1945	-1057	62	-67
3S2-2-30	3217	95	2559	-1648	87	-104
3S2-2-50	2659	86	2141	-1880	78	-94
3S2-2-70	2402	77	1945	-2039	71	-83
3S2-3-30	3313	98	2575	-2546	87	-111
3S2-3-50	2659	86	2141	-2401	78	-101
3S2-3-70	2402	77	1945	-2158	71	-89
3S2-4-30	3313	98	2575	-3275	87	-115
3S2-4-50	2659	86	2141	-2682	78	-101
3S2-4-70	2402	77	1945	-2180	71	-89
T-1-00	2509	68	2029	-1140	65	-72
T-2-30	3172	95	2534	-1878	86	-105
T-2-50	2737	85	2110	-2107	77	-93
T-2-70	2509	76	2029	-2240	70	-82
T-3-30	3174	96	2534	-2856	86	-112
T-3-50	2737	85	2110	-2542	77	-100
T-3-70	2509	76	2029	-2284	70	-88
T-4-30	3174	96	2534	-3253	86	-114
T-4-50	2737	85	2110	-2641	77	-100
T-4-70	2509	76	2029	-2284	70	-88

Table B-6 (cont'd.) Maximum Unfactored Load Effects for 160 ft. Long Spans

Loading	Three-Span Continuous					
	Pos. M span 1 (ft.k)	Pos. M span 2 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear left of 1st int. support (kips)	Shear right of 1st int. support (kips)
HL-93 Truck	2094	1753	-1161	67	-70	69
HL-93 Tandem	1589	1353	-817	49	-50	50
HL-93 Lane	1643	1237	-1892	46	-63	60
HL-93 Truck	-	-	-2063	-	-	-
HS 20 Truck	2094	1753	-1161	67	-70	69
HS 20 Tandem	1526	1299	-784	47	-48	48
HS 20 Lane	2230	1741	-2418	72	-89	86
33-1-00	1994	1640	-1227	65	-72	70
33-2-30	2410	1865	-1875	84	-104	94
33-2-50	1994	1522	-2060	76	-92	84
33-2-70	1994	1350	-2158	69	-82	78
33-3-30	2410	1636	-2595	84	-110	103
33-3-50	1994	1282	-2313	76	-98	93
33-3-70	1994	1281	-2166	69	-86	83
33-4-30	2410	1416	-2958	84	-111	106
33-4-50	1994	1282	-2355	76	-98	93
33-4-70	1994	1281	-2166	69	-86	83
3S2-1-00	1918	1582	-1127	61	-67	65
3S2-2-30	2515	1967	-1758	86	-105	96
3S2-2-50	2108	1621	-1816	78	-95	86
3S2-2-70	1918	1413	-1954	70	-84	77
3S2-3-30	2531	1951	-2482	87	-110	104
3S2-3-50	2108	1379	-2325	78	-100	95
3S2-3-70	1918	1242	-2048	70	-89	85
3S2-4-30	2531	1545	-3069	87	-114	109
3S2-4-50	2108	1325	-2508	78	-100	96
3S2-4-70	1918	1242	-2048	70	-89	85
T-1-00	2000	1628	-1216	65	-72	69
T-2-30	2492	1939	-1823	85	-106	95
T-2-50	2082	1598	-2029	77	-94	85
T-2-70	2000	1388	-2132	70	-82	78
T-3-30	2492	1757	-2715	85	-111	104
T-3-50	2082	1320	-2372	77	-99	94
T-3-70	2000	1280	-2158	70	-87	84
T-4-30	2492	1482	-3037	85	-113	108
T-4-50	2082	1320	-2440	77	-99	95
T-4-70	2000	1280	-2158	70	-87	84

Table B-7 Maximum Unfactored Load Effects for 200 ft. Long Spans

Loading	Simple Span		Two-Span Continuous			
	M midspan (ft.k)	End shear (kips)	Pos. M span 1 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear at int. support (kips)
HL-93 Truck	3320	69	2715	-1365	68	-70
HL-93 Tandem	2450	50	2020	-958	49	-50
HL-93 Lane	3200	64	2438	-3168	56	-80
HL-93 Truck	-	-	-	-2727	-	-
HS 20 Truck	3320	69	2715	-1365	68	-70
HS 20 Tandem	2352	48	1939	-919	47	-48
HS 20 Lane	4100	90	3181	-3859	82	-106
33-1-00	3340	70	2679	-1471	68	-74
33-2-30	4640	107	3679	-2356	98	-118
33-2-50	3978	99	3170	-2491	90	-109
33-2-70	3426	91	2739	-2720	83	-99
33-3-30	4836	112	3700	-3486	100	-124
33-3-50	3978	99	3170	-3436	90	-116
33-3-70	3426	91	2739	-3192	83	-107
33-4-30	4836	112	3700	-4636	100	-131
33-4-50	3978	99	3170	-4107	90	-118
33-4-70	3426	91	2739	-3362	83	-107
3S2-1-00	3122	65	2535	-1343	64	-68
3S2-2-30	4644	105	3695	-2302	97	-114
3S2-2-50	4023	98	3201	-2118	90	-107
3S2-2-70	3449	91	2795	-2371	83	-99
3S2-3-30	5210	119	3970	-3079	107	-132
3S2-3-50	4033	100	3201	-3196	90	-113
3S2-3-70	3449	91	2795	-3089	83	-105
3S2-4-30	5210	119	3970	-4339	107	-138
3S2-4-50	4033	100	3201	-4122	90	-116
3S2-4-70	3449	91	2795	-3516	83	-106
T-1-00	3309	70	2684	-1461	68	-74
T-2-30	4760	108	3758	-2388	99	-119
T-2-50	4068	100	3251	-2436	91	-110
T-2-70	3537	92	2829	-2675	84	-101
T-3-30	5091	116	3846	-3538	104	-130
T-3-50	4068	100	3251	-3504	91	-117
T-3-70	3537	92	2829	-3222	84	-108
T-4-30	5091	116	3846	-4654	104	-138
T-4-50	4068	100	3251	-4195	91	-119
T-4-70	3537	92	2829	-3449	84	-108

Table B-7 (cont'd.) Maximum Unfactored Load Effects for 200 ft. Long Spans

Loading	Three-Span Continuous					
	Pos. M span 1 (ft.k)	Pos. M span 2 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear left of 1st int. support (kips)	Shear right of 1st int. support (kips)
HL-93 Truck	2682	2257	-1456	68	-70	69
HL-93 Tandem	1997	1703	-1022	49	-50	50
HL-93 Lane	2566	1933	-2957	58	-79	75
HL-93 Truck	-	-	-2589	-	-	-
HS 20 Truck	2682	2257	-1456	68	-70	69
HS 20 Tandem	1918	1635	-981	47	-48	48
HS 20 Lane	3300	2563	-3613	84	-105	101
33-1-00	2643	2190	-1569	68	-74	72
33-2-30	3617	2841	-2513	97	-118	108
33-2-50	3116	2385	-2422	89	-109	99
33-2-70	2699	2082	-2622	82	-100	91
33-3-30	3636	2868	-3454	99	-125	117
33-3-50	3116	2167	-3357	89	-115	109
33-3-70	2699	1740	-3055	82	-106	100
33-4-30	3636	2341	-4361	99	-131	124
33-4-50	3116	1864	-3833	89	-116	111
33-4-70	2699	1740	-3144	82	-106	100
3S2-1-00	2502	2078	-1432	64	-68	67
3S2-2-30	3634	2882	-2456	97	-115	107
3S2-2-50	3146	2431	-2204	89	-107	99
3S2-2-70	2752	2132	-2298	82	-99	90
3S2-3-30	3902	3174	-3109	106	-133	119
3S2-3-50	3146	2434	-3167	89	-113	107
3S2-3-70	2752	1862	-3003	82	-105	99
3S2-4-30	3902	2836	-4124	106	-138	127
3S2-4-50	3146	1905	-3864	89	-116	111
3S2-4-70	2752	1753	-3285	82	-105	100
T-1-00	2647	2177	-1558	68	-74	72
T-2-30	3695	2923	-2547	98	-119	109
T-2-50	3197	2448	-2370	90	-110	100
T-2-70	2789	2151	-2586	83	-101	92
T-3-30	3763	3008	-3429	103	-131	119
T-3-50	3197	2278	-3371	90	-117	110
T-3-70	2789	1786	-3090	83	-107	101
T-4-30	3763	2528	-4390	103	-137	128
T-4-50	3197	1917	-3915	90	-118	113
T-4-70	2789	1786	-3231	83	-107	102

Table B-8 Maximum Unfactored Load Effects for 250 ft. Long Spans

Loading	Simple Span		Two-Span Continuous			
	M midspan (ft.k)	End shear (kips)	Pos. M span 1 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear at int. support (kips)
HL-93 Truck	4220	69	3458	-1711	69	-70
HL-93 Tandem	3075	50	2536	-1198	50	-50
HL-93 Lane	5000	80	3810	-4950	70	-100
HL-93 Truck	-	-	-	-3421	-	-
HS 20 Truck	4220	69	3458	-1711	69	-70
HS 20 Tandem	2952	48	2435	-1150	48	-48
HS 20 Lane	6125	106	4739	-5814	96	-126
33-1-00	4340	72	3502	-1860	71	-75
33-2-30	6640	118	5263	-3252	109	-128
33-2-50	5898	111	4695	-3007	102	-122
33-2-70	5258	105	4187	-3098	96	-115
33-3-30	7620	136	5803	-4201	122	-151
33-3-50	6146	118	4723	-4409	106	-129
33-3-70	5258	105	4187	-4417	96	-122
33-4-30	7620	136	5803	-6003	122	-157
33-4-50	6146	118	4723	-5880	106	-136
33-4-70	5258	105	4187	-5432	96	-124
3S2-1-00	4022	67	3275	-1696	65	-69
3S2-2-30	6444	113	5140	-3071	106	-122
3S2-2-50	5751	107	4606	-2887	100	-116
3S2-2-70	5175	101	4124	-2648	93	-110
3S2-3-30	7910	139	6068	-3884	125	-153
3S2-3-50	6470	121	4903	-3929	109	-134
3S2-3-70	5205	105	4124	-4047	95	-117
3S2-4-30	8039	144	6105	-5302	128	-160
3S2-4-50	6470	121	4903	-5488	109	-140
3S2-4-70	5205	105	4124	-5204	95	-121
T-1-00	4309	72	3504	-1858	70	-75
T-2-30	6760	119	5352	-3275	110	-129
T-2-50	5988	112	4773	-3039	103	-122
T-2-70	5348	106	4274	-3043	96	-115
T-3-30	7829	139	6012	-4165	124	-154
T-3-50	6406	120	4844	-4380	108	-132
T-3-70	5348	107	4274	-4415	96	-123
T-4-30	7829	140	6012	-5957	125	-160
T-4-50	6406	120	4844	-5852	108	-139
T-4-70	5348	107	4274	-5511	96	-125

Table B-8 (cont'd.) Maximum Unfactored Load Effects for 250 ft. Long Spans

Loading	Three-Span Continuous					
	Pos. M span 1 (ft.k)	Pos. M span 2 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear left of 1st int. support (kips)	Shear right of 1st int. support (kips)
HL-93 Truck	3417	2887	-1825	69	-71	70
HL-93 Tandem	2508	2141	-1278	49	-50	50
HL-93 Lane	4010	3020	-4620	72	-98	93
HL-93 Truck	-	-	-3245	-	-	-
HS 20 Truck	3417	2887	-1825	69	-71	70
HS 20 Tandem	2407	2055	-1226	48	-48	48
HS 20 Lane	4927	3808	-5441	98	-124	119
33-1-00	3458	2886	-1984	70	-75	74
33-2-30	5179	4130	-3469	109	-129	120
33-2-50	4615	3597	-3207	102	-122	113
33-2-70	4115	3148	-3021	95	-115	105
33-3-30	5703	4612	-4256	121	-152	136
33-3-50	4642	3736	-4400	105	-130	122
33-3-70	4115	3009	-4342	95	-121	115
33-4-30	5703	4250	-5721	121	-157	145
33-4-50	4642	3037	-5554	105	-136	128
33-4-70	4115	2466	-5071	95	-123	118
3S2-1-00	3234	2702	-1809	65	-69	68
3S2-2-30	5061	4066	-3276	106	-122	115
3S2-2-50	4530	3563	-3080	99	-117	109
3S2-2-70	4054	3135	-2825	93	-111	102
3S2-3-30	5968	4825	-4143	124	-154	140
3S2-3-50	4808	3952	-3960	108	-134	121
3S2-3-70	4054	3211	-4021	94	-116	111
3S2-4-30	6002	4763	-5103	127	-161	147
3S2-4-50	4808	3464	-5216	108	-140	129
3S2-4-70	4054	2547	-4906	94	-120	115
T-1-00	3458	2867	-1982	70	-75	74
T-2-30	5267	4218	-3493	109	-130	121
T-2-50	4692	3673	-3241	102	-123	114
T-2-70	4203	3240	-2968	96	-116	106
T-3-30	5910	4763	-4201	123	-155	139
T-3-50	4757	3862	-4364	107	-133	123
T-3-70	4203	3113	-4351	96	-122	116
T-4-30	5910	4484	-5690	124	-160	147
T-4-50	4757	3231	-5556	107	-139	130
T-4-70	4203	2523	-5150	96	-124	119

Table B-9 Maximum Unfactored Load Effects for 300 ft. Long Spans

Loading	Simple Span		Two-Span Continuous			
	M midspan (ft.k)	End shear (kips)	Pos. M span 1 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear at int. support (kips)
HL-93 Truck	5120	70	4201	-2059	69	-71
HL-93 Tandem	3700	50	3052	-1438	50	-50
HL-93 Lane	7200	96	5486	-7128	84	-120
HL-93 Truck	-	-	-	-4114	-	-
HS 20 Truck	5120	70	4201	-2059	69	-71
HS 20 Tandem	3552	48	2930	-1380	48	-48
HS 20 Lane	8550	122	6601	-8165	110	-146
33-1-00	5340	74	4326	-2254	72	-76
33-2-30	8640	125	6875	-4106	117	-135
33-2-50	7840	120	6272	-3899	111	-130
33-2-70	7178	114	5716	-3658	105	-124
33-3-30	10620	154	8141	-5207	139	-170
33-3-50	9020	138	6822	-5160	123	-152
33-3-70	7468	122	5750	-5353	110	-133
33-4-30	10800	160	8235	-7012	143	-178
33-4-50	9020	138	6822	-7308	123	-158
33-4-70	7468	122	5750	-7047	110	-141
3S2-1-00	4922	68	4018	-2045	66	-69
3S2-2-30	8244	118	6601	-3823	112	-126
3S2-2-50	7524	113	6039	-3650	107	-122
3S2-2-70	6903	108	5522	-3453	101	-117
3S2-3-30	10610	151	8226	-5109	139	-166
3S2-3-50	9170	137	6984	-4513	124	-151
3S2-3-70	7730	123	5870	-4772	110	-135
3S2-4-30	11376	168	8832	-5984	150	-186
3S2-4-50	9170	140	6984	-6545	125	-157
3S2-4-70	7730	123	5870	-6550	110	-141
T-1-00	5309	74	4325	-2254	72	-76
T-2-30	8760	125	6969	-4124	118	-135
T-2-50	7960	120	6357	-3925	112	-130
T-2-70	7268	115	5793	-3689	106	-125
T-3-30	10829	156	8366	-5298	141	-172
T-3-50	9229	140	7031	-5104	125	-154
T-3-70	7721	124	5860	-5302	112	-136
T-4-30	11210	165	8571	-6909	146	-184
T-4-50	9229	140	7031	-7275	125	-161
T-4-70	7721	124	5860	-6991	112	-143

Table B-9 (cont'd.) Maximum Unfactored Load Effects for 300 ft. Long Spans

Loading	Three-Span Continuous					
	Pos. M span 1 (ft.k)	Pos. M span 2 (ft.k)	Neg. M at inter. support (ft.k)	End shear (kips)	Shear left of 1st int. support (kips)	Shear right of 1st int. support (kips)
HL-93 Truck	4152	3517	-2196	69	-71	70
HL-93 Tandem	3018	2578	-1534	50	-50	50
HL-93 Lane	5774	4349	-6653	87	-118	112
HL-93 Truck	-	-	-3904	-	-	-
HS 20 Truck	4152	3517	-2196	69	-71	70
HS 20 Tandem	2897	2475	-1472	48	-48	48
HS 20 Lane	6874	5294	-7638	113	-144	138
33-1-00	4273	3583	-2404	72	-76	75
33-2-30	6770	5454	-4380	117	-135	128
33-2-50	6170	4881	-4159	111	-130	122
33-2-70	5619	4365	-3901	105	-125	116
33-3-30	8005	6478	-5554	138	-171	155
33-3-50	6704	5473	-5219	122	-153	138
33-3-70	5652	4609	-5321	109	-134	125
33-4-30	8097	6448	-6750	141	-179	162
33-4-50	6704	4911	-6951	122	-159	146
33-4-70	5652	3765	-6692	109	-140	131
3S2-1-00	3968	3331	-2182	66	-70	69
3S2-2-30	6505	5277	-4078	112	-127	121
3S2-2-50	5943	4731	-3894	106	-122	116
3S2-2-70	5430	4255	-3683	101	-118	110
3S2-3-30	8096	6571	-5450	138	-167	154
3S2-3-50	6868	5589	-4803	123	-152	138
3S2-3-70	5746	4737	-4778	110	-136	122
3S2-4-30	8680	6904	-6079	149	-188	168
3S2-4-50	6868	5311	-6278	124	-157	145
3S2-4-70	5746	4110	-6261	110	-141	131
T-1-00	4269	3557	-2404	72	-76	75
T-2-30	6864	5551	-4399	117	-136	128
T-2-50	6254	4962	-4187	111	-131	122
T-2-70	5695	4437	-3935	105	-125	116
T-3-30	8229	6635	-5652	140	-173	157
T-3-50	6912	5619	-5172	124	-155	140
T-3-70	5760	4715	-5254	111	-137	126
T-4-30	8425	6720	-6735	145	-185	166
T-4-50	6912	5151	-6935	124	-161	148
T-4-70	5760	3934	-6666	111	-143	133

APPENDIX C

RATIO OF TRUCK PLATOONS LOAD EFFECTS

TO

HL-93 AND HS 20 DESIGN LOAD EFFECTS

APPENDIX C

RATIO OF TRUCK PLATOONS LOAD EFFECTS
TO
HL-93 AND HS 20 DESIGN LOAD EFFECTS

Table C-1 through Table C-12show the ratio of the maximum load effects from different platoon configurations divided by the maximum load effects from the HL-93 design loads. For the HL-93 loading, the dynamic load allowance was applied to the load effects from the design truck or design tandem only and not to the uniform load as specified in AASHTO LRFD (2017). The dynamic load allowance was applied to the entire load effects from the truck platoons.

Table C-13 through Table C-24 show the ratio of the maximum load effects from different platoon configurations divided by the maximum load effects from the HS 20 design loads. The impact factor, calculated as specified in AASHTO Standard Specifications (2002), was applied to the load effects due to all components of the HS 20 loading and to the entire load effects from the truck platoons.

For ease of identification of the cases that may be affected by different platoon configurations, ratios greater than 1.0 but equal or less than 1.2 are shown in bold type face in Tables C-1 through Table C-24. Ratios greater than 1.2 are shown in bold type face and underlined.

Table C-1. Platoon Moment Ratio to HL-93 Moment. Positive Moment, Simple Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
50	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
70	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
100	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
130	0.63	0.68	0.63	0.63	0.68	0.63	0.63	0.68	0.63	0.63
160	0.61	0.74	0.63	0.61	0.74	0.63	0.61	0.74	0.63	0.61
200	0.58	0.81	0.69	0.60	0.84	0.69	0.60	0.84	0.69	0.60
250	0.54	0.83	0.74	0.66	0.95	0.77	0.66	0.95	0.77	0.66
300	0.51	0.82	0.74	0.68	**1.01**	0.86	0.71	**1.03**	0.86	0.71

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
50	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
70	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
100	0.62	0.65	0.62	0.62	0.65	0.62	0.62	0.65	0.62	0.62
130	0.61	0.71	0.61	0.61	0.71	0.61	0.61	0.71	0.61	0.61
160	0.58	0.78	0.64	0.58	0.80	0.64	0.58	0.80	0.64	0.58
200	0.55	0.81	0.70	0.60	0.91	0.70	0.60	0.91	0.70	0.60
250	0.50	0.81	0.72	0.65	0.99	0.81	0.65	**1.01**	0.81	0.65
300	0.47	0.78	0.71	0.66	**1.01**	0.87	0.73	**1.08**	0.87	0.73

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
50	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
70	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
100	0.62	0.64	0.62	0.62	0.64	0.62	0.62	0.64	0.62	0.62
130	0.62	0.72	0.62	0.62	0.72	0.62	0.62	0.72	0.62	0.62
160	0.61	0.77	0.66	0.61	0.77	0.66	0.61	0.77	0.66	0.61
200	0.58	0.83	0.71	0.62	0.89	0.71	0.62	0.89	0.71	0.62
250	0.54	0.85	0.75	0.67	0.98	0.80	0.67	0.98	0.80	0.67
300	0.50	0.83	0.76	0.69	**1.03**	0.88	0.73	**1.06**	0.88	0.73

Table C-2. Platoon End Shear Ratio to HL-93 Shear. End Shear, Simple Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
50	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
70	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
100	0.68	0.73	0.68	0.68	0.73	0.68	0.68	0.73	0.68	0.68
130	0.67	0.81	0.73	0.67	0.81	0.73	0.67	0.81	0.73	0.67
160	0.64	0.89	0.79	0.71	0.89	0.79	0.71	0.89	0.79	0.71
200	0.60	0.92	0.85	0.78	0.96	0.85	0.78	0.96	0.85	0.78
250	0.56	0.91	0.86	0.81	**1.05**	0.91	0.81	**1.05**	0.91	0.81
300	0.52	0.88	0.84	0.80	**1.08**	0.97	0.86	**1.13**	0.97	0.86

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
50	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
70	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
100	0.66	0.75	0.68	0.66	0.75	0.68	0.66	0.75	0.68	0.66
130	0.63	0.86	0.75	0.67	0.86	0.75	0.67	0.86	0.75	0.67
160	0.60	0.90	0.81	0.73	0.93	0.81	0.73	0.93	0.81	0.73
200	0.56	0.90	0.84	0.78	**1.02**	0.86	0.78	**1.02**	0.86	0.78
250	0.51	0.87	0.83	0.78	**1.07**	0.94	0.81	**1.11**	0.94	0.81
300	0.48	0.83	0.80	0.76	**1.07**	0.97	0.86	**1.18**	0.98	0.86

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
50	0.59	0.60	0.59	0.59	0.60	0.59	0.59	0.60	0.59	0.59
70	0.66	0.67	0.66	0.66	0.67	0.66	0.66	0.67	0.66	0.66
100	0.68	0.75	0.68	0.68	0.75	0.68	0.68	0.75	0.68	0.68
130	0.66	0.82	0.74	0.68	0.83	0.74	0.68	0.83	0.74	0.68
160	0.64	0.90	0.80	0.72	0.90	0.80	0.72	0.90	0.80	0.72
200	0.60	0.93	0.86	0.79	0.99	0.86	0.79	0.99	0.86	0.79
250	0.56	0.92	0.87	0.82	**1.07**	0.93	0.82	**1.08**	0.93	0.82
300	0.52	0.88	0.85	0.81	**1.10**	0.99	0.87	**1.16**	0.99	0.87

Table C-3. Platoon Moment Ratio to HL-93 Moment. Positive Moment in Span 1, Two Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
50	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
70	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
100	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
130	0.63	0.65	0.63	0.63	0.65	0.63	0.63	0.65	0.63	0.63
160	0.61	0.74	0.61	0.61	0.74	0.61	0.61	0.74	0.61	0.61
200	0.59	0.81	0.70	0.60	0.81	0.70	0.60	0.81	0.70	0.60
250	0.55	0.83	0.74	0.66	0.92	0.75	0.66	0.92	0.75	0.66
300	0.52	0.83	0.75	0.69	0.98	0.82	0.69	0.99	0.82	0.69

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
50	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
70	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
100	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
130	0.61	0.71	0.61	0.61	0.71	0.61	0.61	0.71	0.61	0.61
160	0.59	0.78	0.65	0.59	0.78	0.65	0.59	0.78	0.65	0.59
200	0.56	0.81	0.70	0.61	0.87	0.70	0.61	0.87	0.70	0.61
250	0.52	0.81	0.73	0.65	0.96	0.77	0.65	0.97	0.77	0.65
300	0.48	0.79	0.73	0.66	0.99	0.84	0.70	**1.06**	0.84	0.70

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
50	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
70	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
100	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
130	0.63	0.68	0.63	0.63	0.68	0.63	0.63	0.68	0.63	0.63
160	0.62	0.77	0.64	0.62	0.77	0.64	0.62	0.77	0.64	0.62
200	0.59	0.83	0.71	0.62	0.84	0.71	0.62	0.84	0.71	0.62
250	0.55	0.85	0.75	0.68	0.95	0.77	0.68	0.95	0.77	0.68
300	0.52	0.84	0.76	0.70	1.00	0.84	0.70	**1.03**	0.84	0.70

Table C-4. Platoon Moment Ratio to HL-93 Moment. Negative Moment at Intermediate Support, Two Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
50	0.67	0.74	0.67	0.67	0.74	0.67	0.67	0.74	0.67	0.67
70	0.40	0.69	0.57	0.42	0.69	0.57	0.42	0.69	0.57	0.42
100	0.37	0.74	0.73	0.65	0.75	0.73	0.65	0.75	0.73	0.65
130	0.36	0.67	0.72	0.72	0.81	0.72	0.72	0.83	0.72	0.72
160	0.35	0.58	0.65	0.68	0.82	0.73	0.69	0.95	0.77	0.69
200	0.32	0.51	0.54	0.59	0.76	0.75	0.69	**1.01**	0.89	0.73
250	0.29	0.51	0.47	0.48	0.65	0.69	0.69	0.93	0.91	0.84
300	0.26	0.48	0.46	0.43	0.61	0.61	0.63	0.82	0.86	0.83

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
50	0.64	0.80	0.64	0.64	0.80	0.64	0.64	0.80	0.64	0.64
70	0.38	0.75	0.64	0.48	0.75	0.64	0.48	0.75	0.64	0.48
100	0.36	0.69	0.72	0.68	0.74	0.72	0.68	0.77	0.72	0.68
130	0.34	0.58	0.65	0.68	0.81	0.70	0.68	0.90	0.71	0.68
160	0.32	0.50	0.57	0.61	0.77	0.72	0.65	0.98	0.81	0.66
200	0.29	0.50	0.46	0.52	0.67	0.69	0.67	0.94	0.90	0.76
250	0.26	0.48	0.45	0.41	0.60	0.61	0.63	0.82	0.85	0.81
300	0.24	0.45	0.43	0.40	0.60	0.53	0.56	0.70	0.77	0.77

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
50	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
70	0.46	0.67	0.58	0.46	0.67	0.58	0.46	0.67	0.58	0.46
100	0.37	0.72	0.73	0.66	0.74	0.73	0.66	0.74	0.73	0.66
130	0.36	0.65	0.71	0.72	0.86	0.72	0.72	0.86	0.72	0.72
160	0.34	0.56	0.63	0.67	0.86	0.76	0.69	0.98	0.79	0.69
200	0.32	0.52	0.53	0.58	0.77	0.76	0.70	**1.01**	0.91	0.75
250	0.29	0.51	0.47	0.47	0.65	0.68	0.69	0.93	0.91	0.86
300	0.26	0.48	0.46	0.43	0.62	0.60	0.62	0.81	0.85	0.82

Table C- 5. Platoon End Shear Ratio to HL-93 Shear. End Shear, Two Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
50	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
70	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
100	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
130	0.67	0.77	0.69	0.67	0.77	0.69	0.67	0.77	0.69	0.67
160	0.65	0.84	0.76	0.69	0.84	0.76	0.69	0.84	0.76	0.69
200	0.62	0.89	0.82	0.75	0.91	0.82	0.75	0.91	0.82	0.75
250	0.58	0.90	0.84	0.79	1.00	0.87	0.79	1.00	0.87	0.79
300	0.54	0.88	0.84	0.80	**1.05**	0.93	0.83	**1.08**	0.93	0.83

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
50	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
70	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
100	0.66	0.72	0.66	0.66	0.72	0.66	0.66	0.72	0.66	0.66
130	0.64	0.81	0.72	0.65	0.81	0.72	0.65	0.81	0.72	0.65
160	0.61	0.86	0.78	0.70	0.87	0.78	0.70	0.87	0.78	0.70
200	0.58	0.88	0.81	0.75	0.97	0.82	0.75	0.97	0.82	0.75
250	0.54	0.87	0.82	0.77	**1.03**	0.90	0.78	**1.06**	0.90	0.78
300	0.50	0.85	0.80	0.76	**1.05**	0.93	0.83	**1.13**	0.94	0.83

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
50	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
70	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
100	0.67	0.72	0.67	0.67	0.72	0.67	0.67	0.72	0.67	0.67
130	0.66	0.79	0.70	0.66	0.79	0.70	0.66	0.79	0.70	0.66
160	0.65	0.85	0.77	0.70	0.85	0.77	0.70	0.85	0.77	0.70
200	0.62	0.90	0.82	0.76	0.94	0.82	0.76	0.94	0.82	0.76
250	0.58	0.91	0.85	0.79	**1.02**	0.89	0.79	**1.03**	0.89	0.79
300	0.54	0.89	0.84	0.80	**1.06**	0.95	0.84	**1.10**	0.95	0.84

Table C-6. Platoon End Shear Ratio to HL-93 Shear. Shear left of intermediate support, Two Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
50	0.60	0.62	0.60	0.60	0.62	0.60	0.60	0.62	0.60	0.60
70	0.66	0.70	0.67	0.66	0.70	0.67	0.66	0.70	0.67	0.66
100	0.67	0.73	0.71	0.69	0.78	0.71	0.69	0.78	0.71	0.69
130	0.65	0.81	0.71	0.68	0.87	0.77	0.69	0.88	0.77	0.69
160	0.61	0.88	0.78	0.69	0.94	0.84	0.74	0.96	0.84	0.74
200	0.57	0.90	0.84	0.76	0.96	0.89	0.82	**1.01**	0.91	0.82
250	0.52	0.88	0.84	0.79	**1.04**	0.89	0.84	**1.08**	0.94	0.85
300	0.47	0.84	0.81	0.77	**1.06**	0.95	0.83	**1.11**	0.99	0.88

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
50	0.63	0.66	0.63	0.63	0.66	0.63	0.63	0.66	0.63	0.63
70	0.66	0.70	0.68	0.66	0.70	0.68	0.66	0.70	0.68	0.66
100	0.64	0.75	0.68	0.66	0.81	0.71	0.66	0.81	0.71	0.66
130	0.60	0.86	0.73	0.65	0.91	0.79	0.69	0.93	0.79	0.69
160	0.57	0.89	0.80	0.71	0.94	0.86	0.76	0.97	0.86	0.76
200	0.52	0.88	0.82	0.76	**1.01**	0.87	0.81	**1.06**	0.89	0.81
250	0.47	0.84	0.80	0.76	**1.05**	0.92	0.80	**1.10**	0.96	0.83
300	0.43	0.78	0.76	0.73	**1.03**	0.94	0.84	**1.16**	0.97	0.88

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
50	0.58	0.61	0.58	0.58	0.61	0.58	0.58	0.61	0.58	0.58
70	0.65	0.70	0.67	0.65	0.70	0.67	0.65	0.70	0.67	0.65
100	0.67	0.78	0.71	0.69	0.80	0.71	0.69	0.80	0.71	0.69
130	0.64	0.84	0.72	0.68	0.89	0.78	0.71	0.89	0.78	0.71
160	0.61	0.89	0.79	0.70	0.95	0.85	0.75	0.97	0.85	0.75
200	0.57	0.91	0.84	0.77	1.00	0.90	0.83	**1.06**	0.92	0.83
250	0.52	0.89	0.84	0.79	**1.06**	0.91	0.84	**1.10**	0.95	0.86
300	0.47	0.84	0.81	0.78	**1.07**	0.96	0.85	**1.14**	1.00	0.89

Table C-7. Platoon Moment Ratio to HL-93 Moment. Positive Moment in Span 1, Three Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.48	0.48	0.50	0.48	0.48	0.50	0.48	0.48	0.50	0.48
50	0.50	0.50	0.50	0.53	0.50	0.50	0.53	0.50	0.50	0.53
70	0.55	0.55	0.55	0.58	0.55	0.55	0.58	0.55	0.55	0.58
100	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
130	0.61	0.63	0.61	0.61	0.63	0.61	0.61	0.63	0.61	0.61
160	0.60	0.72	0.60	0.60	0.72	0.60	0.60	0.72	0.60	0.60
200	0.57	0.78	0.68	0.59	0.79	0.68	0.59	0.79	0.68	0.59
250	0.54	0.81	0.72	0.64	0.89	0.72	0.64	0.89	0.72	0.64
300	0.50	0.80	0.73	0.66	0.94	0.79	0.67	0.95	0.79	0.67

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.57	0.57	0.60	0.57	0.57	0.60	0.57	0.57	0.60	0.57
50	0.57	0.57	0.60	0.60	0.57	0.60	0.60	0.57	0.60	0.60
70	0.61	0.61	0.61	0.62	0.61	0.61	0.62	0.61	0.61	0.62
100	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
130	0.60	0.70	0.60	0.60	0.70	0.60	0.60	0.70	0.60	0.60
160	0.58	0.76	0.63	0.58	0.76	0.63	0.58	0.76	0.63	0.58
200	0.54	0.79	0.68	0.60	0.85	0.68	0.60	0.85	0.68	0.60
250	0.50	0.79	0.70	0.63	0.93	0.75	0.63	0.93	0.75	0.63
300	0.47	0.77	0.70	0.64	0.95	0.81	0.68	**1.02**	0.81	0.68

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.62	0.62	0.65	0.62	0.62	0.65	0.62	0.62	0.65	0.62
50	0.61	0.61	0.61	0.63	0.61	0.61	0.63	0.61	0.61	0.63
70	0.58	0.58	0.58	0.61	0.58	0.58	0.61	0.58	0.58	0.61
100	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
130	0.62	0.67	0.62	0.62	0.67	0.62	0.62	0.67	0.62	0.62
160	0.60	0.75	0.63	0.60	0.75	0.63	0.60	0.75	0.63	0.60
200	0.57	0.80	0.69	0.60	0.82	0.69	0.60	0.82	0.69	0.60
250	0.54	0.82	0.73	0.65	0.92	0.74	0.65	0.92	0.74	0.65
300	0.50	0.81	0.74	0.67	0.97	0.81	0.68	0.99	0.81	0.68

Table C-8. Platoon Moment Ratio to HL-93 Moment. Positive Moment in Span 2, Three Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
50	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
70	0.55	0.44	0.49	0.55	0.44	0.49	0.55	0.44	0.49	0.55
100	0.61	0.48	0.45	0.50	0.46	0.45	0.50	0.46	0.45	0.50
130	0.62	0.60	0.50	0.47	0.49	0.48	0.47	0.49	0.48	0.47
160	0.61	0.70	0.57	0.50	0.61	0.48	0.48	0.53	0.48	0.48
200	0.59	0.77	0.64	0.56	0.77	0.58	0.47	0.63	0.50	0.47
250	0.56	0.80	0.70	0.61	0.89	0.72	0.58	0.82	0.59	0.48
300	0.53	0.80	0.72	0.64	0.95	0.81	0.68	0.95	0.72	0.55

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
50	0.57	0.51	0.57	0.57	0.51	0.57	0.57	0.51	0.57	0.57
70	0.61	0.47	0.52	0.60	0.47	0.52	0.60	0.47	0.52	0.60
100	0.62	0.56	0.48	0.49	0.48	0.48	0.49	0.48	0.48	0.49
130	0.61	0.66	0.54	0.48	0.58	0.48	0.48	0.52	0.48	0.48
160	0.59	0.73	0.60	0.53	0.73	0.51	0.46	0.58	0.49	0.46
200	0.56	0.78	0.66	0.57	0.86	0.66	0.50	0.76	0.51	0.47
250	0.52	0.79	0.69	0.61	0.94	0.77	0.62	0.92	0.67	0.49
300	0.49	0.78	0.70	0.63	0.97	0.82	0.70	**1.02**	0.78	0.61

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
50	0.54	0.52	0.54	0.54	0.52	0.54	0.54	0.52	0.54	0.54
70	0.57	0.48	0.53	0.57	0.48	0.53	0.57	0.48	0.53	0.57
100	0.61	0.51	0.47	0.51	0.47	0.47	0.51	0.47	0.47	0.51
130	0.62	0.63	0.52	0.48	0.52	0.48	0.48	0.52	0.48	0.48
160	0.61	0.72	0.60	0.52	0.65	0.49	0.48	0.55	0.49	0.48
200	0.59	0.79	0.66	0.58	0.81	0.61	0.48	0.68	0.52	0.48
250	0.56	0.82	0.71	0.63	0.92	0.75	0.60	0.87	0.63	0.49
300	0.52	0.82	0.73	0.65	0.98	0.83	0.69	0.99	0.76	0.58

Table C-9. Platoon Moment Ratio to HL-93 Moment. Negative Moment at First Interior Support, Three Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
50	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
70	0.43	0.69	0.55	0.43	0.69	0.55	0.43	0.69	0.55	0.43
100	0.42	0.74	0.72	0.64	0.75	0.72	0.64	0.75	0.72	0.64
130	0.41	0.68	0.72	0.72	0.79	0.73	0.72	0.81	0.73	0.72
160	0.39	0.60	0.66	0.69	0.83	0.74	0.69	0.94	0.75	0.69
200	0.36	0.58	0.56	0.61	0.80	0.78	0.71	**1.01**	0.89	0.73
250	0.33	0.57	0.53	0.50	0.70	0.73	0.72	0.95	0.92	0.84
300	0.30	0.55	0.52	0.49	0.69	0.65	0.66	0.84	0.87	0.83

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
50	0.66	0.76	0.66	0.66	0.76	0.66	0.66	0.76	0.66	0.66
70	0.44	0.76	0.64	0.45	0.76	0.64	0.45	0.76	0.64	0.45
100	0.40	0.69	0.71	0.66	0.75	0.71	0.66	0.75	0.71	0.66
130	0.38	0.60	0.66	0.68	0.81	0.70	0.68	0.89	0.70	0.68
160	0.36	0.56	0.58	0.62	0.79	0.74	0.65	0.98	0.80	0.65
200	0.33	0.57	0.51	0.53	0.72	0.73	0.69	0.95	0.89	0.76
250	0.30	0.54	0.51	0.47	0.69	0.65	0.66	0.84	0.86	0.81
300	0.27	0.51	0.49	0.46	0.68	0.60	0.60	0.76	0.78	0.78

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
50	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
70	0.49	0.68	0.57	0.49	0.68	0.57	0.49	0.68	0.57	0.49
100	0.42	0.72	0.72	0.65	0.73	0.72	0.65	0.74	0.72	0.65
130	0.41	0.66	0.71	0.71	0.85	0.72	0.71	0.85	0.72	0.71
160	0.39	0.58	0.65	0.68	0.87	0.76	0.69	0.97	0.78	0.69
200	0.36	0.59	0.55	0.60	0.79	0.78	0.71	**1.01**	0.90	0.75
250	0.33	0.58	0.54	0.49	0.69	0.72	0.72	0.94	0.92	0.85
300	0.30	0.55	0.52	0.49	0.71	0.65	0.66	0.84	0.87	0.83

Table C-10. Platoon End Shear Ratio to HL-93 Shear. End Shear, Three Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
50	0.58	0.58	0.60	0.59	0.58	0.60	0.59	0.58	0.60	0.59
70	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
100	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
130	0.66	0.76	0.68	0.66	0.76	0.68	0.66	0.76	0.68	0.66
160	0.64	0.83	0.75	0.68	0.83	0.75	0.68	0.83	0.75	0.68
200	0.61	0.87	0.80	0.74	0.89	0.80	0.74	0.89	0.80	0.74
250	0.57	0.88	0.83	0.77	0.98	0.86	0.77	0.98	0.86	0.77
300	0.54	0.87	0.82	0.78	**1.03**	0.91	0.81	**1.05**	0.91	0.81

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.61	0.61	0.63	0.62	0.61	0.63	0.62	0.61	0.63	0.62
50	0.62	0.62	0.62	0.63	0.62	0.62	0.63	0.62	0.62	0.63
70	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
100	0.65	0.71	0.65	0.65	0.71	0.65	0.65	0.71	0.65	0.65
130	0.63	0.80	0.71	0.64	0.80	0.71	0.64	0.80	0.71	0.64
160	0.61	0.85	0.77	0.69	0.85	0.77	0.69	0.85	0.77	0.69
200	0.57	0.87	0.80	0.74	0.95	0.80	0.74	0.95	0.80	0.74
250	0.53	0.86	0.81	0.76	**1.01**	0.88	0.77	**1.04**	0.88	0.77
300	0.49	0.83	0.79	0.75	**1.03**	0.92	0.82	**1.11**	0.92	0.82

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.67	0.67	0.69	0.68	0.67	0.69	0.68	0.67	0.69	0.68
50	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
70	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
100	0.66	0.71	0.66	0.66	0.71	0.66	0.66	0.71	0.66	0.66
130	0.66	0.78	0.69	0.66	0.78	0.69	0.66	0.78	0.69	0.66
160	0.64	0.84	0.76	0.69	0.84	0.76	0.69	0.84	0.76	0.69
200	0.61	0.88	0.81	0.75	0.93	0.81	0.75	0.93	0.81	0.75
250	0.57	0.89	0.83	0.78	1.00	0.87	0.78	**1.01**	0.87	0.78
300	0.54	0.87	0.83	0.79	**1.04**	0.93	0.83	**1.08**	0.93	0.83

Table C-11. Platoon End Shear Ratio to HL-93 Shear. Shear left of First Interior Support, Three Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
50	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
70	0.67	0.69	0.67	0.67	0.69	0.67	0.67	0.69	0.67	0.67
100	0.68	0.73	0.70	0.68	0.77	0.70	0.68	0.77	0.70	0.68
130	0.65	0.82	0.72	0.68	0.87	0.76	0.69	0.87	0.76	0.69
160	0.62	0.89	0.79	0.70	0.94	0.84	0.74	0.95	0.84	0.74
200	0.57	0.92	0.85	0.77	0.97	0.89	0.82	**1.01**	0.90	0.82
250	0.52	0.89	0.85	0.80	**1.05**	0.90	0.84	**1.09**	0.94	0.85
300	0.48	0.85	0.82	0.78	**1.07**	0.96	0.84	**1.12**	0.99	0.88

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
50	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
70	0.66	0.70	0.67	0.66	0.70	0.67	0.66	0.70	0.67	0.66
100	0.64	0.76	0.68	0.65	0.81	0.70	0.65	0.81	0.70	0.65
130	0.61	0.86	0.74	0.66	0.91	0.78	0.69	0.92	0.78	0.69
160	0.57	0.90	0.81	0.72	0.94	0.86	0.76	0.98	0.86	0.76
200	0.53	0.89	0.83	0.77	**1.03**	0.87	0.81	**1.06**	0.90	0.81
250	0.48	0.85	0.81	0.76	**1.06**	0.93	0.80	**1.11**	0.97	0.83
300	0.44	0.79	0.77	0.74	**1.05**	0.95	0.85	**1.17**	0.98	0.88

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
50	0.59	0.60	0.59	0.59	0.60	0.59	0.59	0.60	0.59	0.59
70	0.66	0.69	0.66	0.66	0.69	0.66	0.66	0.69	0.66	0.66
100	0.67	0.78	0.70	0.68	0.80	0.70	0.68	0.80	0.70	0.68
130	0.65	0.85	0.73	0.68	0.88	0.78	0.70	0.89	0.78	0.70
160	0.62	0.90	0.80	0.70	0.95	0.85	0.75	0.97	0.85	0.75
200	0.57	0.92	0.85	0.78	**1.01**	0.90	0.83	**1.06**	0.91	0.83
250	0.52	0.90	0.85	0.80	**1.07**	0.92	0.85	**1.11**	0.96	0.86
300	0.48	0.85	0.82	0.79	**1.08**	0.97	0.86	**1.16**	1.01	0.89

Table C-12. Platoon End Shear Ratio to HL-93 Shear. Shear Right of First Interior Support, Three Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
50	0.57	0.60	0.57	0.57	0.60	0.57	0.57	0.60	0.57	0.57
70	0.64	0.69	0.65	0.64	0.69	0.65	0.64	0.69	0.65	0.64
100	0.66	0.74	0.71	0.68	0.74	0.71	0.68	0.74	0.71	0.68
130	0.64	0.76	0.72	0.69	0.85	0.74	0.69	0.85	0.74	0.69
160	0.61	0.83	0.74	0.68	0.91	0.82	0.73	0.94	0.82	0.73
200	0.57	0.86	0.79	0.72	0.93	0.87	0.80	0.99	0.89	0.80
250	0.53	0.86	0.80	0.75	0.97	0.87	0.82	**1.03**	0.92	0.84
300	0.49	0.83	0.79	0.75	1.00	0.89	0.81	**1.05**	0.95	0.85

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
50	0.61	0.65	0.61	0.61	0.65	0.61	0.61	0.65	0.61	0.61
70	0.64	0.70	0.66	0.64	0.70	0.66	0.64	0.70	0.66	0.64
100	0.63	0.72	0.69	0.66	0.79	0.69	0.66	0.79	0.69	0.66
130	0.60	0.80	0.70	0.66	0.89	0.78	0.67	0.90	0.78	0.67
160	0.57	0.85	0.76	0.68	0.92	0.83	0.75	0.96	0.84	0.75
200	0.53	0.85	0.79	0.72	0.95	0.86	0.79	**1.01**	0.89	0.80
250	0.48	0.82	0.78	0.73	1.00	0.86	0.79	**1.05**	0.92	0.82
300	0.44	0.78	0.75	0.71	1.00	0.89	0.79	**1.09**	0.94	0.85

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
50	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
70	0.63	0.69	0.65	0.63	0.69	0.65	0.63	0.69	0.65	0.63
100	0.65	0.75	0.71	0.68	0.79	0.71	0.68	0.79	0.71	0.68
130	0.64	0.81	0.72	0.69	0.87	0.75	0.69	0.87	0.75	0.69
160	0.61	0.84	0.75	0.68	0.92	0.83	0.74	0.95	0.83	0.74
200	0.57	0.87	0.80	0.73	0.95	0.88	0.81	**1.02**	0.90	0.81
250	0.53	0.86	0.81	0.76	0.99	0.88	0.83	**1.05**	0.93	0.85
300	0.48	0.83	0.79	0.75	1.02	0.91	0.81	**1.08**	0.96	0.86

Table C-13. Platoon Moment Ratio to HS 20 Moment. Positive Moment, Simple Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
50	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
70	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
100	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
130	0.94	**1.02**	0.94	0.94	**1.02**	0.94	0.94	**1.02**	0.94	0.94
160	0.92	**1.11**	0.94	0.92	**1.11**	0.94	0.92	**1.11**	0.94	0.92
200	0.81	**1.13**	0.97	0.84	**1.18**	0.97	0.84	**1.18**	0.97	0.84
250	0.71	**1.08**	0.96	0.86	**1.24**	1.00	0.86	**1.24**	1.00	0.86
300	0.62	**1.01**	0.92	0.84	**1.24**	**1.05**	0.87	**1.26**	**1.05**	0.87

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
50	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
70	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
100	0.87	0.91	0.87	0.87	0.91	0.87	0.87	0.91	0.87	0.87
130	0.90	**1.06**	0.90	0.90	**1.06**	0.90	0.90	**1.06**	0.90	0.90
160	0.87	**1.16**	0.96	0.87	**1.20**	0.96	0.87	**1.20**	0.96	0.87
200	0.76	**1.13**	0.98	0.84	**1.27**	0.98	0.84	**1.27**	0.98	0.84
250	0.66	**1.05**	0.94	0.84	**1.29**	1.06	0.85	**1.31**	**1.06**	0.85
300	0.58	0.96	0.88	0.81	**1.24**	1.07	0.90	**1.33**	**1.07**	0.90

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
50	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
70	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
100	0.87	0.90	0.87	0.87	0.90	0.87	0.87	0.90	0.87	0.87
130	0.93	**1.08**	0.93	0.93	**1.08**	0.93	0.93	**1.08**	0.93	0.93
160	0.91	**1.15**	0.99	0.91	**1.15**	0.99	0.91	**1.15**	0.99	0.91
200	0.81	**1.16**	0.99	0.86	**1.24**	0.99	0.86	**1.24**	0.99	0.86
250	0.70	**1.10**	0.98	0.87	**1.28**	**1.05**	0.87	**1.28**	**1.05**	0.87
300	0.62	**1.02**	0.93	0.85	**1.27**	**1.08**	0.90	**1.31**	**1.08**	0.90

Table C-14. Platoon End Shear Ratio to HS 20 Shear. End Shear, Simple Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
50	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
70	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
100	0.93	0.99	0.93	0.93	0.99	0.93	0.93	0.99	0.93	0.93
130	0.97	**1.18**	**1.05**	0.98	**1.18**	**1.05**	0.98	**1.18**	**1.05**	0.98
160	0.88	**1.22**	**1.09**	0.98	**1.22**	**1.09**	0.98	**1.22**	**1.09**	0.98
200	0.78	**1.19**	**1.10**	**1.01**	**1.25**	**1.10**	**1.01**	**1.25**	**1.10**	**1.01**
250	0.68	**1.11**	**1.05**	0.99	**1.29**	**1.11**	0.99	**1.29**	**1.11**	0.99
300	0.60	**1.02**	0.98	0.94	**1.26**	**1.13**	1.00	**1.31**	**1.13**	1.00

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
50	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
70	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
100	0.90	**1.03**	0.93	0.90	**1.03**	0.93	0.90	**1.03**	0.93	0.90
130	0.91	**1.24**	**1.08**	0.97	**1.24**	**1.08**	0.97	**1.24**	**1.08**	0.97
160	0.82	**1.23**	**1.12**	1.00	**1.27**	**1.12**	1.00	**1.27**	**1.12**	1.00
200	0.73	**1.17**	**1.09**	**1.01**	**1.32**	**1.11**	**1.01**	**1.32**	**1.11**	**1.01**
250	0.63	**1.06**	**1.01**	0.96	**1.31**	**1.14**	0.99	**1.36**	**1.14**	0.99
300	0.55	0.97	0.93	0.89	**1.24**	**1.12**	1.01	**1.38**	**1.15**	**1.01**

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
50	0.71	0.72	0.71	0.71	0.72	0.71	0.71	0.72	0.71	0.71
70	0.84	0.85	0.84	0.84	0.85	0.84	0.84	0.85	0.84	0.84
100	0.93	**1.03**	0.93	0.93	**1.03**	0.93	0.93	1.03	0.93	0.93
130	0.96	**1.19**	**1.07**	0.99	**1.20**	**1.07**	0.99	**1.20**	**1.07**	0.99
160	0.88	**1.23**	**1.10**	0.99	**1.24**	**1.10**	0.99	**1.24**	**1.10**	0.99
200	0.78	**1.20**	**1.11**	**1.02**	**1.29**	**1.11**	**1.02**	**1.29**	**1.11**	**1.02**
250	0.68	**1.12**	**1.06**	1.00	**1.31**	**1.13**	**1.01**	**1.32**	**1.13**	**1.01**
300	0.60	**1.03**	0.98	0.94	**1.28**	**1.15**	**1.01**	**1.35**	**1.15**	**1.01**

Table C-15. Platoon Moment Ratio to HS 20 Moment. Positive Moment in Span 1, Two Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
50	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
70	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
100	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
130	0.92	0.94	0.92	0.92	0.94	0.92	0.92	0.94	0.92	0.92
160	0.94	**1.14**	0.94	0.94	**1.14**	0.94	0.94	**1.14**	0.94	0.94
200	0.84	**1.16**	1.00	0.86	**1.16**	1.00	0.86	**1.16**	1.00	0.86
250	0.74	**1.11**	0.99	0.88	<u>**1.22**</u>	1.00	0.88	<u>**1.22**</u>	1.00	0.88
300	0.66	**1.04**	0.95	0.87	<u>**1.23**</u>	**1.03**	0.87	<u>**1.25**</u>	**1.03**	0.87

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
50	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
70	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
100	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
130	0.90	**1.04**	0.90	0.90	**1.04**	0.90	0.90	**1.04**	0.90	0.90
160	0.90	**1.19**	0.99	0.90	**1.19**	0.99	0.90	**1.19**	0.99	0.90
200	0.80	**1.16**	**1.01**	0.88	<u>**1.25**</u>	**1.01**	0.88	<u>**1.25**</u>	**1.01**	0.88
250	0.69	**1.08**	0.97	0.87	<u>**1.28**</u>	**1.03**	0.87	<u>**1.29**</u>	**1.03**	0.87
300	0.61	1.00	0.91	0.84	<u>**1.25**</u>	**1.06**	0.88	<u>**1.34**</u>	**1.06**	0.88

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
50	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
70	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
100	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
130	0.92	1.00	0.92	0.92	1.00	0.92	0.92	1.00	0.92	0.92
160	0.94	**1.18**	0.98	0.94	**1.18**	0.98	0.94	**1.18**	0.98	0.94
200	0.84	**1.18**	**1.02**	0.89	**1.20**	**1.02**	0.89	**1.20**	**1.02**	0.89
250	0.74	**1.13**	**1.01**	0.90	<u>**1.27**</u>	**1.02**	0.90	<u>**1.27**</u>	**1.02**	0.90
300	0.66	**1.06**	0.96	0.88	<u>**1.27**</u>	**1.07**	0.89	<u>**1.30**</u>	**1.07**	0.89

Table C-16. Platoon Moment Ratio to HS 20 Moment. Negative Moment at Intermediate Support, Two Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
50	0.84	0.93	0.84	0.84	0.93	0.84	0.84	0.93	0.84	0.84
70	0.64	**1.11**	0.92	0.68	**1.11**	0.92	0.68	**1.11**	0.92	0.68
100	0.57	**1.12**	**1.11**	0.99	**1.14**	**1.11**	0.99	**1.14**	**1.11**	0.99
130	0.50	0.93	1.00	1.00	**1.12**	1.00	1.00	**1.16**	1.00	1.00
160	0.45	0.75	0.83	0.88	**1.06**	0.94	0.89	**1.23**	0.99	0.89
200	0.38	0.61	0.65	0.70	0.90	0.89	0.83	**1.20**	**1.06**	0.87
250	0.32	0.56	0.52	0.53	0.72	0.76	0.76	**1.03**	**1.01**	0.93
300	0.28	0.50	0.48	0.45	0.64	0.63	0.66	0.86	0.90	0.86

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
50	0.81	**1.02**	0.81	0.81	**1.02**	0.81	0.81	**1.02**	0.81	0.81
70	0.61	**1.21**	**1.02**	0.76	**1.21**	**1.02**	0.76	**1.21**	**1.02**	0.76
100	0.54	**1.04**	**1.08**	**1.02**	**1.13**	**1.08**	**1.02**	**1.17**	**1.08**	**1.02**
130	0.47	0.81	0.91	0.94	**1.12**	0.97	0.94	**1.25**	0.98	0.94
160	0.41	0.64	0.73	0.79	0.99	0.93	0.84	**1.27**	**1.04**	0.84
200	0.35	0.60	0.55	0.61	0.80	0.83	0.80	**1.12**	**1.07**	0.91
250	0.29	0.53	0.50	0.46	0.67	0.68	0.70	0.91	0.94	0.90
300	0.25	0.47	0.45	0.42	0.63	0.55	0.58	0.73	0.80	0.80

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
50	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
70	0.74	**1.08**	0.94	0.74	**1.08**	0.94	0.74	**1.08**	0.94	0.74
100	0.56	**1.10**	**1.10**	1.00	**1.13**	**1.10**	1.00	**1.13**	**1.10**	1.00
130	0.50	0.91	0.98	0.99	**1.19**	1.00	0.99	**1.20**	1.00	0.99
160	0.44	0.73	0.82	0.87	**1.11**	0.99	0.89	**1.26**	**1.02**	0.89
200	0.38	0.62	0.63	0.69	0.92	0.91	0.83	**1.21**	**1.09**	0.89
250	0.32	0.56	0.52	0.52	0.72	0.75	0.76	**1.02**	**1.01**	0.95
300	0.28	0.51	0.48	0.45	0.65	0.63	0.65	0.85	0.89	0.86

Table C-17. Platoon End Shear Ratio to HS 20 Shear. End Shear, Two Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
50	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
70	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
100	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
130	0.95	**1.09**	0.98	0.95	**1.09**	0.98	0.95	**1.09**	0.98	0.95
160	0.92	**1.19**	**1.08**	0.98	**1.19**	**1.08**	0.98	**1.19**	**1.08**	0.98
200	0.83	**1.19**	**1.09**	**1.01**	**1.22**	**1.09**	**1.01**	**1.22**	**1.09**	**1.01**
250	0.73	**1.14**	**1.06**	1.00	**1.27**	**1.10**	1.00	**1.27**	**1.10**	1.00
300	0.65	**1.06**	**1.01**	0.96	**1.26**	**1.12**	1.00	**1.29**	**1.12**	1.00

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
50	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
70	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
100	0.87	0.96	0.87	0.87	0.96	0.87	0.87	0.96	0.87	0.87
130	0.90	**1.15**	**1.02**	0.92	**1.15**	**1.02**	0.92	**1.15**	**1.02**	0.92
160	0.87	**1.22**	**1.10**	1.00	**1.23**	**1.10**	1.00	**1.23**	**1.10**	1.00
200	0.78	**1.18**	**1.09**	**1.01**	**1.30**	**1.09**	**1.01**	**1.30**	**1.09**	**1.01**
250	0.68	**1.10**	**1.04**	0.97	**1.30**	**1.13**	0.99	**1.34**	**1.13**	0.99
300	0.60	**1.02**	0.97	0.92	**1.26**	**1.12**	1.00	**1.36**	**1.14**	1.00

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
50	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
70	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
100	0.89	0.96	0.89	0.89	0.96	0.89	0.89	0.96	0.89	0.89
130	0.94	**1.12**	0.99	0.94	**1.12**	0.99	0.94	**1.12**	0.99	0.94
160	0.92	**1.21**	1.09	0.99	**1.21**	**1.09**	0.99	**1.21**	**1.09**	0.99
200	0.83	**1.20**	**1.11**	**1.02**	**1.27**	**1.11**	**1.02**	**1.27**	**1.11**	**1.02**
250	0.73	**1.14**	**1.07**	1.00	**1.29**	**1.12**	1.00	**1.30**	**1.12**	1.00
300	0.65	**1.07**	**1.02**	0.96	**1.28**	**1.14**	1.01	**1.33**	**1.14**	**1.01**

Table C-18. Platoon End Shear Ratio to HS 20 Shear. Shear left of intermediate support, Two Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
50	0.74	0.77	0.74	0.74	0.77	0.74	0.74	0.77	0.74	0.74
70	0.87	0.92	0.89	0.87	0.92	0.89	0.87	0.92	0.89	0.87
100	0.97	**1.05**	**1.02**	0.99	**1.13**	**1.02**	0.99	**1.13**	**1.02**	0.99
130	0.89	**1.12**	0.99	0.95	<u>**1.21**</u>	**1.07**	0.96	<u>**1.21**</u>	**1.07**	0.96
160	0.80	**1.15**	**1.02**	0.91	<u>**1.23**</u>	**1.10**	0.97	<u>**1.25**</u>	**1.10**	0.97
200	0.70	**1.11**	**1.03**	0.94	<u>**1.18**</u>	**1.10**	**1.01**	<u>**1.24**</u>	**1.11**	**1.01**
250	0.60	**1.02**	0.97	0.91	**1.20**	**1.03**	0.97	<u>**1.25**</u>	**1.08**	0.99
300	0.52	0.92	0.89	0.85	**1.16**	**1.04**	0.92	<u>**1.22**</u>	**1.09**	0.97

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
50	0.79	0.82	0.79	0.79	0.82	0.79	0.79	0.82	0.79	0.79
70	0.87	0.93	0.89	0.87	0.93	0.89	0.87	0.93	0.89	0.87
100	0.92	**1.09**	0.99	0.95	**1.17**	**1.03**	0.95	**1.17**	**1.03**	0.95
130	0.84	**1.18**	**1.02**	0.90	<u>**1.27**</u>	**1.09**	0.96	<u>**1.29**</u>	**1.09**	0.96
160	0.74	**1.16**	**1.05**	0.93	<u>**1.23**</u>	**1.12**	1.00	<u>**1.27**</u>	**1.13**	1.00
200	0.64	**1.08**	**1.01**	0.93	<u>**1.25**</u>	**1.07**	0.99	<u>**1.30**</u>	**1.10**	1.00
250	0.55	0.97	0.92	0.87	<u>**1.22**</u>	**1.06**	0.93	<u>**1.27**</u>	**1.11**	0.96
300	0.48	0.87	0.84	0.80	**1.14**	**1.04**	0.92	<u>**1.28**</u>	**1.07**	0.97

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
50	0.73	0.75	0.73	0.73	0.75	0.73	0.73	0.75	0.73	0.73
70	0.86	0.92	0.89	0.86	0.92	0.89	0.86	0.92	0.89	0.86
100	0.96	**1.12**	**1.02**	0.99	**1.16**	**1.02**	0.99	**1.16**	**1.02**	0.99
130	0.89	**1.17**	1.00	0.95	<u>**1.23**</u>	**1.08**	0.98	<u>**1.24**</u>	**1.08**	0.98
160	0.80	**1.17**	**1.04**	0.91	<u>**1.24**</u>	**1.11**	0.98	<u>**1.27**</u>	**1.12**	0.98
200	0.70	**1.12**	**1.04**	0.95	<u>**1.23**</u>	**1.11**	**1.02**	<u>**1.30**</u>	**1.13**	**1.02**
250	0.60	**1.02**	0.97	0.92	<u>**1.22**</u>	**1.05**	0.98	<u>**1.27**</u>	**1.10**	1.00
300	0.52	0.93	0.89	0.86	**1.18**	**1.06**	0.93	<u>**1.26**</u>	**1.10**	0.98

Table C-19. Platoon Moment Ratio to HS 20 Moment. Positive Moment in Span 1, Three Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.58	0.58	0.61	0.59	0.58	0.61	0.59	0.58	0.61	0.59
50	0.60	0.62	0.62	0.64	0.62	0.62	0.64	0.62	0.62	0.64
70	0.72	0.72	0.72	0.76	0.72	0.72	0.76	0.72	0.72	0.76
100	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
130	0.91	0.94	0.91	0.91	0.94	0.91	0.91	0.94	0.91	0.91
160	0.89	**1.08**	0.89	0.89	**1.08**	0.89	0.89	**1.08**	0.89	0.89
200	0.80	**1.10**	0.94	0.82	**1.10**	0.94	0.82	**1.10**	0.94	0.82
250	0.70	**1.05**	0.94	0.84	**1.16**	0.94	0.84	**1.16**	0.94	0.84
300	0.62	0.98	0.90	0.82	**1.16**	0.98	0.82	**1.18**	0.98	0.82

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.69	0.69	0.73	0.69	0.69	0.73	0.69	0.69	0.73	0.69
50	0.71	0.71	0.75	0.75	0.71	0.75	0.75	0.71	0.75	0.75
70	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
100	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
130	0.89	**1.04**	0.89	0.89	**1.04**	0.89	0.89	**1.04**	0.89	0.89
160	0.86	**1.13**	0.95	0.86	**1.14**	0.95	0.86	**1.14**	0.95	0.86
200	0.76	**1.10**	0.95	0.83	**1.18**	0.95	0.83	**1.18**	0.95	0.83
250	0.66	**1.03**	0.92	0.82	**1.21**	0.98	0.82	**1.22**	0.98	0.82
300	0.58	0.95	0.86	0.79	**1.18**	1.00	0.83	**1.26**	1.00	0.83

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.75	0.75	0.79	0.75	0.75	0.79	0.75	0.75	0.79	0.75
50	0.76	0.76	0.76	0.79	0.76	0.76	0.79	0.76	0.76	0.79
70	0.76	0.76	0.76	0.80	0.76	0.76	0.80	0.76	0.76	0.80
100	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
130	0.92	1.00	0.92	0.92	1.00	0.92	0.92	1.00	0.92	0.92
160	0.90	**1.12**	0.93	0.90	**1.12**	0.93	0.90	**1.12**	0.93	0.90
200	0.80	**1.12**	0.97	0.85	**1.14**	0.97	0.85	**1.14**	0.97	0.85
250	0.70	**1.07**	0.95	0.85	**1.20**	0.97	0.85	**1.20**	0.97	0.85
300	0.62	1.00	0.91	0.83	**1.20**	**1.01**	0.84	**1.23**	**1.01**	0.84

Table C-20. Platoon Moment Ratio to HS 20 Moment. Positive Moment in Span 2, Three Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
50	0.56	0.51	0.56	0.56	0.51	0.56	0.56	0.51	0.56	0.56
70	0.71	0.53	0.63	0.71	0.53	0.63	0.71	0.53	0.63	0.71
100	0.83	0.63	0.59	0.67	0.59	0.59	0.67	0.59	0.59	0.67
130	0.90	0.87	0.68	0.64	0.65	0.65	0.64	0.65	0.65	0.64
160	0.94	**1.06**	0.86	0.72	0.93	0.67	0.69	0.74	0.67	0.69
200	0.85	**1.11**	0.93	0.79	**1.12**	0.85	0.64	0.91	0.66	0.61
250	0.76	**1.08**	0.94	0.83	**1.21**	0.98	0.79	**1.12**	0.80	0.60
300	0.68	**1.03**	0.92	0.82	**1.22**	**1.03**	0.87	**1.22**	0.93	0.71

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
50	0.69	0.62	0.69	0.69	0.62	0.69	0.69	0.62	0.69	0.69
70	0.78	0.56	0.67	0.76	0.56	0.67	0.76	0.56	0.67	0.76
100	0.84	0.74	0.61	0.66	0.62	0.61	0.66	0.62	0.61	0.66
130	0.88	0.96	0.76	0.66	0.83	0.65	0.66	0.69	0.65	0.66
160	0.90	**1.12**	0.91	0.77	**1.11**	0.79	0.67	0.88	0.69	0.67
200	0.81	**1.12**	0.95	0.81	**1.24**	0.95	0.73	**1.11**	0.74	0.62
250	0.71	**1.07**	0.94	0.82	**1.27**	**1.04**	0.84	**1.25**	0.91	0.67
300	0.63	1.00	0.89	0.80	**1.24**	1.06	0.89	**1.30**	1.00	0.78

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
50	0.64	0.62	0.64	0.64	0.62	0.64	0.64	0.62	0.64	0.64
70	0.73	0.56	0.68	0.73	0.56	0.68	0.73	0.56	0.68	0.73
100	0.83	0.69	0.61	0.69	0.61	0.61	0.69	0.61	0.61	0.69
130	0.89	0.91	0.73	0.65	0.71	0.66	0.65	0.69	0.66	0.65
160	0.93	**1.11**	0.89	0.76	1.00	0.70	0.70	0.77	0.69	0.70
200	0.85	**1.14**	0.95	0.82	**1.17**	0.89	0.67	0.99	0.68	0.63
250	0.75	**1.11**	0.96	0.84	**1.25**	**1.01**	0.82	**1.18**	0.85	0.63
300	0.67	**1.05**	0.94	0.84	**1.25**	**1.06**	0.89	**1.27**	0.97	0.74

Table C-21. Platoon Moment Ratio to HS 20 Moment. Negative Moment at First Interior Support, Three Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
50	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
70	0.69	**1.09**	0.88	0.69	**1.09**	0.88	0.69	**1.09**	0.88	0.69
100	0.65	**1.13**	**1.10**	0.98	**1.14**	**1.10**	0.98	**1.14**	**1.10**	0.98
130	0.57	0.95	**1.01**	1.00	**1.11**	**1.01**	1.00	**1.13**	**1.01**	1.00
160	0.51	0.78	0.85	0.89	**1.07**	0.96	0.90	<u>**1.22**</u>	0.97	0.90
200	0.43	0.70	0.67	0.73	0.96	0.93	0.85	<u>**1.21**</u>	**1.06**	0.87
250	0.36	0.64	0.59	0.56	0.78	0.81	0.80	**1.05**	**1.02**	0.93
300	0.31	0.57	0.54	0.51	0.73	0.68	0.70	0.88	0.91	0.88

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
50	0.85	0.98	0.85	0.85	0.98	0.85	0.85	0.98	0.85	0.85
70	0.69	**1.20**	**1.01**	0.71	**1.20**	**1.01**	0.71	**1.20**	**1.01**	0.71
100	0.62	**1.06**	**1.09**	**1.01**	**1.14**	**1.09**	**1.01**	**1.14**	**1.09**	1.01
130	0.53	0.84	0.93	0.95	**1.13**	0.98	0.95	<u>**1.24**</u>	**0.98**	0.95
160	0.47	0.73	0.75	0.81	**1.03**	0.96	0.85	<u>**1.27**</u>	**1.04**	0.85
200	0.40	0.68	0.61	0.64	0.86	0.88	0.83	**1.14**	**1.07**	0.91
250	0.33	0.60	0.57	0.52	0.76	0.73	0.74	0.94	0.96	0.90
300	0.29	0.53	0.51	0.48	0.71	0.63	0.63	0.80	0.82	0.82

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
50	**1.01**	**1.01**	**1.01**	**1.01**	**1.01**	**1.01**	**1.01**	**1.01**	**1.01**	**1.01**
70	0.78	**1.08**	0.91	0.78	**1.08**	0.91	0.78	**1.08**	0.91	0.78
100	0.64	**1.10**	**1.10**	0.99	**1.12**	**1.10**	0.99	**1.13**	**1.10**	0.99
130	0.57	0.93	1.00	1.00	**1.19**	**1.01**	1.00	**1.19**	**1.01**	1.00
160	0.50	0.75	0.84	0.88	**1.12**	0.98	0.89	<u>**1.26**</u>	**1.01**	0.89
200	0.43	0.70	0.66	0.72	0.95	0.93	0.86	<u>**1.21**</u>	**1.08**	0.89
250	0.36	0.64	0.60	0.55	0.77	0.80	0.80	**1.05**	**1.02**	0.95
300	0.31	0.58	0.55	0.52	0.74	0.68	0.69	0.88	0.91	0.87

Table C-22. Platoon End Shear Ratio to HS 20 Shear. End Shear, Three Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.59	0.60	0.59	0.59	0.60	0.59	0.59	0.60	0.59	0.59
50	0.69	0.69	0.71	0.71	0.69	0.71	0.71	0.69	0.71	0.71
70	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
100	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
130	0.94	**1.09**	0.97	0.94	**1.09**	0.97	0.94	**1.09**	0.97	0.94
160	0.90	**1.16**	**1.05**	0.96	**1.16**	**1.05**	0.96	**1.16**	**1.05**	0.96
200	0.81	**1.16**	**1.07**	0.98	**1.19**	**1.07**	0.98	**1.19**	**1.07**	0.98
250	0.72	**1.11**	**1.04**	0.97	**1.23**	**1.07**	0.97	**1.23**	**1.07**	0.97
300	0.64	**1.04**	0.98	0.93	**1.22**	**1.09**	0.97	**1.26**	**1.09**	0.97

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.70	0.70	0.71	0.70	0.70	0.71	0.70	0.70	0.71	0.70
50	0.74	0.74	0.74	0.76	0.74	0.74	0.76	0.74	0.74	0.76
70	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
100	0.87	0.96	0.87	0.87	0.96	0.87	0.87	0.96	0.87	0.87
130	0.90	**1.15**	**1.01**	0.92	**1.15**	**1.01**	0.92	**1.15**	**1.01**	0.92
160	0.85	**1.19**	**1.08**	0.97	**1.20**	**1.08**	0.97	**1.20**	**1.08**	0.97
200	0.76	**1.15**	**1.06**	0.98	**1.26**	**1.07**	0.98	**1.26**	**1.07**	0.98
250	0.67	**1.08**	**1.01**	0.95	**1.27**	**1.10**	0.96	**1.30**	**1.10**	0.96
300	0.59	0.99	0.94	0.89	**1.23**	**1.09**	0.97	**1.32**	**1.10**	0.97

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.77	0.77	0.78	0.77	0.77	0.78	0.77	0.77	0.78	0.77
50	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
70	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
100	0.89	0.96	0.89	0.89	0.96	0.89	0.89	0.96	0.89	0.89
130	0.94	**1.11**	0.98	0.94	**1.11**	0.98	0.94	**1.11**	0.98	0.94
160	0.90	**1.18**	**1.06**	0.97	**1.18**	**1.06**	0.97	**1.18**	**1.06**	0.97
200	0.81	**1.17**	**1.08**	0.99	**1.23**	**1.08**	0.99	**1.23**	**1.08**	0.99
250	0.72	**1.12**	**1.04**	0.98	**1.26**	**1.09**	0.98	**1.26**	**1.09**	0.98
300	0.64	**1.04**	0.99	0.94	**1.24**	**1.10**	0.98	**1.29**	**1.10**	0.98

Table C-23. Platoon End Shear Ratio to HS 20 Shear. Shear left of First Interior Support, Three Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
50	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
70	0.88	0.91	0.88	0.88	0.91	0.88	0.88	0.91	0.88	0.88
100	0.97	**1.04**	**1.01**	0.98	**1.11**	**1.01**	0.98	**1.11**	**1.01**	0.98
130	0.91	**1.14**	**1.00**	0.94	**1.21**	**1.06**	0.96	**1.21**	**1.06**	0.96
160	0.81	**1.17**	**1.04**	0.92	**1.24**	**1.10**	0.97	**1.25**	**1.10**	0.97
200	0.71	**1.13**	**1.04**	0.95	**1.19**	**1.10**	**1.01**	**1.25**	**1.11**	**1.01**
250	0.61	**1.04**	0.98	0.93	**1.22**	**1.05**	0.97	**1.26**	**1.09**	0.99
300	0.53	0.94	0.90	0.87	**1.18**	**1.06**	0.93	**1.24**	**1.10**	0.97

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
50	0.79	0.80	0.79	0.79	0.80	0.79	0.79	0.80	0.79	0.79
70	0.87	0.91	0.88	0.87	0.91	0.88	0.87	0.91	0.88	0.87
100	0.92	**1.09**	0.97	0.94	**1.16**	**1.01**	0.94	**1.16**	**1.01**	0.94
130	0.85	**1.20**	**1.03**	0.91	**1.27**	**1.09**	0.96	**1.28**	**1.09**	0.96
160	0.75	**1.18**	**1.06**	0.94	**1.24**	**1.12**	0.99	**1.28**	**1.12**	0.99
200	0.65	**1.10**	**1.02**	0.95	**1.27**	**1.08**	1.00	**1.31**	**1.11**	1.00
250	0.55	0.98	0.94	0.89	**1.24**	**1.08**	0.93	**1.29**	**1.12**	0.97
300	0.48	0.88	0.85	0.82	**1.16**	**1.05**	0.94	**1.30**	**1.09**	0.98

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
50	0.72	0.74	0.72	0.72	0.74	0.72	0.72	0.74	0.72	0.72
70	0.87	0.91	0.87	0.87	0.91	0.87	0.87	0.91	0.87	0.87
100	0.97	**1.12**	**1.01**	0.98	**1.14**	**1.01**	0.98	**1.14**	**1.01**	0.98
130	0.90	**1.18**	**1.02**	0.94	**1.23**	**1.08**	0.97	**1.23**	**1.08**	0.97
160	0.81	**1.19**	**1.05**	0.93	**1.25**	**1.12**	0.98	**1.27**	**1.12**	0.98
200	0.71	**1.14**	**1.05**	0.96	**1.25**	**1.11**	**1.02**	**1.31**	**1.13**	**1.02**
250	0.61	**1.04**	0.99	0.93	**1.24**	**1.07**	0.98	**1.29**	**1.11**	0.99
300	0.53	0.94	0.91	0.87	**1.20**	**1.08**	0.95	**1.28**	**1.12**	0.99

Table C-24. Platoon End Shear Ratio to HS 20 Shear. Shear Right of First Interior Support, Three Equal Continuous Spans

Span (ft.)	33-1-00	33-2-30	33-2-50	33-2-70	33-3-30	33-3-50	33-3-70	33-4-30	33-4-50	33-4-70
30	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
50	0.71	0.74	0.71	0.71	0.74	0.71	0.71	0.74	0.71	0.71
70	0.83	0.90	0.85	0.83	0.90	0.85	0.83	0.90	0.85	0.83
100	0.93	**1.05**	1.00	0.96	**1.05**	1.00	0.96	**1.05**	**1.00**	0.96
130	0.90	**1.06**	1.00	0.97	**1.18**	**1.04**	0.97	**1.19**	**1.04**	0.97
160	0.81	**1.10**	0.98	0.91	<u>**1.21**</u>	**1.09**	0.97	<u>**1.24**</u>	**1.09**	0.97
200	0.72	**1.08**	0.99	0.90	**1.17**	**1.08**	1.00	<u>**1.23**</u>	**1.11**	1.00
250	0.62	**1.01**	0.95	0.88	**1.14**	**1.02**	0.97	<u>**1.21**</u>	**1.08**	0.99
300	0.54	0.93	0.88	0.84	**1.12**	1.00	0.91	**1.18**	**1.06**	0.95

Span (ft.)	3S2-1-00	3S2-2-30	3S2-2-50	3S2-2-70	3S2-3-30	3S2-3-50	3S2-3-70	3S2-4-30	3S2-4-50	3S2-4-70
30	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
50	0.76	0.80	0.76	0.76	0.80	0.76	0.76	0.80	0.76	0.76
70	0.84	0.92	0.87	0.84	0.92	0.87	0.84	0.92	0.87	0.84
100	0.90	**1.02**	0.99	0.94	**1.13**	0.99	0.94	**1.13**	0.99	0.94
130	0.85	**1.13**	0.98	0.93	<u>**1.24**</u>	**1.09**	0.94	<u>**1.27**</u>	**1.09**	0.94
160	0.76	**1.12**	1.00	0.90	<u>**1.22**</u>	**1.11**	0.99	<u>**1.28**</u>	**1.12**	0.99
200	0.66	**1.06**	0.98	0.90	**1.18**	**1.07**	0.99	<u>**1.26**</u>	**1.11**	0.99
250	0.57	0.97	0.91	0.86	**1.17**	**1.02**	0.93	<u>**1.23**</u>	**1.08**	0.97
300	0.50	0.88	0.84	0.80	**1.12**	1.00	0.89	<u>**1.22**</u>	**1.05**	0.95

Span (ft.)	T-1-00	T-2-30	T-2-50	T-2-70	T-3-30	T-3-50	T-3-70	T-4-30	T-4-50	T-4-70
30	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
50	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
70	0.82	0.90	0.85	0.82	0.90	0.85	0.82	0.90	0.85	0.82
100	0.93	**1.07**	1.00	0.97	**1.12**	1.00	0.97	**1.12**	1.00	0.97
130	0.89	**1.14**	1.00	0.97	<u>**1.22**</u>	**1.05**	0.97	<u>**1.22**</u>	**1.05**	0.97
160	0.81	**1.11**	0.99	0.91	<u>**1.22**</u>	**1.10**	0.98	<u>**1.26**</u>	**1.10**	0.98
200	0.71	**1.09**	1.00	0.91	**1.18**	**1.09**	**1.01**	<u>**1.28**</u>	**1.12**	**1.01**
250	0.62	**1.01**	0.95	0.89	**1.17**	**1.03**	0.97	<u>**1.24**</u>	**1.09**	1.00
300	0.54	0.93	0.89	0.84	**1.14**	**1.01**	0.91	<u>**1.21**</u>	**1.08**	0.97

APPENDIX D

CHARACTERISTICS OF THE BRIDGES IN THE LIMITED BRIDGE SAMPLE FOR DETAILED ANALYSIS

Table D-1: Bridge Characteristics for Bridge Sample, Reinforced Concrete Slab Bridges

Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Exterior/ Interior Girder	Average Girder Spacing (ft)
RC Slab	Y	1	21	0	N/A	N/A
RC Slab	Y	1	41.58	0	N/A	N/A
RC Slab	Y	1	42.59	0	N/A	N/A
RC Slab	Y	3	20.50, 20.50, 20.50	0	N/A	N/A
RC Slab	Y	3	42.00, 52.00, 42.00	0	N/A	N/A
RC Slab	Y	3	41.00, 52.50, 39.28	0	N/A	N/A
RC Slab	Y	3	42.42, 53.00, 42.42	0	N/A	N/A

Table D-2: Bridge Characteristics for Bridge Sample, Reinforced Concrete T-Beam Bridges

Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Exterior/ Interior Girder	Average Girder Spacing (ft)
RC T-Beam	N	1	61.17	0	I	9
RC T-Beam	N	1	61.17	0	E	5.81

Table D-3: Bridge Characteristics for Bridge Sample, Prestressed Concrete Box Beam Bridges

Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Exterior/ Interior Girder	Average Girder Spacing (ft)
P/S Box	Y	1	106	-10.5	E	3.27
P/S Box	Y	1	106	-10.5	I	4
P/S Box	Y	1	75.56	-30	I	4.13
P/S Box	Y	1	71.25	-7.44	I	7.38
P/S Box	Y	1	53.35	0	I	7.38
P/S Box	Y	1	50.67	0	I	8.04
P/S Box	Y	1	38.67	10	I	9.83
P/S Box	N	1	115	30	E	2.3
P/S Box	N	1	115	30	I	3.1
P/S Box	N	1	74.88	-38.78	I	3
P/S Box	N	1	47.99	15.08	I	3.91

Table D-4: Bridge Characteristics for Bridge Sample, Simple Span Prestressed Concrete I-Beam Bridges

Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Exterior/ Interior Girder	Average Girder Spacing (ft)
P/S I	Y	1	162.25	-60	I	5.54
P/S I	Y	1	162.25	-60	E	4.22
P/S I	Y	1	144.18	0.82	I	8.17
P/S I	Y	1	144.18	0.82	E	5.83
P/S I	Y	1	90.85	19.41	I	10.58
P/S I	Y	1	78.23	29	I	7
P/S I	Y	1	78.23	29	E	5.44
P/S I	Y	1	52.5	0	I	7
P/S I	Y	1	52.5	0	E	5.44

Table D-5: Bridge Characteristics for Bridge Sample, Continuous Span Prestressed Concrete I-Beam Bridges

Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Exterior/ Interior Girder	Average Girder Spacing (ft)
P/S I	Y	2	134.21, 123.21	-9.24	I	10
P/S I	Y	2	134.21, 123.21	-9.24	E	7.17
P/S I	Y	2	115.33, 115.33	8.38	I	9.5
P/S I	Y	2	115.33, 115.33	8.38	E	6.42
P/S I	Y	2	109.68, 107.42	-25.52	E	4.85
P/S I	Y	2	109.68, 107.42	-25.52	I	7.25
P/S I	Y	2	68.13, 102.13	0	I	9.17
P/S I	Y	2	68.13, 102.13	0	E	6.29
P/S I	Y	3	125.00, 131.50, 95.50	0	I	5.83
P/S I	Y	3	66.29, 126.00, 66.29	29.67	I	8.67
P/S I	Y	3	96.08, 119.81, 96.08	25	I	8.46
P/S I	Y	3	96.08, 119.81, 96.08	25	E	5.79
P/S I	Y	3	84.71, 111.96, 86.22	-15	I	10.17
P/S I	Y	3	69.23, 71.00, 69.23	-45	E	5.77
P/S I	Y	3	69.23, 71.00, 69.23	-45	I	8.08
P/S I	Y	3	35.00, 35.00, 35.00	0	I	8.5
P/S I	Y	3	35.00, 35.00, 35.00	0	E	5.94

Table D-6: Bridge Characteristics for Bridge Sample, Simple Span Steel Plate Girder Bridges

Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Exterior/ Interior Girder	Average Girder Spacing (ft)
Steel Plate	Y	1	153.61	67.5	E	4.88
Steel Plate	Y	1	153.61	67.5	I	7.25
Steel Plate	Y	1	63	37.09	E	2.44
Steel Plate	Y	1	63	37.09	I	3.5
Steel Plate	Y	1	80	0	I	10.5
Steel Plate	Y	1	204	-5	I	9.67
Steel Plate	Y	1	80	0	E	6.29
Steel Plate	Y	1	204	-5	E	6.54
Steel Plate	Y	1	126	0	E	6.35
Steel Plate	Y	1	126	0	I	9.75

Table D-7: Bridge Characteristics for Bridge Sample, Continuous Span Steel Plate Girder Bridges

Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Exterior/ Interior Girder	Average Girder Spacing (ft)
Steel Plate	Y	2	189.00, 189.00	9.66	E	6.4
Steel Plate	Y	2	189.00, 189.00	9.66	I	9.75
Steel Plate	Y	2	161.00, 141.00	0	I	7.67
Steel Plate	Y	2	161.00, 141.00	0	E	4.9
Steel Plate	Y	2	102.00, 132.00	8	E	6.3
Steel Plate	Y	2	102.00, 132.00	8	I	10.2
Steel Plate	Y	2	118.50, 118.50	30	I	8.5
Steel Plate	Y	2	118.50, 118.50	30	E	5.71
Steel Plate	N	3	140.58, 179.83, 140.58	0	I	7.71
Steel Plate	N	3	140.58, 179.83, 140.58	0	I	7.71
Steel Plate	Y	3	188.50, 273.00, 188.50	0	I	12.75
Steel Plate	Y	3	188.50, 273.00, 188.50	0	E	8.92
Steel Plate	Y	3	140.00, 180.00, 140.00	0	I	8.75
Steel Plate	Y	3	140.00, 180.00, 140.00	0	E	6.31
Steel Plate	Y	4	130.00, 250.00, 250.00, 215.00	-5.79	E	6.5
Steel Plate	Y	4	130.00, 250.00, 250.00, 215.00	-5.79	I	10
Steel Plate	Y	4	138.21, 185.00, 143.00, 138.21	55	E	5.58
Steel Plate	Y	4	138.21, 185.00, 143.00, 138.21	55	I	8.17
Steel Plate	Y	4	48.00, 123.00, 123.00, 53.00	-45.53	I	10
Steel Plate	Y	4	48.00, 123.00, 123.00, 53.00	-45.53	E	6.67

Table D-8: Bridge Characteristics for Bridge Sample, Simple Span Steel Rolled Beam Bridges

Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Exterior/ Interior Girder	Average Girder Spacing (ft)
Steel Rolled Beam	Y	1	100	0	I	6.83
Steel Rolled Beam	Y	1	100	0	E	4.63
Steel Rolled Beam	N	1	89	0	I	5.5
Steel Rolled Beam	N	1	89	0	E	3.25
Steel Rolled Beam	Y	1	75.75	0	E	4.81
Steel Rolled Beam	Y	1	75.75	0	I	7.08
Steel Rolled Beam	N	1	73.89	0	I	6
Steel Rolled Beam	N	1	73.89	0	E	4.08

Table D-9: Bridge Characteristics for Bridge Sample, Continuous Span Steel Rolled Beam Bridges

Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Exterior/ Interior Girder	Average Girder Spacing (ft)
Steel Rolled Beam	Y	2	49.75, 81.77	18.57	E	4.19
Steel Rolled Beam	Y	2	49.75, 81.77	18.57	I	6.22
Steel Rolled Beam	Y	2	82.88, 82.88	0	I	6.47
Steel Rolled Beam	Y	2	51.00, 51.00	0	I	7.54
Steel Rolled Beam	Y	3	79.08, 81.98, 79.08	-50	I	5.54
Steel Rolled Beam	Y	3	79.08, 81.98, 79.08	-50	E	3.5
Steel Rolled Beam	N	3	50.00, 80.00, 50.00	0	E	4.38
Steel Rolled Beam	N	3	50.00, 80.00, 50.00	0	I	6.67
Steel Rolled Beam	Y	3	28.83, 36.33, 28.83	0	I	7.29
Steel Rolled Beam	Y	4	101.00, 90.00, 90.00, 87.50	47.79	I	7
Steel Rolled Beam	Y	4	101.00, 90.00, 90.00, 87.50	47.79	E	4.67
Steel Rolled Beam	N	4	60.00, 75.00, 75.00, 60.00	10	E	4.06
Steel Rolled Beam	N	4	42.00, 56.00, 56.00, 42.00	0	I	7.67