IMPACT OF TRUCK PLATOONING ON LOADING OF BRIDGES IN OREGON

Final Report

SPR 848

Oregon Department of Transportation

IMPACT OF TRUCK PLATOONING ON LOADING OF BRIDGES IN OREGON

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PROJECT 848

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16. Abstract

Truck platooning is an autonomous vehicle technology where multiple heavy trucks operate at close spacing. In 2018, Oregon House Bill HB 4059 Section 40 allowed limited implementation of such technology without requiring permitting or notification to ODOT. However, the close spacing of platooned trucks may impose loading on some bridges in excess of the load levels currently limited by the weight regulations that are applicable to individual trucks. This potential overloading could reduce the lifespan of Oregon bridges. To preserve the life of existing bridges and ensure the structural safety of bridges where truck platooning is expected, it is important to understand the magnitude of truck platoon loading effects. In this research, truck platoon technology and performed studies were reviewed. Moving load analyses were performed for design, OR legal, and OR permit loads in single and platoon configuration for single-span, two-span, and three-span bridges with span lengths ranging from 15 to 80 m. Platoon configurations studied included two and three vehicles with head spacings ranging from 3 to 18 m. Ratios of internal forces from truck platoons to legal and single-truck live loads were computed and analyzed in depth.

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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	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	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	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

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	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

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1.0 INTRODUCTION AND BACKGROUND

Truck platooning is an emerging autonomous vehicle technology where two or more heavy trucks operate at close spacing to achieve fuel economies and perhaps, in the future, a reduction in labor by partial or full autonomous operations. Truck platoons are expected to be more widely and quickly adopted than autonomous vehicles (Banker, 2019; Bishop, 2019). Current versions of truck platooning technology available in the market use radar and vehicle-to-vehicle communications (V2V) to synchronize acceleration and braking of lead and rear truck, with both trucks operated by humans (Bishop, 2019). However, higher return of investment is expected when the follower truck is automated (Bishop, 2020a). Platooning technology is being viewed as a way to improve safety and throughput and is expected to have applications in other sectors such as forestry, mining, port drayage, and military logistics (Bishop, 2020a; Bishop 2020b). Sanctions in ORS 811.485 against a vehicle operator following another vehicle too closely have been excepted by House Bill 4059 Section 40 when a "connected automated braking system" is employed, without requiring permitting or notification to ODOT. The close spacing of platooned trucks allowed by this provision can impose loading on some bridges in excess of the load levels currently limited by weight regulations applicable to individual trucks. This potential overloading could reduce the lifespan of Oregon bridges and it is therefore important to understand the magnitude of truck platoon loading effects. To this end, this interim report contains a review and summary of the available literature on truck platooning technology, truck platoon studies, literature reporting structural analyses performed to quantify truck platoon loading effects, and a discussion of refined structural analysis methods which can capture those load effects and load distributions more accurately.

1.1 OBJECTIVE

The objective of this research was to determine what combination of truck configurations (axle weights and axle spacings) and platoon vehicle spacings (headspace) may exceed acceptable load levels for Oregon bridges. To answer this question, bridge analyses were performed on representative bridges with truck platoon configurations consisting of trucks allowed under Oregon law and analysis results were compared with those based on truck loads currently used in Oregon. Analysis results are used for policy and regulatory recommendations and for recommendations to update load ratings on Oregon's bridges.

1.2 ORGANIZATION OF REPORT

This report contains a literature review on existing truck platoon technologies and published truck platoon studies, structural analyses performed to quantify the load effects from truck platoons on bridge components, and refined structural analysis methodologies that can capture the distribution of vehicle loads in bridges. The Society of Automotive (SAE) International definitions of Level 0 to Level 5 are used to refer to the various levels of driving automation standards in this report (Shuttleworth, 2019). Moving load analyses performed as part of this research are discussed and ratios of internal forces from truck platoon configurations to legal and single-truck live loads analyzed in depth. A load rating example is discussed for reference. Finally, the results are summarized, and recommendations presented.

2.0 LITERATURE REVIEW

2.1 TRUCK PLATOONING

This section reviews research projects and demonstration and evaluation studies on truck platooning conducted in the United States, Europe, and Asia over the last two decades.

Advantages of truck platooning are increased fuel efficiency and safety, as well as increased comfort and convenience for the driver (Tsugawa et al., 2016). This study reviews results from three continents describing configurations, technologies, and studies performed. Besides reporting fuel savings, one of the interesting findings is that autonomous driving for trucks may be implemented easier and faster than autonomous passenger cars because of the direct cost savings from reduced fuel consumption and, in the long run, reduced personnel costs.

The National Renewable Energy Laboratory (NREL) has conducted a series of research projects to determine the value of truck platooning in different aspects. The fuel savings varied with driving conditions, ambient temperature, load, and distance between platoons. In a three-truck platoon, fuel savings of up to 10%, 17%, and 13% were observed for the leading, follower, and trailer vehicles, respectively (Lammert et al., 2020, 2014; McAuliffe et al., 2018). The research also found that up to 63% of total miles driven by Class 8 trucks were at speeds for which platooning can occur and 65% of total miles driven by FHWA Class 7 and Class 8 trucks (see Figure 2-1) could be driven in platoon formation (Lammert et al., 2018; Muratori et al., 2017). Several other studies have also highlighted the fuel and environmental benefits of truck platooning (Zhang et al., 2020; Humphreys et al., 2016; Tsugawa et al., 2016). Given the cost benefits of truck platooning, Bhoopalam et al. (2018) provide a detailed survey of optimizing and planning the supply chain and logistics operations under platoons.

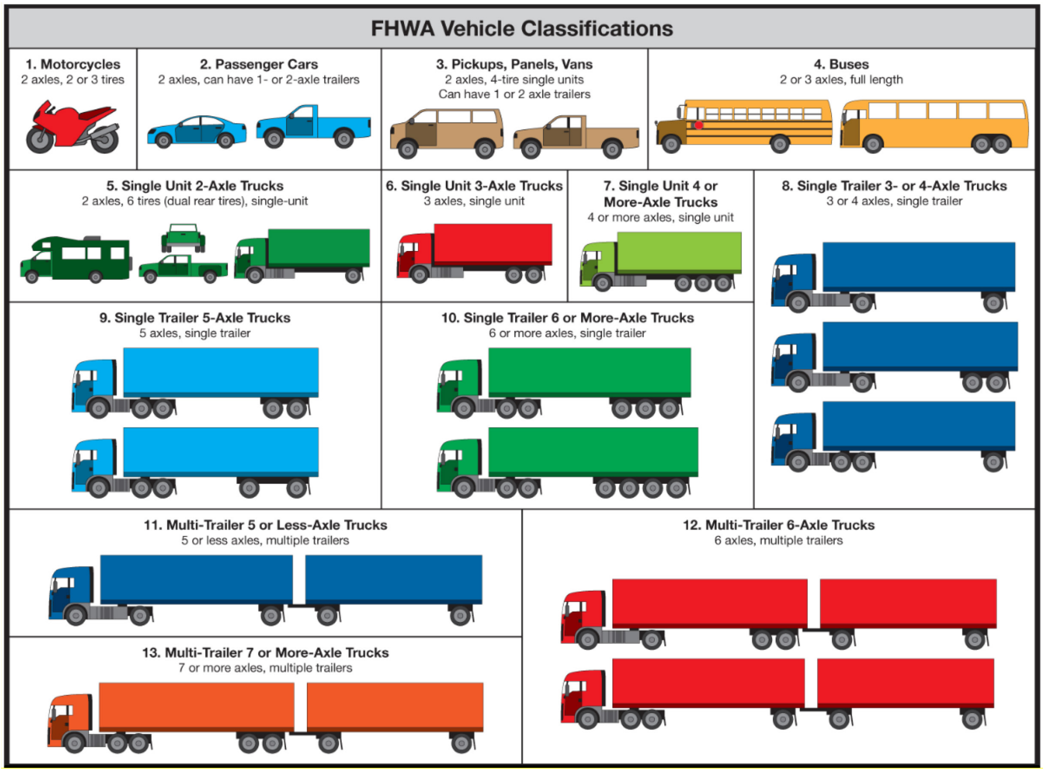

Figure 2.1: FHWA 13 Vehicle Classification (Source: Federal Highway Administration, 2016)

Kuhn et al. (2017) recommended ideal roadway characteristics for truck platoons, e.g., interstate or multi-lane divided highways with two or more lanes in each direction, level terrain, low curvature, and sufficient lane and shoulder width as well as sufficient exit and on-ramp distances. With desirable roadway characteristics, the key question to consider for platoons is their effect on transportation structures, particularly bridges, many of which were built in the interstate expansion of the 1950s and are now reaching the end of their design lives.

Hartmann (2019) summarized many of the key issues to consider with truck platoons. Platoons of two to four trucks are expected in the near term, but it is possible that as platoon technology matures, larger platoons will emerge. One of the main interests in truck platoons is fuel savings (Roberts et al., 2016), which tends to increase as truck spacing decreases. Accordingly, truck spacing is an important consideration because spacing will have a significant impact on load effects in bridges. Similarly, individual axle weights are of concern in closely spaced platoons as well as bridge postings for weight and spacing limits of platoons. Consistent with structural engineering intuition, it is likely that long span bridges will be affected by truck platoons more so than short span bridges.

According to Bishop (2019), the first-generation truck platoons are expected to follow level one automated driving protocols where the driver is driving even when the automated driving support is engaged (Shuttleworth, 2019). The driver is expected to supervise and monitor the driving and accelerate, decelerate, brake, and steer to maintain safety. The lead driver may or may not use Adaptive Cruise Control. However, the Forward Collision Avoidance and Mitigation feature must always be turned on for the leader and the follower trucks. The longitudinal control of the follower truck is automated and controlled by the leader. However, the driver of the follower truck is responsible for reacting to real-world traffic, weather conditions, and appropriately steering the truck. Both drivers will be communicating while driving.

Table 2.1 shows a number of truck platooning studies in the United States, Europe, and Asia which had extensive testing and validation (Bishop, 2019). All of the tests have leader trucks following level one automation. Most of the research efforts are focusing on platooning with two-trucks. By 2020 in the United States, full and commercial deployment was allowed in 27 states. Testing was allowed in five more states – California, Washington, Wyoming, Virginia, and New Jersey (see Figure 2.2). These 32 states account for 80% of US annual truck freight traffic (Bishop, 2020a).

Table 2.1: Truck Platooning Studies with Extensive Evaluation and Validation (Source: Bishop, 2019)

Commercial / Research	Country	Organization	Automation Level Leader	Automation Level Follower	Number Of Trucks	Year of Operation
Commercial	USA	Peloton	L1	L1	2	2018
Commercial	USA	Freightliner	L1	L1	2	2018
Research	USA/ Canada	Auburn University	L1	L2	2-4	2018
Commercial	Germany	MAN	L1	L2	2	2018
Research	UK	Transp. Research Lab (Helm-UK)	L1	L2	3	2018
Research	NL	Rijkswaterstaat	L1	L1	2	2019
Research	Sweden	Volvo/Scania	L1	L2	2	2019
Commercial	Finland	Scania	L1	L2	3	2019
Research	Europe	ENSEMBLE, EC	L1	L2	2	2019
Research	Singapore	Port of Singapore	L1	L4 Driverless	2	2019
Research	Japan	METI	L1	L4 Driverless	3	2019

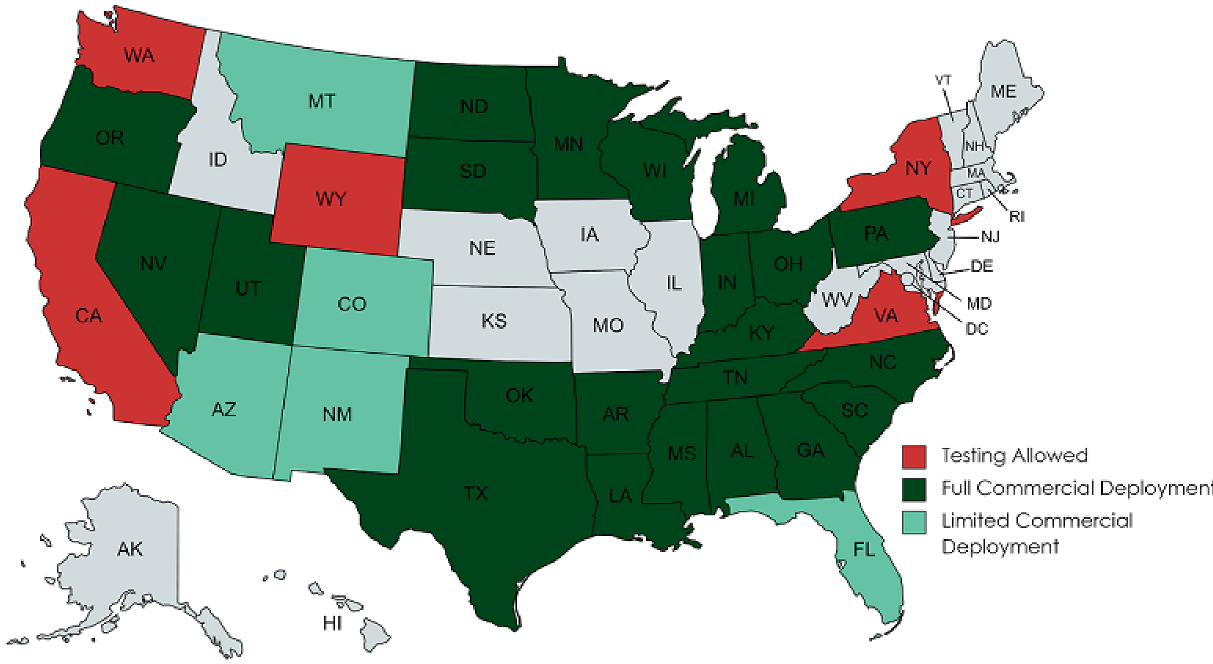

Figure 2.2: Truck Platooning Status in US (Source: Bishop, 2020a)

Truck platooning studies have been conducted in Europe since 2002. One of the earliest studies was the CHAUFFEUR project from 2000 to 2003, funded by the European Union (TRIMIS, 2021). The project focused on a detailed evaluation of the technology needed for the electronic coupling of two-trucks with only the leader truck driver being active. The project also conducted a feasibility study for truck platooning with more than two-trucks with only the leader truck driver being active as well as automated truck platooning. A system, CHAUFFEUR Assistant, which enables two-truck platooning, and five prototype vehicles, was developed.

Kunze et al. (2010) developed an electronic coupling system for trucks called KONVOI which enabled both longitudinal and lateral control. The system was tested on test tracks and trial runs conducted on motorways. The platoon had up to four trucks at a spacing of 10 m (33 ft).

The Grand Cooperative Driving Challenge (GCDC) was an open competition on cooperative, autonomous driving in the Netherlands in the summer of 2011 (Lauer, 2011). The objective was to create a longitudinal control setup in a platoon with a human driver taking care of lateral control. Unlike previous demonstrations, The GCDC testing was done on a different vehicle of various sizes – small to large trucks with the lead vehicle chosen by the organizers. The competition was held on a highway; however, the highway was closed off to regular traffic during the competition. Processing and fusing data from multiple vehicles using different control and communication systems in regular traffic as well as data from on-board sensors, was identified as a key challenge.

Bergenheim et al. (2012) compared five platooning projects (see Table 2.2):

- SARTRE: European project to develop platooning systems for mixed traffic – passenger car and trucks. The project focused on both longitudinal and lateral control. A five-vehicle platoon demonstration was conducted in Barcelona, Spain, in 2012.

- PATH research project is based in California. The experiments showed that two-truck platoons could be implemented at a gap of 3 m (10 ft), whereas three-truck platoons can be implemented at a gap of 4 m (13 ft). The research showed that truck platooning could lead to 10% to 15% fuel savings for the follower trucks. PATH focused on platooning of homogenous vehicles.

- GCDC, which was explained above, focused on integrating solutions from several vendors for platooning of heterogeneous vehicles in mixed traffic flow.

- Energy ITS is a platooning experiment and demonstration in Japan with three-truck platoons traveling at 80 km/h (50 mi/h) with a gap of 10 m (33 ft). The platoons are assumed to consist of homogenous trucks.

- SCANIA-platooning is a series of truck platooning experiments and research efforts in Sweden. The main goal of the research was fuel savings through platooning. The truck gaps considered in trials were 40 to 60 m (130 to 200 ft).

Table 2.2: Comparison of Truck Platooning Projects (Bergenheim et al., 2012)

	Vehicle Type	Control	Infrastructure Requirements	Traffic Integration	Sensors	Goals
SARTRE	Mixed	Lat + Long	None	Highway, mixed	Production	Comfort, safety, congestion, energy
PATH	Cars or Heavy	Lat + Long	Reference markers in road surface	Dedicated lane	Mixed	Increased throughput per lane, energy saving
GCDC	Mixed	Long	Augmented GPS	Mixed	State of Art (SoA)[1] and production	Accelerate deployment of cooperative driving systems
Energy-ITS	Heavy	Lat + Long	Lane markings	Dedicated lane	State of Art (SoA)	Mitigate lack of skilled drivers
SCANIA	Heavy	Long	None	Highway, Mixed	No V2V communication in first stage	Commercial fleet, energy

The COMPANION research project based in Sweden, with SCANIA as the lead partner, focuses on developing off-board and on-board platforms to promote cooperative mobility and evaluate legislative challenges (Eilers et al., 2015). The project's focus is to develop systems that aid in route optimization, including other vehicles to platoon with, speeds, merge and split points, etc. The project also evaluates systems for automated longitudinal control once the driver reaches the highway.

In the United States, Maxwell et al. (2013) highlights the need for developing standards for evaluating platooning technologies for military convoy applications. The authors describe features specific to military convoy applications such as obstacle avoidance and area mapping and stress the importance of developing clear benchmarks for evaluating technology solutions.

In collaboration with Peloton trucking, Auburn University evaluated the possibility of using truck platooning in reducing freight transport costs (Bevly et al., 2015). They tested a "Driver Assistive Truck Platooning" System, an SAE Level 1 Automated system (Shuttleworth, 2019) where the longitudinal control is automated, but the driver still controls the steering, acceleration, and braking. A computational fluid dynamics model was developed to evaluate drag reductions from two-truck platooning. Fuel economy testing was done on a test track with spacings of 9, 12, 15, 23, and 46 m (30, 40, 50, 75, and 150 ft) with total savings of around 7% observed for a 9 m (30 ft) gap. However, the gap for commercial operations was expected to be at least 15 to 23 m (50 to 75 ft) to account for driver comfort with greater distances under poor weather conditions. The research concluded that while further studies are needed, the initial results demonstrate the economic viability of truck platooning in reducing freight costs and improving efficiency.

Individual trucking companies have conducted truck platooning demonstrations in collaboration with other public and private sector enterprises. Daimler conducted two-truck platooning tests on select highways in Oregon and Nevada in 2017 (Daimler, 2017). Peloton technology demonstrated two Volvo Class 8 truck platoons on I-96 in Michigan and over 1000 miles in the Florida turnpike. The trucks were separated at 20 m (65 ft) and both trucks had drivers in control (CCJ, 2017a; CCJ, 2017b). North America conducted a demonstration of three-truck platoons on Triangle Expressway, NC 540 in collaboration with FedEx and North Carolina Turnpike Authority (Fleet Magazine, 2018). The platoons consisted of three Volvo NL trucks pulling two 28 ft trailers. The platoon traveled at 100 km/h (62 mi/h) with a gap of 1.5 seconds (around 41.5 m (136 ft)). All three-trucks had professional truck drivers. Dedicated short range communication based Cooperative Adaptive Cruise Control technology was used for the platoons.

Locomation, a startup specializing in autonomous and truck platooning technology have conducted demonstrations in multiple regions of the United States. Locomation in collaboration with Smart Belt Coalition, a consortium of 12 agencies and universities based in Pennsylvania, Michigan, and Ohio, demonstrated a L1 automated platoon of two tractor trailer platoons. The platoon made a trip of 450 km (280 mi) from Pennsylvania to Michigan through Ohio (Carey, 2020; The Trucker, 2020). Locomation in collaboration with Wilson logistics conducted deliveries of 14 loads from Portland, Oregon to Nampa, Idaho – a distance of 675 km (420 mi) along I-84. The platoon comprised of two-trucks with drivers equipped with the company's Autonomous Relay System (Fisher, 2020).

2.2 STRUCTURAL ANALYSES USING TRUCK PLATOONS

Through structural analysis, bridge engineers can obtain an estimate of the effects of truck platoons on bridge condition. However, the literature on structural analyses for truck platoons is limited, presumably because platoons do not pose the types of additional analysis complexity or changes in analysis methodology that tend to invite academic research. This section summarizes literature documenting the structural analyses used to quantify the loading effects of hypothetical truck platoons.

Yarnold and Weidner (2019) present a parameter study to evaluate the live load effects of two to four platooning FDOT C5 trucks on hypothetical single and multi-span steel-girder composite bridges with different span lengths modeled with girder line analysis. Using a distribution factor of 1 for all cases, the shear force and bending moment demands were computed for a range of truck platoon configurations and compared to those generated from the AASHTO LRFD (2017) as well as the AASHTO Standard Specification (2002) design live load models. Multiple presence was not investigated, and the number of girders, deck thickness, and web depth were kept the same for all analyses.

The following variables were studied:

- Bridge span configuration (L = span length):
  - Simple span, span length, L
  - Two-span continuous, span lengths, L – L
  - Three-span continuous, span lengths, 0.8L – L – 0.8L
  - Three-span continuous, span lengths, 0.4L – L – 0.4L
- Span length, L ranging from 6.1 to 91 m (20 to 300 ft) in equal increments of 6.1 m (20 ft)
- Live load models considered:
  - Two-, three-, and four-truck platoons consisting of FDOT C5 trucks, vehicle spacings, *Sa* ranging from 6.1 to 12.2 m (20 to 40 ft) in equal increments of 1.5 m (5 ft) (see Figure 2-3)
  - AASHTO LRFD design live load (HS20-44 + lane load or tandem axle + lane load)
  - AASHTO Standard Specifications design live load (HS20-44 or lane load + concentrated loads)

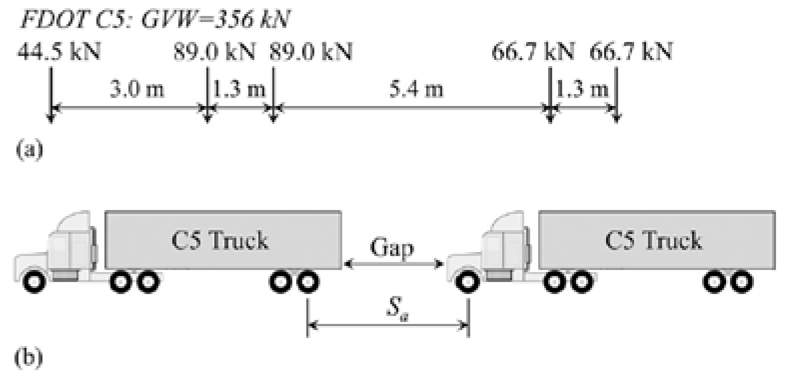

Fig. 1. (a) C5 truck axle weights and spacings; and (b) C5 truck platoon configuration (two-truck platoon displayed).

Figure 2.3: Truck selected for parameter study. (Source: Yarnold and Weidner, 2019) Gross vehicle weight (GVW) = 356 kN (80 kip).

Three-dimensional envelopes were generated separately for positive and negative bending moments, and maximum shear forces, allowing for a comparison between truck platoons and the two LRFD design loads. The main findings of the study are that bridges designed with AASHTO LRFD will fare overall much better compared to bridges that were designed using the outdated AASHTO Standard Specifications. For multi-span bridges, the AASHTO LRFD live loads were found to produce larger negative bending moments compared to the moments found considering the truck platoons. Bridges with longer spans and closely spaced truck platoons are of concern no matter which design code was used. The authors recommend that the following factors are considered in future research: dynamic load allowance, multiple presence, fatigue, braking forces, load ratings, other truck platoon configurations, and other structure types.

In subsequent work, Tohme and Yarnold (2020) performed a parameter study based on the AASHTO Manual for Bridge Evaluation's load rating procedure (AASHTO 2018). Only the operating level was studied, but both the design and legal live loads were considered. The variables in this study included span length, number of spans (all having equal span length), number of trucks, and vehicle spacing. The benchmark bridge they used was the AASHTO MBE Example Bridge A1, which is a single-span steel girder composite bridge. The same girder line analysis was employed to compute ratios of load rating factors (LR) for truck platoon loadings and the AASHTO design live loads and legal loads. The study only considered bending moments. In addition to the most current load rating procedure, i.e. LRFR, the authors also computed LR ratios for the older LFR and ASR methodologies for comparison. Since the authors ultimately report load rating ratios, the live load factors cancel out. This implies that the authors assume that the live load factors for the design loads and the truck platoons are identical. In reality, live load factors for truck platoons would have to be calibrated based on actual data, which currently does not exist or is not publicly available. The study confirmed that the number of trucks in a platoon and their spacing plays an important role in the load effects on steel girder composite bridges.

Sayed et al. (2020) analyzed a typical single-span and a typical three-span continuous bridge for truck platoons consisting of 35-ton (315 kN = 70 kip) FDOT SU4 trucks. A comprehensive case study on an actual single-span bridge was also performed following the integrated bridge load rating (IBLR) methodology, which considers both super as well as substructure load ratings. The final load rating is based on the lower of the two rating factors. The authors found that platoons can lead to significant increases in live load reaction compared to single truck loadings. As vehicle spacing increases, the detrimental effect of truck platoons on flexural response tends to decrease; however, platooning causes significant increases in shear. The most significant increases in load effects due to truck platoons, which also translate to the substructure, were found for simple span bridges with span lengths over 15.2 m (50 ft). The authors emphasize the need to reassess the applicability of the federal bridge formula (FBF) for truck platoons. The assumption that as long as trucks adhere to the formula seems inadequate given that several states currently allow truck weights higher than those specified by the formula (NCHRP Report 575). Finally, bridge inspection and monitoring are discussed as an important tool to create data to identify critical loading conditions due to truck platoons and to improve maintenance and preservation.

Kamranian (2018) studied platoons of Canadian legal trucks (two, three, and four-truck platoons with as little as 1 m (3 ft) spacing) for a specific bridge in Alberta, Canada. The bridge was built in 1960 and is a three-span steel-concrete composite bridge with riveted steel girders. Span lengths are 45.1 - 49.4 - 45.1 m (148 - 162 - 148 ft). The Canadian load rating procedure was followed, which is similar to the MBE procedure. Using the computer program CSiBridge, a detailed finite element analysis was performed to compute live load rating factors (LLRF) for all girders. Additionally, to verify the output, a simple 2D model was set up in SAP2000. Both Alberta legal non-permit (NP) as well as permit trucks were considered. Specifically, CS1 (28 ton), CS2 (49 ton), and CS3 (63.5-ton) legal NP trucks were used. Note that target reliability indices in the Canadian code are a function of the permit type, structural system, element behavior, and inspection level. Kamranian found that the bridge could handle two-truck platoons consisting of Alberta NP trucks, but the weights of individual trucks would have to be restricted for three and four-truck platoons.

Devault (2017) performed an approximate analysis in which they first derived bridge capacities from recorded rating factors. These capacities where then used to infer TP rating factors for two-truck platoons consisting of C5 80-kip trucks for selected routes in Florida. Rating factors from the platoons were compared with the ones obtained using the AASHTO design live loads (HL-93 operating) as well as FL120 permit ratings. In addition, 88-kip trucks were used in two-truck platoon configuration. The load demands for these trucks were simply scaled based on the truck weight ratio. The analysis showed that for the 80 and 88-kip truck platoon configurations, 6 and 22, respectively, out of 2467 analyzed bridges would be insufficient. The analysis assumed a 40 ft spacing between vehicle axles. When spacing was increased to 60 feet, all analyzed bridges passed the load rating for the 80-kip truck platoon configuration and 10 remained unsuitable for the 88-kip truck platoon configurations.

Based on the Florida DOT report by Devault (2017), Crane et al. (2018) found that two-truck platoons with 30 ft spacing will not generate critical load effects in 99% of bridges on Florida interstates and turnpikes. The analysis methods were simplified in order to assess 2467 bridges, so Crane et al. recommended more detailed modeling of load effects in bridges in order to assess the effect of truck platoons. Additional modeling is also necessary for closer spacing and larger platoons.

2.3 STRUCTURAL ANALYSIS METHODOLOGIES

Load rating is an essential component of bridge preservation and in most cases a sufficient substitute for load testing or other on-site monitoring practices. In the process of load rating, structural analysis is performed to determine the load effects (or demands) on the structure due to both design live loads as well as certain legal trucks on an operational level. The capacity side of load rating should reflect actual system and material conditions of the structure (AASHTO 2018). The resulting bridge rating factor (RF) is the smallest of the rating factors obtained for all components and corresponds to the usable live load capacity of a bridge.

Since the early 1900s, bridges in the US have been designed considering multiple trucks in succession. For example, in 1923, "Shoemaker's Truck Train and Equivalent Load" was proposed and is based on five trucks spaced at 9 m (30 ft) with individual trucks weighing, 150 - 150 - 200 - 150 - 150 kN (34 - 34 - 45 - 34 - 34 kip) (Kulicki 2014). The individual trucks were assumed to have two axles. The notional design live loads proposed based on this truck train were a distributed and concentrated load of 8.75 kN/m (600 lb/ft) and 125 kN (28 kip), respectively. While debated and continually adjusted since then, some combination of two different live load models have prevailed in current standards. The design live load model used in the current AASHTO LRFD specifications is referred to as the HL-93 (AASHTO 2020). While this live load does prescribe a train of two design trucks, typically used to determine the maximum negative bending moment in a multi-span bridge, the truck spacing is fixed at 15 m (50 ft) and the truck weights are reduced by 10%. It has been recognized by many bridge engineers that the current design loads might not capture the demands exerted by truck platoons. The main reason is that even if the individual trucks in a platoon conform to the federal bridge formula (FHWA, 2019a), the potentially very small spacings between trucks will likely result in higher load demands in bridge components.

The challenge with truck platoons is that they do not currently exist, i.e. no actual data is available, e.g. from weigh-in-motion (WIM) stations, to estimate their occurrence in conjunction with regular traffic. Hence, live load factors, which are needed to determine factored demands in both structural analysis and load rating procedures, do not exist. A framework to include truck platoons in load rating procedures once data is available, and that can be readily adapted for truck platoons, is presented by HNTB and Ghosn (2019). In their methodology they determined live load factors for Fast Act Emergency Vehicles (EV) using statistical analysis of available WIM data in combination with Monte Carlo simulations, accounting for the probability of EV occurrences with legal trucks and random lane loads over multiple lanes.

With lane and axle loads and spacings established, numerical simulation of bridge response to vehicle loading covers a wide range of approaches, from girder line analysis to three-dimensional (3D) finite element analysis (FHWA 2019b). As structural analyses increase in complexity, the results generally become more accurate. While girder line analyses have low computational cost, i.e., they take seconds to run, these models are known for their inaccuracies in capturing actual live load distribution (see, e.g. Michaelson (2010)). Additionally, current AASHTO LRFD live load distribution factors might not be applicable for all truck platoon configurations. 2D grillage models lead to better estimates of load distribution between girders but are more computationally intensive. Analyses based on 3D solid finite element models can require hours to run, but can lead to accurate assessments of load effects in specific bridge components and can consider nonlinear response due to overloading or deterioration. Furthermore, refined 3D modeling using the finite element method (FEM) can provide improved distribution factors for simplified girder line analyses (Song et al (2003), Hughs and Idriss (2006), Terzioglu et al (2017)). The tradeoff between accuracy and computational cost is illustrated in Figure 2.4.

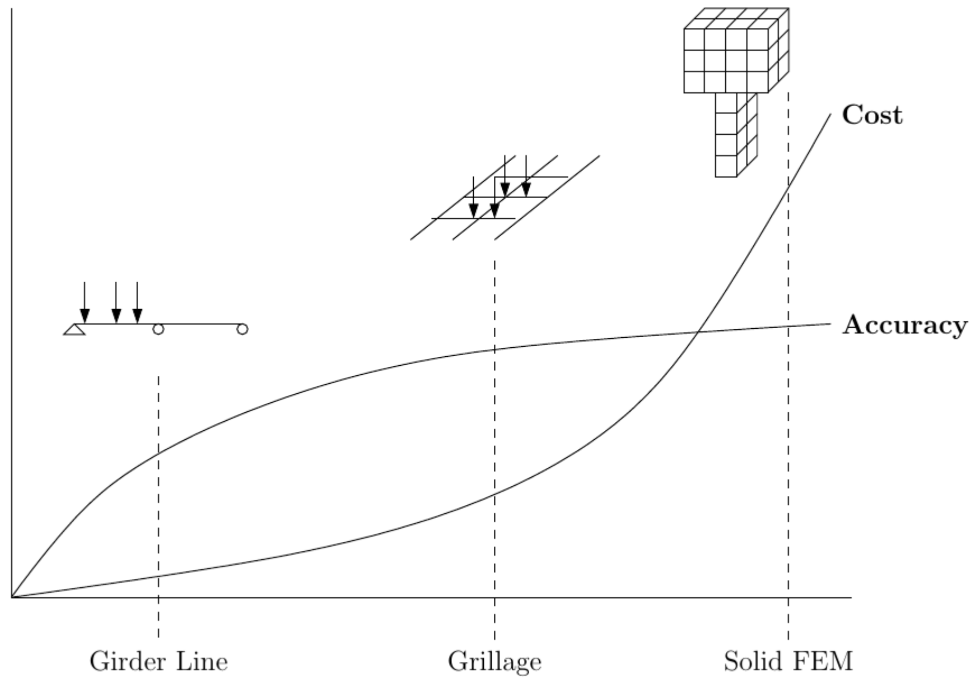

Figure 2.4: Tradeoff between accuracy and computational cost for common bridge analysis approaches for vehicle loading.

Analysis of bridges for moving vehicle loads is a semi-automated process that is already incorporated in many software packages such as CSiBridge. The typical approach for moving load analysis is to sweep a configuration of axles with known weights and relative spacings in small increments across a bridge model and perform a static structural analysis at each location. For girder line analysis, the bridge is modeled as a series of separate 1D beams and distribution factors (DF) approximate the effects of 2D load distribution. This type of analysis is still commonly employed for both design as well as load rating of slab and slab-girder bridges. Detailed 3D bridge models can be used to obtain a more accurate load distribution and to examine load effects on substructure components. 3D analysis is also necessary to analyze more complex bridge designs such as arch, suspension, or cable stayed bridges. However, 3D models can be computationally expensive and require special skill and expertise to develop, verify, and interpret correctly. Some software packages build FE models for specific bridge types automatically based on minimal user input via a so-called “Wizard” (e.g. CSI 2021). Dynamic vehicle effects are typically approximated with an impact factor applied to the static analysis results (AASTHO 2020).

The BRASS suite of computer programs is commonly used for moving load analysis as well as load rating. BRASS-Girder (WYDOT 2020) performs moving load analysis of simple span and continuous bridge girders as well as other span configurations. Other programs from the BRASS family can analyze other bridge components, e.g., BRASS-Pier and BRASS-Pad, and other bridge types, e.g., BRASS-Truss. Other commercial software for load rating and analysis of bridges is available from Bentley Systems, CSiBridge (CSI 2020), and Midas-Civil.

The open-source software OpenSees is also capable of being augmented with programming for moving load analysis and probabilistic assessment of bridge models (Scott and Higgins 2006). With programming capabilities, originally via Tcl (a scripted programming language) and more recently with Python, OpenSees lets engineers customize analysis and load rating calculations (Scott et al. 2008). The software includes 3D formulations for solid elements as well as 2D line elements for grillage models. Rapid model building and moving load analysis can be achieved and visualized with Python commands through the use of Jupyter Notebooks to contain programming, documentation and results presentation. Moment and shear interactions from a girder line analysis obtained using OpenSees and Jupyter Notebooks are shown in Figure 2-5 for the bridge model considered in Scott et al (2008).

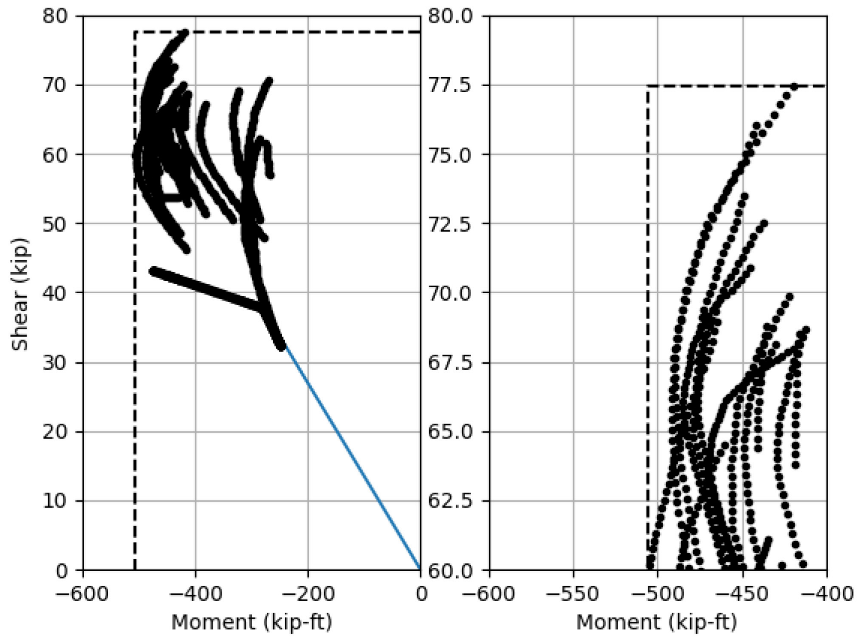

Figure 2.5: Girder moment-shear response history near an interior support of the McKenzie River Bridge on I-5 in Oregon. Loading scenario is two Legal 3-3 trucks with 20 ft head spacing.

In load rating, an important part of bridge preservation, the demands incurred by vehicle loads are compared with capacity estimates for bridge components. Reliability-based assessment and load rating are implemented in the AASHTOWare (2018) software. Reliability-based load rating of Oregon bridges using girder line analysis for reinforced concrete deck girder bridges has been performed in previous research projects (ODOT 2006). Additionally, live load factors have been calibrated based on WIM data (Pelphrey et al., 2008); however, there is a general lack of literature on load rating for connected autonomous vehicles because calibration of live load factors is currently not possible.

2.4 SUMMARY

Truck platooning is an emerging technology in the United States with various levels of State legislation and adoption. This literature review has identified the following key takeaways and knowledge gaps relative to preserving Oregon bridge infrastructure and mitigating the adverse loading effects of truck platoons:

- Truck platooning in the U.S. is not regulated top-down as it is done, for example in Europe. As a result, many different companies are developing their own autonomous driving technologies and are currently testing them on U.S. roads. Compared to autonomous passenger cars, truck platooning is expected to be adapted more quickly, due to the direct cost savings that it will provide trucking companies (Tsugawa et al., 2016).

- Reported truck spacings vary from study to study. While the largest fuel savings are reported for spacings as little as 6 m (20 ft), it is not expected that these will necessarily be adopted, due to safety concerns. Research indicates that the gap for commercial operations was expected to be at least 15 to 23 m (50 to 75 ft) with greater distances under poor weather conditions (Bevly et al., 2015).

- Very little literature is available on the impact of truck platoons on bridges as quantified by structural analyses. The lack of literature may be due to some rather intuitive results, e.g., that truck platoons increase shear at supports and can lead to increased flexural demands only on longer spans. A challenge is that truck platoon configurations, i.e. type of number of participating trucks and truck spacings, are currently unknown.

- Only one study (Kamranian 2018) to date has gone past the standard 1D girder line analysis. One question is what distribution factors should be used for girder line analysis and these factors could be computed from 2D grillage type models.

- All analyses, including the load rating study by Thome and Yarnold (2020), are based on comparisons between demands from hypothetical truck platoons and design live or legal loads. Actual load ratings involving truck platoons cannot be performed currently because they require live load factors. Since there are no actual data, e.g. from WIM stations, available, these factors are unknown.

- Comprehensive moving load analyses for the truck platoons expected in Oregon will lead to more detailed assessments of impacts on the state's bridge infrastructure and will provide the foundation to develop policies.

3.0 METHODOLOGY

3.1 REPRESENTATIVE BRIDGE MODELS

In this research, the National Bridge Inventory (NBI) dataset was utilized to compile a record of bridges located in the State of Oregon. The initial dataset for Oregon encompassed a total of 8,214 bridges. This baseline dataset was progressively refined by adding filters until a more manageable set, consisting of 832 bridges, was obtained. Table 3-1 summarizes the selected NBI items that were used as variables to characterize the final dataset and determine a set of representative bridge models. For each of these variables, histograms, frequency tables, and percentile tables (only for continuous variables) were created and are shown in Appendix A, Figures A1 to A40.

Table 3.1: NBI Items Used As Variables In This Study. Terminology Follows (FHWA 1995).

NBI Item	Name	Type	Unit	Filter?
27	Year built	Continuous	yr	No
31	Design load	Categorical	-	No
34	Skew	Continous	Degrees	Yes
41	Structure open, posted, or closed to traffic	Categorical	-	Yes
43A	Kind of material and/or design	Categorical	-	Yes
43B	Type of design and/or construction	Categorical	-	Yes
45	Number of spans in main unit	Discrete	-	No
48	Length of maximum span	Continous	m	No
58	Deck condition rating	Discrete	-	No
59	Superstructure condition rating	Discrete	-	No
63	Method used to determine operating rating	Categorical	-	Yes
64	Operating rating	Continous	ton	No
65	Method used to determine inventory rating	Categorical	-	Yes
66	Inventory rating	Continous	ton	No
104	Highway system of the inventory route	Categorical	-	Yes

Figure 3.1 shows the total number of bridges that exist in each dataset after different combinations of filters were applied. The goal was to reduce the dataset to a manageable amount of bridges while maintaining a representative set of bridges for moving load analysis under truck platoons.

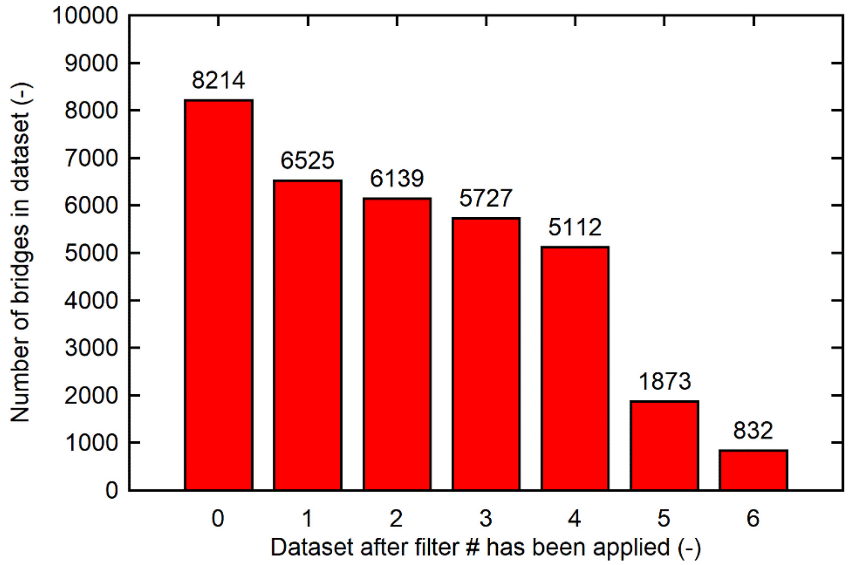

Figure 3.1: Size of datasets, Dataset 0 = unfiltered dataset, Dataset 6 = final dataset

The typical bridge in the final dataset (= Dataset 6) has the following characteristics (based on mode, i.e., highest frequency):

- was built in the early 1960s, i.e., is 55 to 60 years old
- was designed based on the HS 20 live load model (second most common: HS 25)
- has no skew, i.e., skew angle = 0 Degrees
- is made of prestressed concrete (followed by reinforced concrete)
- consists of a stringer/multi-beam or girder structural system (followed by slab)
- has either one or three spans (followed distantly by two, four, five, six, etc. spans)
- has a length of the maximum span, L = 12 to 16 m (for all bridges), and
    - bridges with one span (36% of all bridges): L = 12 to 16 m
    - bridges with two spans (8.3% of all bridges): L = 36 to 40 m
    - bridges with three spans (31% of all bridges): L = 12 to 16 m
    - bridges with four spans (7.2% of all bridges): L = 12 to 16 m
    - bridges with five spans (5.0% of all bridges): L = 20 to 24 m
- has a deck and superstructure condition rating of "7" (= good condition) followed closely by "6" (= satisfactory condition), and

- a load rating of 25 to 30 tons and 20 to 25 tons, respectively

The pertinent variables describing a bridge model are the number of spans encoded in NBI Item 45 and the lengths of the individual spans. For the latter, only the length of the longest span is available in NBI Item 48. Figure 3.2 illustrates the terminology used in this research to describe representative bridge models with one to three spans, i.e., n = 1 to 3.

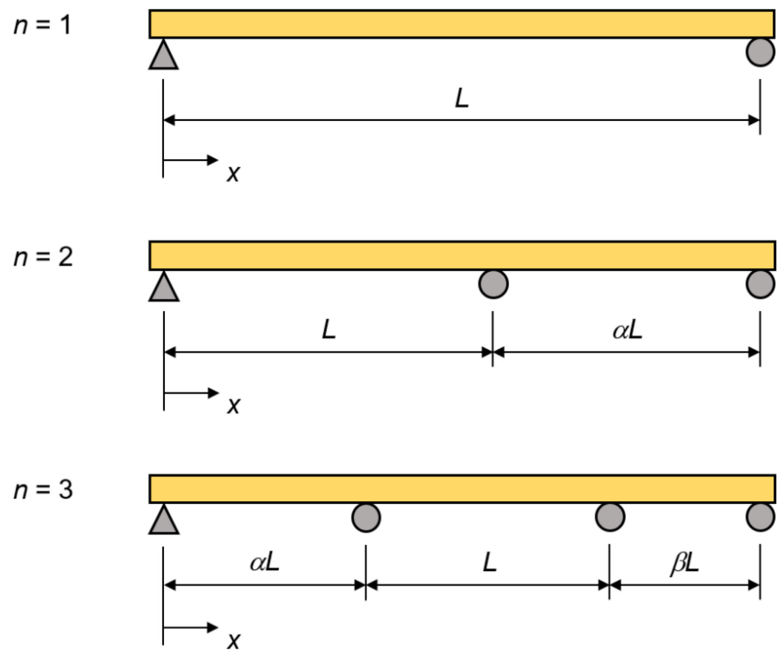

Figure 3.2: Illustration and terminology used for one to three spans

The following representative bridge model configurations were analyzed by means of moving load analysis for 749 cases:

- Single-span with L = 15 to 65 m (in steps of 5 m) – 11 cases
- Two-span with same L = 25 to 75 m (in steps of 5 m) and α = 1.0 to 0.75 (in steps of 0.05) – 66 cases
- Three-span with L = 15 to 80 m (in steps of 5 m), α = 1.0 to 0.75 (in steps of 0.05), and β = 1.0 to 0.65 (in steps of 0.05) – 672 cases

Lower and upper bounds of span lengths correspond, approximately, to the 30 and 99 percentiles, respectively. The following assumptions were made:

- There is no distinction between non-continuous and continuous construction the way it is coded in NBI Item 43A. If a multi-span bridge consists of non-continuous spans, then the results from the corresponding single-span bridge models shall be used for each of the spans.

- More than three spans are not considered; three spans are deemed sufficient to cover bridges with more spans.

3.2 LOADING SCENARIOS

With a suite of representative bridge models, baseline and systematic moving load analyses were performed for the following 20 vehicle live loads, for which axle weight and spacings are known:

- Design live loads (1) - AASHTO LRFD HL-93
- Oregon legal trucks (3) - Type 3, 3S2, and 3-3
- Oregon specialized hauling vehicles (SHVs) (4) - SU4, 5, 6, and 7
- FAST Act emergency vehicles (EVs) (2) - EV2 and EV3
- Oregon continuous trip permit (CTP) trucks (3) - CTP-2A, 2B, and 3
- Oregon single trip permit (STP) trucks (7) - STP-3, 4A, 4B, 4C, 4D, 4E, and 5BW

"Baseline" analyses were conducted for each (non-platooned) vehicle listed above, e.g., the OR 3 Legal truck (see Figure 3-3, left) and the OR 3S2 Legal truck (see Figure 3-3, right), and created output (Section 3.3) for comparison with platooned vehicles (or truck platoons).

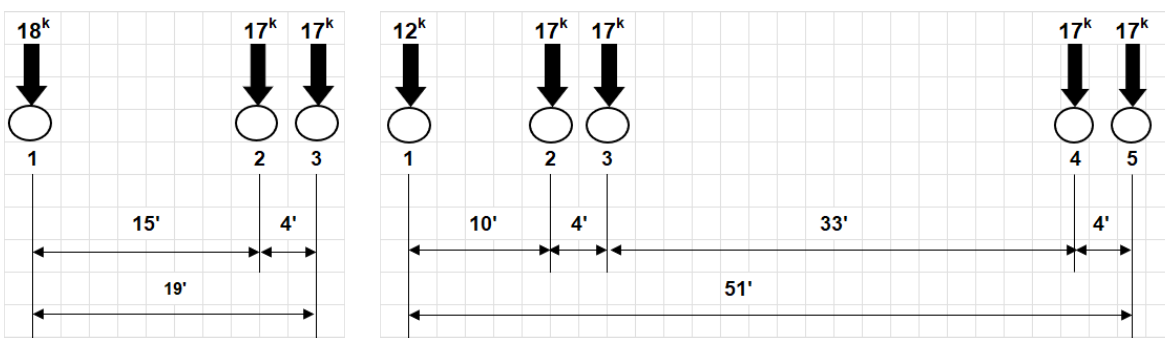

Figure 3.3: Axle weight and spacing for a OR 3 Legal truck (left) and OR 3S2 Legal truck (right) (1 kip = 4.45 kN, 1 ft = 0.305 m)

"Systematic" analyses examined the effects of two and three-truck platoons for each of the live loads listed above. To prevent exponential loading scenarios, only platoons of the same vehicles were considered, e.g., a platoon of two OR 3-3 Legal trucks (see Figure 3.4) and not a platoon of a 3-3 with an STP-3A. Head spacings, *Sa* ranged from 10 ft to 60 ft in 10 ft increments (3 m to 18 m in 3 m increments) and were assumed the same for three-truck platoons. For each vehicle listed above, 13 configurations (single baseline, six head spacings on two-truck platoon, and six head spacings on three-truck platoon) were analyzed for each bridge model.

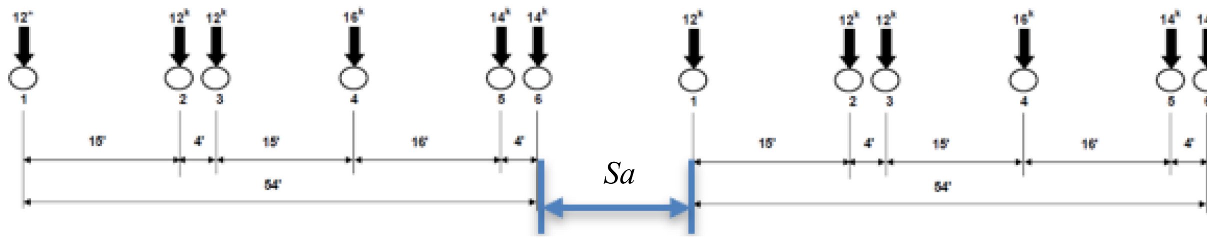

Figure 3.4: Axle weights and spacings for a platoon of two OR 3-3 Legal trucks with a head space, S_a (1 kip = 4.45 kN, 1 ft = 0.305 m)

3.3 MOVING LOAD ANALYSES

For the 749 bridge models and 481 vehicle configurations, there were 360,269 moving load analysis cases to be run. For all analysis cases, the axles for each truck/platoon configuration were swept across the bridge model in both directions: "left to right" and "right to left". Load effects were determined by linear elastic, static analysis at each pseudo-time step as the trucks moved across the bridge models. To minimize computational time, the analyses were run on Amazon Web Services with a c6a.48xlarge EC2 (Elastic Compute Cloud) instance with 192 vCPUs (virtual CPUs) and 384 GB RAM (AWS (2022)).

The 360,269 moving load analyses were distributed to the 192 vCPUs using OpenSeesPy (McKenna et al (2010), Zhu et al (2018)). A single Python script was run on each vCPU and only executed the analyses that match the processor ID. These "embarrassingly parallel" analyses reduced what would have been over a week of serial computing down to about eight hours of computing. The short run times allowed for refinements and tweaking, making the task of re-running analyses less onerous.

3.4 ANALYSIS OUTPUT

For each analysis case, the bending moment and shear force were recorded at uniform locations at 0.1L intervals along each bridge span of length, L (Figure 3.5). These locations capture the worst effects of positive bending moment near midspans and negative bending moment and shear force near continuous supports.

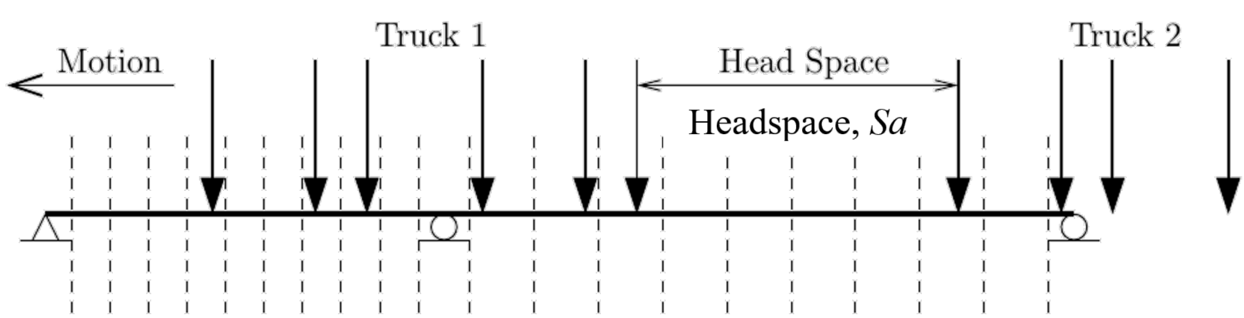

Figure 3.5: Monitoring locations (dashed lines) along each span of a two-span bridge model

For all analysis cases (combinations of vehicle/platoon and bridge model), the following quantities were reported at each monitoring location along each span:

- Maximum positive bending moment
- Shear coincident with maximum positive bending moment
- Maximum negative bending moment
- Shear coincident with maximum negative bending moment
- Maximum shear force
- Bending moment coincident with maximum shear

The entire history of bending moment and shear force were recorded during each analysis case, but for the final analysis (Section 4.0)only the maximum and coincident values listed above were extracted and saved in a summary database (Section 4.1).

4.0 RESULTS AND DISCUSSION

4.1 SUMMARY DATASET

A summary dataset was created using MATLAB coding to import data files for the structural analysis results from the 749 different bridge types and 481 truck type combinations. The information included in the file was comprised of various parameters, such as bridge number, number of spans, length of each span, truck number, truck type, number of trucks, head spacing, maximum positive moment, maximum negative moment, and maximum shear for the entire bridge. For each maximum loading value, corresponding shear force values and their respective locations on the bridge were recorded, except for shear, which had its maximum moment corresponding component and location. The information on the different bridge lengths, truck types, and spreadsheet data can be found in Appendix B, Figures B1 to B4.

To analyze a two or three span bridge, the MATLAB code treated each span individually. The maximum values of all span lengths, even though not representative of the maximum for the entire bridge, were recorded as well. Consequently, the exact same information that was gathered for the entire bridge was also collected separately for each span, including span one, span two, and span three.

Since each span could have positive and negative shear values, the decision was made to record the maximum shear closest to each support. For example, in the case of a single-span bridge, there would be the maximum positive bending moment and two maximum shear forces – one corresponding to the left support and the other corresponding to the right support.

Figure 4.1 is a plot of the data from a sample structural analysis run for one row in the full dataset. It depicts a sample two-span bridge with the first span length of 131 feet and the second span length of 98.4 feet. The live load was modeled after the Type OR CTP-3 truck with a head spacing of 10-feet and platooned to three-trucks. Labeled numerical values are the maximum internal forces stored in the corresponding analysis output file.

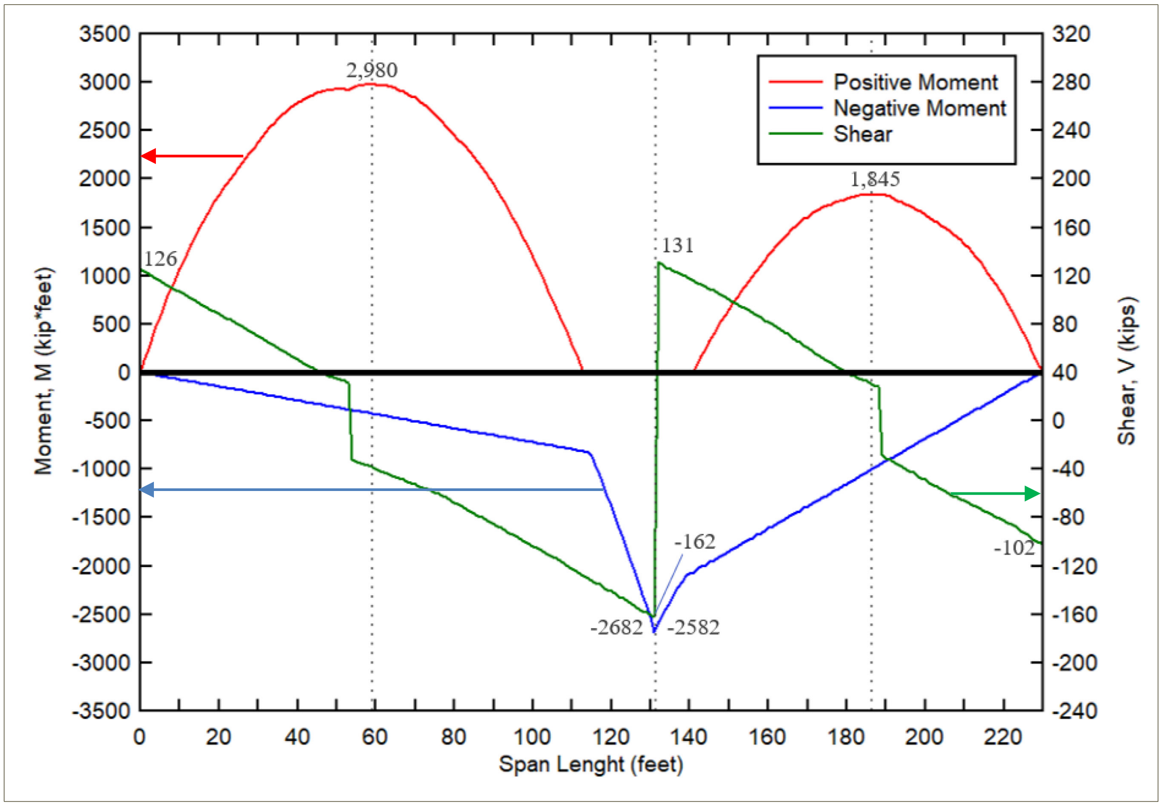

Figure 4.1: Example of the structural analysis results for a two-span bridge under a sample truck type combination pulled from one row of the full database

4.2 ANALYSIS OF SUMMARY DATASET

This section presents an in-depth analysis of the summary dataset, focusing on an overall worst-case analysis, as well as the effects of head spacing and span length on the internal forces. Two distinct approaches were employed to evaluate the overall impacts: Normalizing data using OR Type 3 Legal and OR Type 3S2 Legal truck types and calculating internal force ratios that can be interpreted as amplification factors of individual loading scenarios. Lastly, a case study that uses the platooned live load ratios to calculate rating factors for a select bridge is presented.

4.2.1 Overall Worst-Case Analysis

In the analysis, two distinct approaches were employed to evaluate the effect of different truck types on the internal force response of the analyzed bridges.

The first approach (Equation 1) involved calculating ratios based on one specific truck type, provided by the 2018 ODOT LRFR Manual, with zero head spacing for the OR Type 3 Legal truck type. The internal forces due to all trucks and truck types considering all head spacings were divided by the internal forces for single truck OR Type 3 Legal. This process was also repeated using the OR Type 3S2 Legal truck type. Note that all EV (Emergency Vehicle), HL-93 Tandem, and HS-20 truck types, were excluded from the analysis as it is highly unlikely or impossible that they would participate in platooning in the real-world. The remaining truck types were examined for their worst-case load effects on bridges. Using histograms, Figure 4.2, the normalization of load effects (or internal forces) across all truck types allowed for a comprehensive evaluation of the maximum positive bending moment, maximum negative bending moment, and maximum shear of the entire bridge. To gain a deeper understanding, separate breakdowns were created for each maximum loading value, and histograms were generated to visualize the distribution of ratios greater than or equal to two and by truck type, as seen in Figure 4.3 and Figure 4.4, respectively. In all histograms, the frequency of internal force ratios exceeding 2.0 is substantial. Subsequently, the data were divided into smaller bins, indicated by Roman numerals. The same breakdown was repeated, considering only values at or above the 95th percentile, Figure 4.5 and Figure 4.6. Based on the histogram analysis, further categorizations were derived by examining truck frequency, which indicated the number of instances where a truck exceeded a certain threshold. Additionally, the breakdown was explored in terms of bridge types, leading to a noteworthy observation: bridges with longer spans demonstrated the highest ratios. For figures of the overall max positive bending, max negative bending, and max shear histograms normalized by the OR Type Legal, and OR Type 3S2 Legal, ratio of final bin, 95th percentile, and truck frequencies for maximum live load please refer to Appendix B, Figures B5 to B64.

$$\boldsymbol{Ratio} = \frac{\boldsymbol{Internal\ Force\ from\ a\ Specific\ Platooned\ Truck\ Type}}{\boldsymbol{Internal\ Force\ from\ a\ Single\ Reference\ Truck\ (OR\ Type\ 3\ or\ 3S2\ Legal)}} \tag{4-1}$$

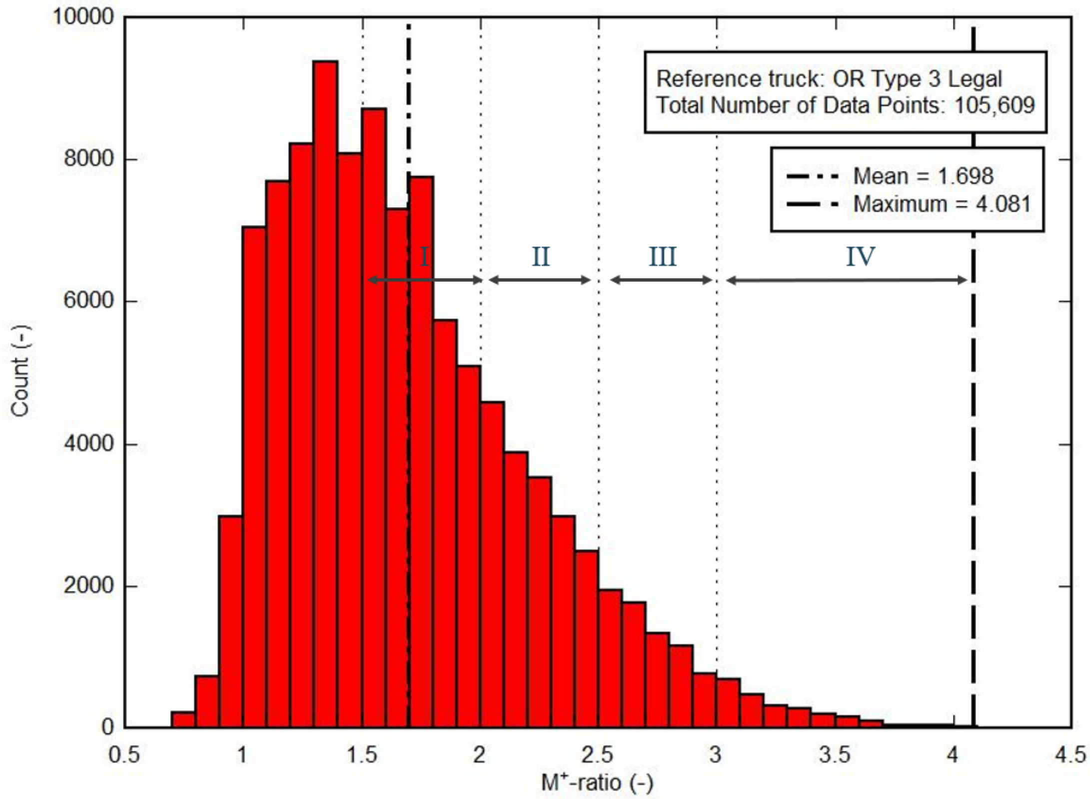

Figure 4.2. Histogram of maximum positive bending moment ratio (full database) normalized by OR Type 3 Legal Truck

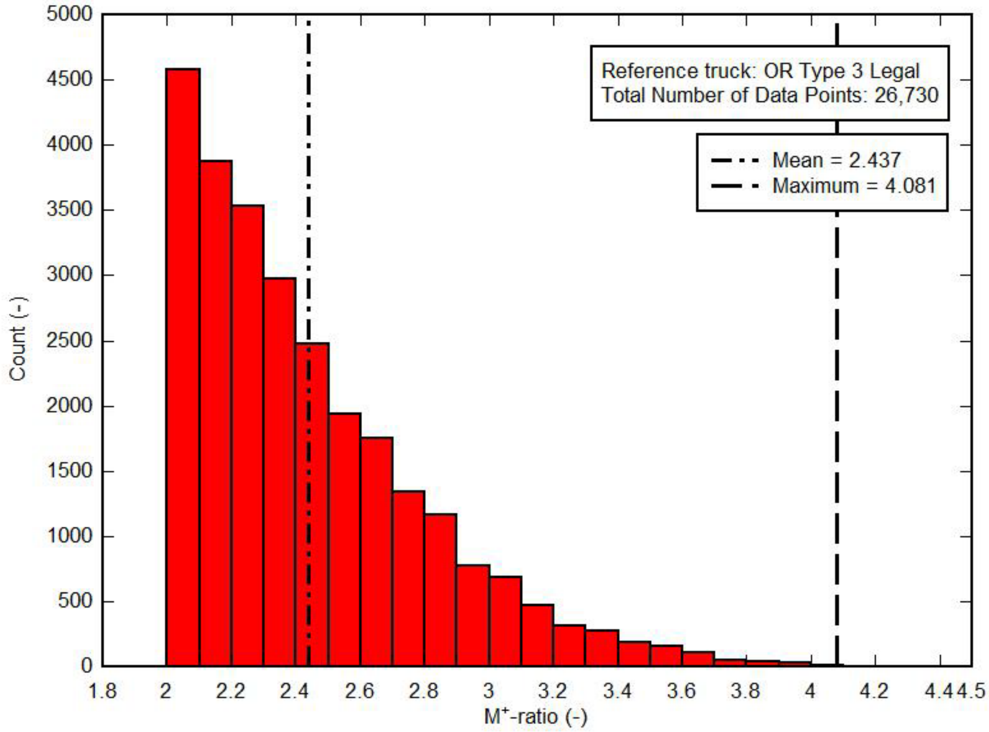

Figure 4.3. Histogram of maximum positive bending moment ratio (2.0+ ratio) normalized by OR Type 3 Legal Truck

Figure 4.3 shows the histogram with the maximum positive bending moment ratios of a total of 26,730 data points, for a ratio of two or greater. These specific data points were singled out for a more detailed examination concerning the types of trucks involved, as illustrated in Figure 4.4. The primary aim was to discern how frequently a particular truck type appeared within this higher ratio range, thereby identifying the most commonly occurring worst truck type. It can be observed that both Type OR CTP-3 and OR SU7 emerge as the predominant truck types with the highest frequency counts.

This same analytical approach was applied to the 95th percentile dataset, comprising 5,282 data points, as depicted in Figure 4.5 and Figure 4.6. In almost all instances, the findings revealed that trucks of Type OR CTP-3 and OR SU7 exhibited the highest frequencies. The sole exception was observed in the final bin pertaining to negative bending moments, where Type OR TP-2B outpaced Type OR CTP-3.

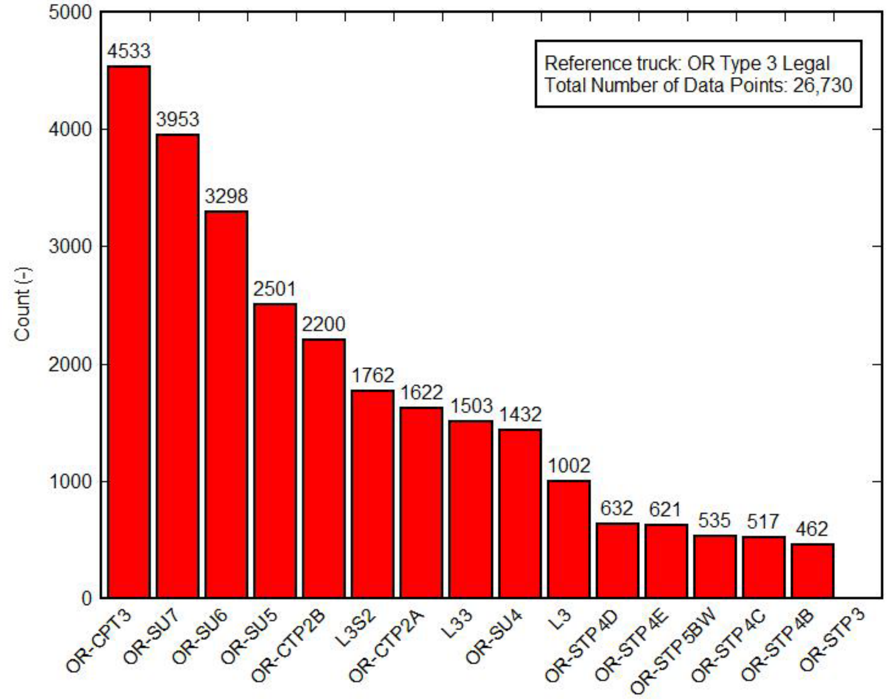

Figure 4.4. Histogram of maximum positive bending moment by truck type (2.0+ ratio) normalized by OR Type 3 Legal Truck

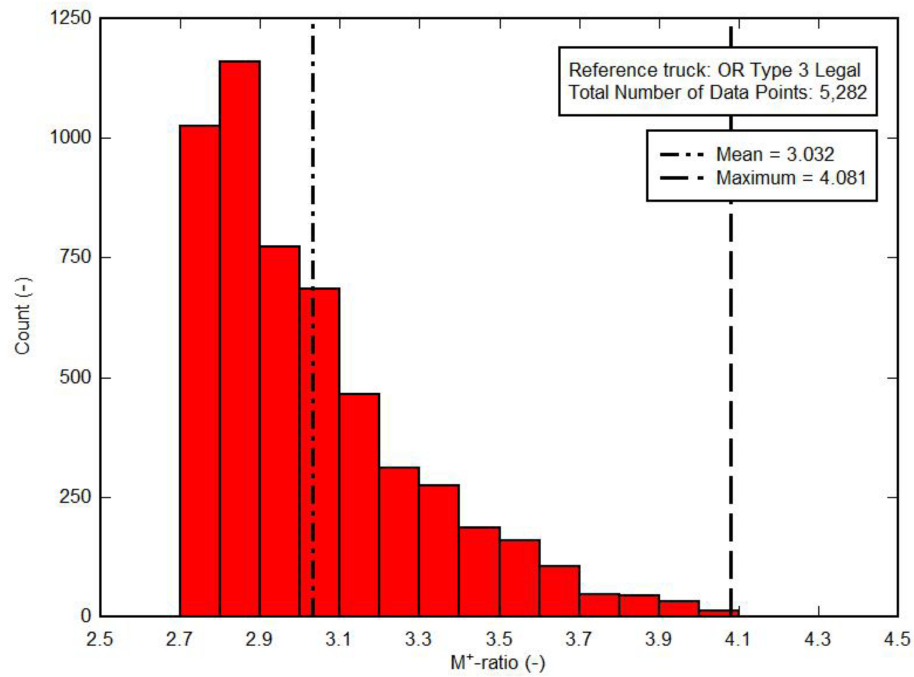

Figure 4.5. Histogram of maximum positive bending moment ratio (the 95th percentile) normalized by OR Type 3 Legal Truck

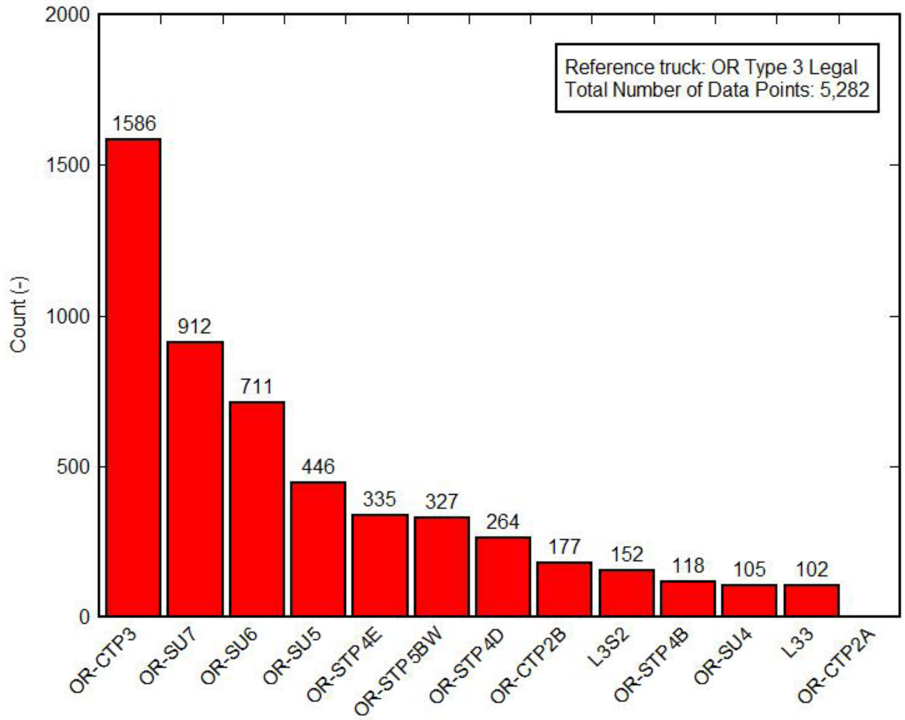

Figure 4.6. Histogram of maximum positive bending by truck type (the 95th percentile) normalized by OR Type 3 Legal Truck

Tables 4.1 and 4.2 show a summary of the internal force ratios for the OR Type 3 Legal and OR Type 3S2 Legal references for all three internal forces. The former produces the larger ratios overall with the highest value being associated with the negative bending moment ratio reaching a value of 5.10, which is for the case where three CPT3s platoon at a head spacing, S_a = 10 ft. For both ratios, the negative bending moment generates the highest ratio, and the positive bending moment results in the lowest ratio. Another interesting note is that the largest negative bending moment ratios are driven by Type OR CTP trucks with three trucks in the platoon, the shear ratios have a mix of truck types with mostly three-truck platoons, and the positive bending moment ratios have a mix of both truck types and two- and three-truck platoons. This shows that the internal force effects are independent with the negative bending moment and shear force being sensitive to the number of trucks in a platoon.

Table 4.1: Summary Table of Largest Internal Force Ratios By Truck Type (Reference: OR Type 3 Legal Truck), Number Of Trucks Platooning And Head Spacing (All Bridges)

Maximum Positive Bending Moment		Maximum Negative Bending Moment		Maximum Shear	
Truck Type	***Ratio***	***Truck Type***	***Ratio***	***Truck Type***	***Ratio***
CTP3_3_10	4.08	CTP3_3_10	5.10	CTP3_3_10	4.77
CTP3_3_20	3.75	CTP2B_3_10	5.07	CTP3_3_20	4.54
SU7_3_10	3.66	CTP2B_3_20	5.04	CTP3_3_30	4.30
CTP3_3_30	3.43	CTP2B_3_30	5.01	SU7_3_10	4.08
SU6_3_10	3.39	CTP2A_3_10	4.97	CTP3_3_40	4.05
SU7_3_20	3.39	CTP2B_3_40	4.97	CTP2B_3_10	3.98
CTP3_2_10	3.19	CTP2A_3_20	4.95	SU7_3_20	3.92
CTP2B_3_10	3.15	CTP2A_3_30	4.92	CTP3_3_50	3.79
SU6_3_20	3.14	CTP2B_3_50	4.89	CTP2A_3_10	3.79
SU7_3_30	3.12	CTP2A_3_40	4.86	SU6_3_10	3.75
SU5_3_10	3.12	CTP3_3_20	4.82	SU7_3_30	3.75
CTP3_3_40	3.12	CTP2B_3_60	4.75	CTP2B_3_20	3.72
Legal3S2_3_10	3.08	CTP2A_3_50	4.74	Legal3S2_3_10	3.65
CTP3_2_20	3.02	CTP3_3_60	4.62	Legal33_3_10	3.61
Legal33_3_10	2.99	CTP3_3_30	4.62	SU6_3_20	3.61
CTP2A_3_10	2.96	CTP3_3_50	4.60	SU7_3_40	3.56
SU6_3_30	2.9	CTP2A_3_60	4.57	CTP3_2_10	3.53
SU5_3_20	2.89	CTP3_3_40	4.56	CTP3_3_60	3.53
CTP3_2_30	2.86	SU7_3_10	4.32	CTP2A_3_20	3.51
SU7_3_40	2.86	SU7_3_20	4.15	CTP3_2_20	3.47

Table 4.2: Summary Table of Largest Internal Force Ratios by Truck Type (Reference: OR Type 3S2 Legal Truck), Number of Trucks Platooning and Head Spacing (All Bridges)

Maximum Positive Bending Moment		Maximum Negative Bending Moment		Maximum Shear	
Truck Type	***Ratio***	***Truck Type***	***Ratio***	***Truck Type***	***Ratio***
CTP3_3_10	2.85	CTP3_3_10	3.47	CTP3_3_10	3.11
CTP3_3_20	2.61	CTP2B_3_10	3.32	CTP3_3_20	2.96
SU7_3_10	2.55	CTP2B_3_20	3.27	CTP3_3_30	2.81
CTP3_3_30	2.39	CTP2A_3_10	3.24	SU7_3_10	2.66
SU6_3_10	2.37	CTP3_3_20	3.23	CTP3_3_40	2.64
SU7_3_20	2.36	CTP2B_3_30	3.22	CTP2B_3_10	2.60
CTP3_2_10	2.22	CTP2A_3_20	3.19	SU7_3_20	2.56
CTP2B_3_10	2.2	CTP2B_3_40	3.19	CTP3_3_50	2.47
SU6_3_20	2.19	CTP2A_3_30	3.15	CTP2A_3_10	2.47
SU7_3_30	2.17	CTP2B_3_50	3.13	SU6_3_10	2.45
SU5_3_10	2.18	CTP2A_3_40	3.11	SU7_3_30	2.45
CTP3_3_40	2.17	CTP3_3_30	3.10	CTP2B_3_20	2.43
Legal3S2_3_10	2.15	CTP2B_3_60	3.05	Legal3S2_3_10	2.38
CTP3_2_20	2.11	CTP2A_3_50	3.04	Legal33_3_10	2.36
Legal33_3_10	2.09	CTP3_3_40	3.00	SU6_3_20	2.35
CTP2A_3_10	2.06	CTP3_3_50	2.98	SU7_3_40	2.33
SU6_3_30	2.02	CTP3_3_60	2.97	CTP3_2_10	2.30
SU5_3_20	2.02	CTP2A_3_60	2.93	CTP3_3_60	2.30
CTP3_2_30	2.00	SU7_3_10	2.84	CTP2A_3_20	2.29
SU7_3_40	2.00	SU7_3_20	2.73	CTP3_2_20	2.26

The second approach (Equation 4-2) aimed to create ratios that show the amplification of each truck type by dividing the load effect of a platooned truck type (two or three-trucks and different head spacings) by the load effect of the single truck of the same truck type. These ratios allowed for assessing the amplification effect platooning has on different trucks. These ratios can be substituted in the load rating equation (see case study presented in Section 4.3).

$$\boldsymbol{Ratio} = \frac{\textbf{Internal Force from a Specific Platooned Truck Type}}{\textbf{Internal Force from a Single Truck for the Same Specific Truck Type}}$$

(4-2)

To identify the worst-case bridges, it was first determined which span the maximum loading, positive or negative bending moment or shear force, was acting upon. This defined the span length for comparison. Then, the normalized ratio data for OR Type 3 Legal and OR Type 3S2 Legal reference trucks were plotted for each bridge, truck and platoon combination based on the defined span length. The Type OR CTP-3 truck at a 10-foot head spacing was chosen as it was the worst overall truck type when looking at the histogram data presented earlier. Figures 4-7 through 4-9 show the results for the internal force ratios for the Type OR CTP-3 truck to the OR Type 3 Legal (L3) and the OR Type 3S2 Legal (L3S2) trucks comparing a single truck and a three-truck platoons at 10-foot head spacings.

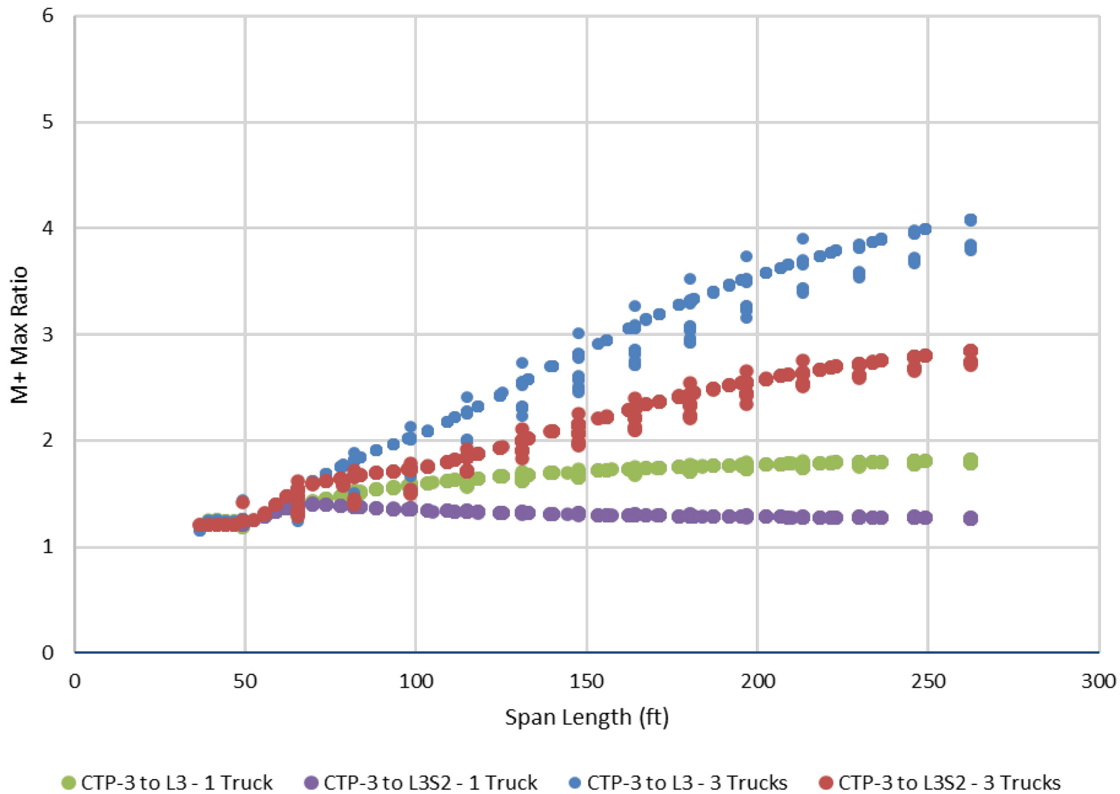

Figure 4.7: Maximum Positive Bending Moment vs. Span Length for the Type OR CTP-3 at 10-foot head spacing normalized by OR Type 3 Legal and OR Type 3S2 Legal trucks

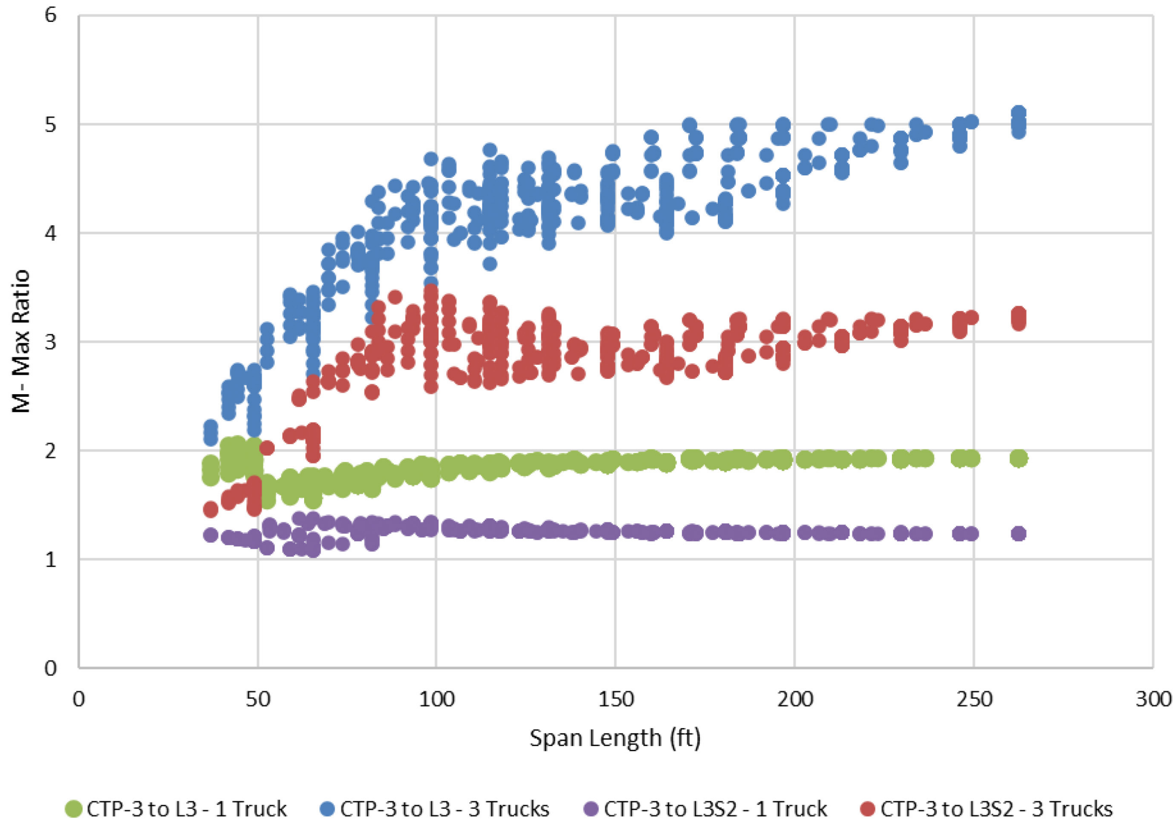

Figure 4.8: Maximum Negative Bending Moment vs. Span Length for the Type OR CTP-3 at 10-foot head spacing normalized by OR Type 3 Legal and OR Type 3S2 Legal trucks

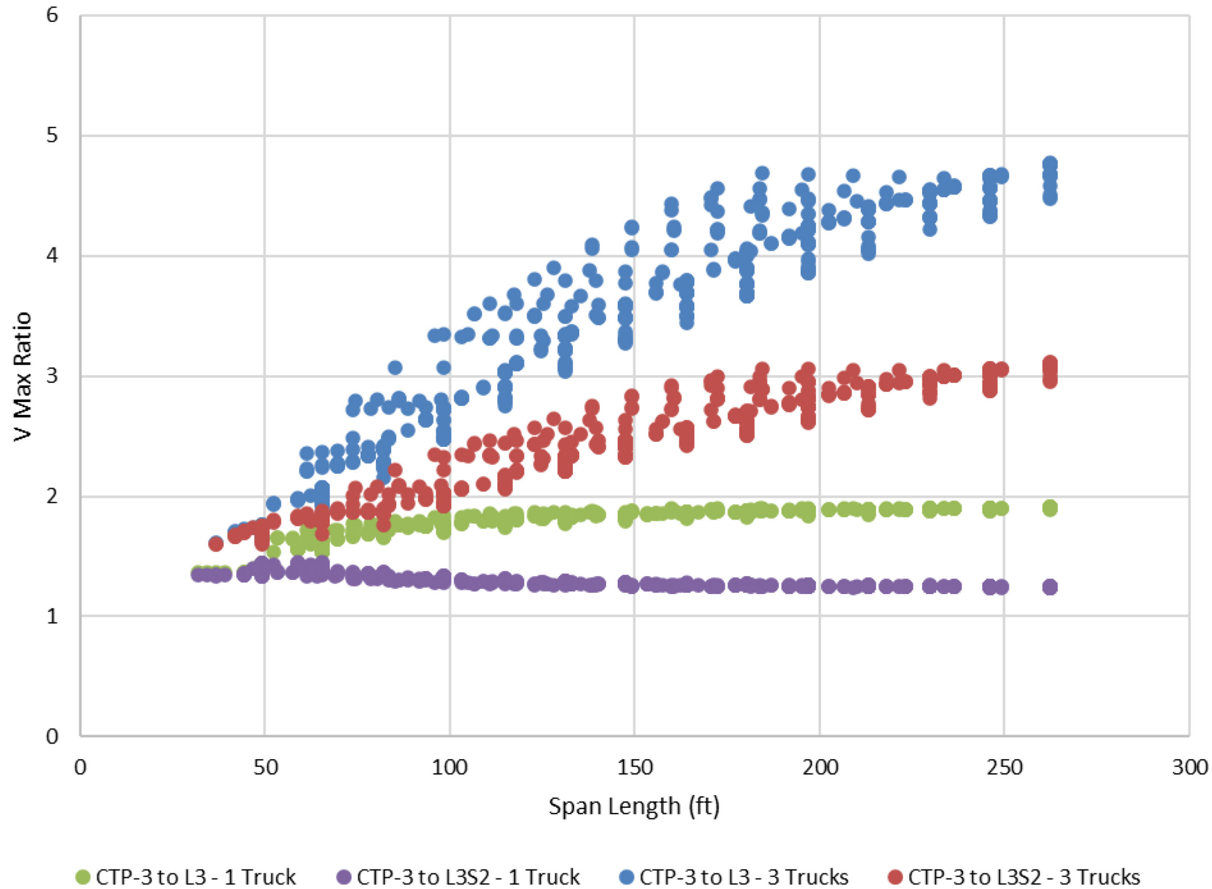

Figure 4.9: Maximum Shear vs. Span Length for the Type OR CTP-3 at 10-foot head spacing normalized by OR Type 3 Legal and OR Type 3S2 Legal trucks

As is evident from the graphs, longer span lengths tend to exhibit higher internal force ratios. This is present in the OR Type 3 Legal data for all three load outputs as well as the OR Type 3S2 Legal positive bending moment and shear force ratios. However, as seen in the individual graph of the OR Type 3S2 Legal negative bending moment ratio in Figure 4.8, some shorter span bridges resulted in a higher ratio. This is likely caused by the longer platoon lengths of the OR Type 3S2 Legal configurations as compared to some of the higher load, shorter length trucks. It would allow for more concentrated loads around the supports on short spans as compared to a longer truck on the same shorter span. Overall, the trend is for longer spans to have higher ratios. Therefore, the longest span bridges, the single span of 213 feet and the three-span bridges with two spans of length 262 feet, are the bridges with the highest ratios and the longest bridges analyzed.

Bridge number 11 of the single-span bridge set (with a length of 213 feet) and bridge number 708 of the three-span set (with two spans having lengths of 262 feet) ended up being the worst-case bridges. However, in the multi-span analysis, the worst-case bridges were all of the same subset with the first two spans having a length 262 feet (bridge numbers 702-709) and were all within 0.1% of bridge number 708's total load effect.

In summary, the analysis highlights that the Type OR CTP-3 and OR SU7 truck types resulted in the highest load effect ratios. The overall highest internal force ratio is associated with the negative bending moment and three CPT3s platooning at 10 ft, which resulted in a ratio of 5.10. Additionally, when considering individual bridge spans, the longest bridge spans (262 feet), such as the 708 bridge exhibited the highest load effect ratios.

4.2.2 Effect of Specific Trucks

For this analysis, single, single-truck types were left in to have available references for these truck types. The analysis was conducted considering the maximum internal force effects of the entire bridge.

Based on insights from the overall worst-case analysis, the specific truck configurations that received further examination were Type OR CTP-3 (Figure 4.10), the OR Type 3 Legal (Figure 4.11), and OR SU7 (Figure 4.12). When comparing the Type OR CTP-3 to the OR Type 3 Legal truck configurations, interesting patterns emerge. The graph for Type OR CTP-3 shows that at a 100-foot span length, the internal forces caused by the different truck platoons are still relatively similar. In contrast, OR Type 3 Legal at a 100-foot span length exhibited the three-truck platoon with 10-foot head spacing already reaching twice the baseline moment, accelerating more rapidly under load compared to Type OR CTP-3. Even at a 60-foot head spacing, Type OR CTP-3 remained close to the baseline up to 150 feet, while OR Type 3 Legal had already diverged from the baseline by the same point.

This observation emphasizes the significance of platooning depending on the truck type. Span length does play a role, but it may vary in impact for different truck types. There isn't a one-size-fits-all cutoff point where platooning becomes a concern. The truck type's ratio is closely tied to the load rating factor analysis, indicating that the worst case for a bridge at a specific loading may not necessarily apply to all platooning scenarios. The platooning ratio from a single-truck type may significantly differ from another, and the load effects may be influenced accordingly.

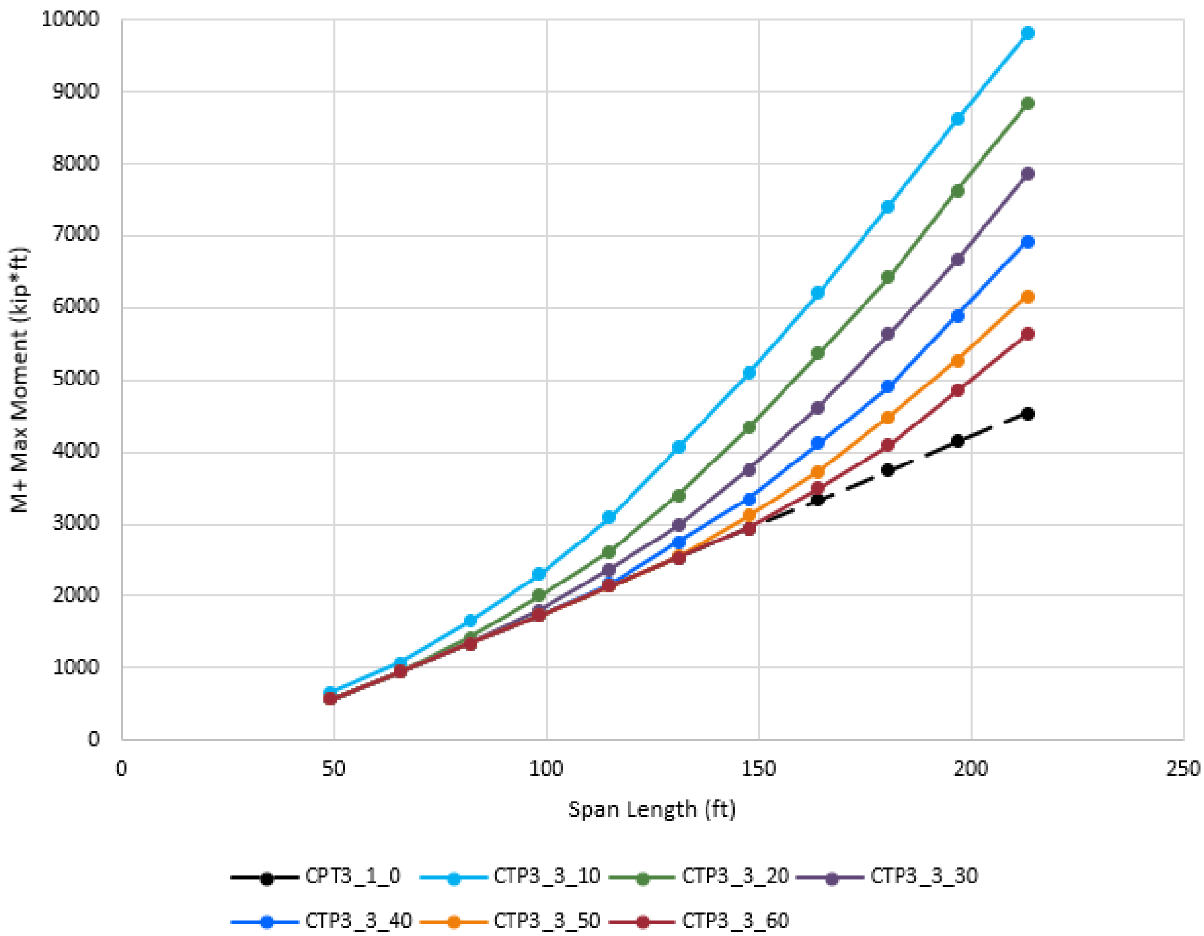

Figure 4.10: Type OR CTP-3 vs. Span Length

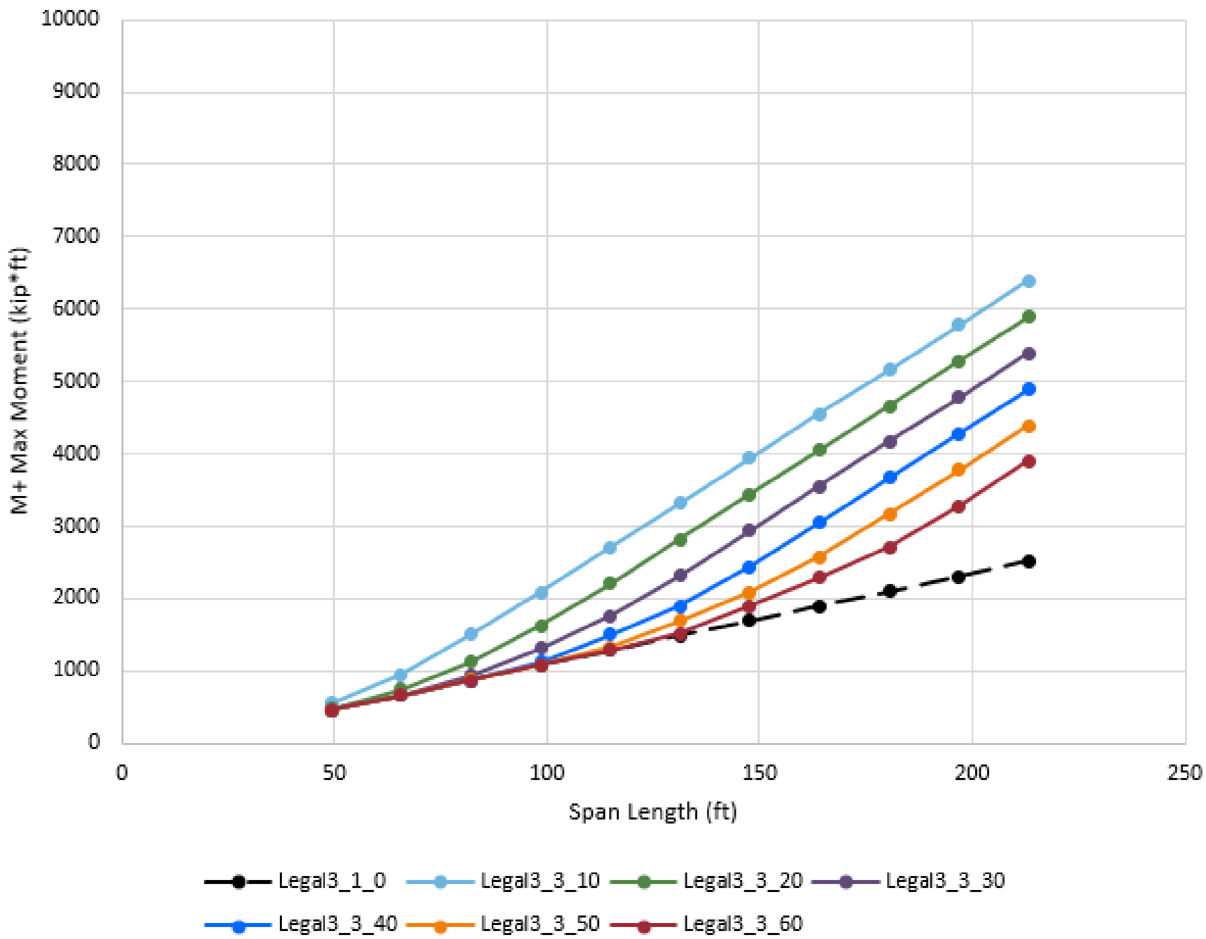

Figure 4.11: Type OR Type 3 Legal vs. Span Length

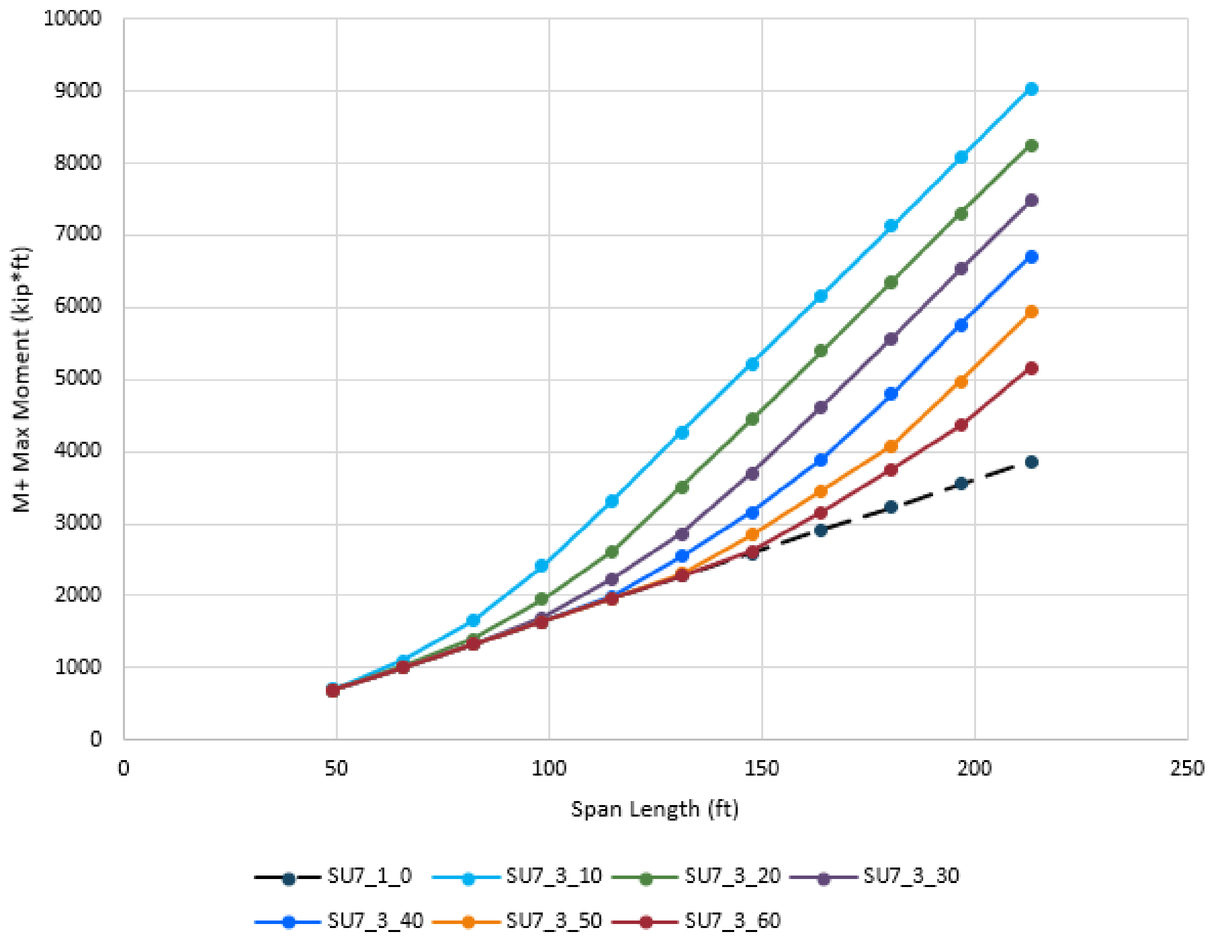

Figure 4.12: Type OR SU7 vs. Span Length

4.2.3 Effect of Head Spacing

To maintain consistency, the analysis continues to focus on Type OR CTP-3, OR Type 3 Legal, OR Type 3S2 Legal, and OR SU7 trucks, exploring the impacts of two-truck and three-truck platooning scenarios based on head spacing. The average values of positive bending moment, negative bending moment, and shear force across all bridges were calculated to compare with the maximum values and identify any potential outliers.

The internal force ratio for a single truck to multiple truck platoons in the averages revealed interesting trends. OR Type 3 Legal exhibited the highest ratio, while Legal Type 3S2 had the lowest, except in the case of shear, where, surprisingly, Type OR CTP-3 at three-trucks showed the lowest ratio for truck platooning. This observation hinted at the normalization effect, highlighting the difference between the ratios that were normalized compared to the ratio of platooned truck types.

The analysis of average graphs revealed a difference between two-truck and three-truck platooning scenarios, Figure 4.13. Three-truck platoons demonstrated a more rapid decrease in average maximum moment compared to two-truck platoons, particularly evident in the positive moment graph, where the slopes of the two versions of the same truck type showed a distinct contrast.

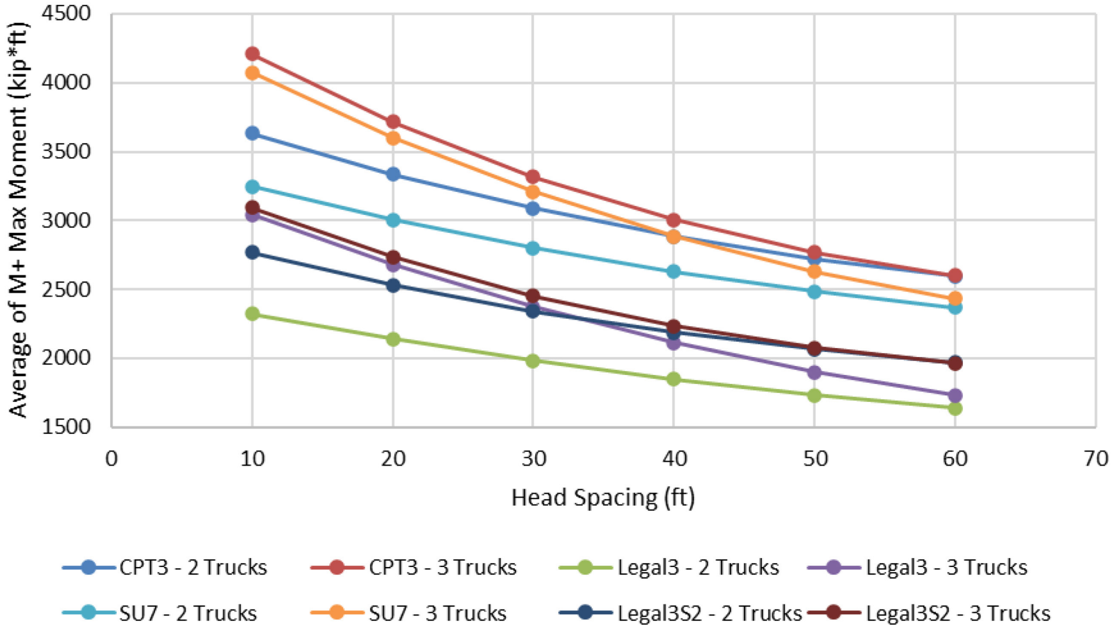

Figure 4.13: Effect of Head Spacing on Average Max Positive Bending Moment of Two and Three-Truck Platoons

The examination of maximum loading figures further supported the significance of head spacing in three-truck platooning scenarios, Figure 4.14. As the space between the three-trucks increased, the difference in distance of the load from the front truck to the rear truck grew more quickly, leading to a more rapid decrease in the maximum values. In contrast, for two-truck platoons, the effect of head spacing on the overall load spacing was less pronounced.

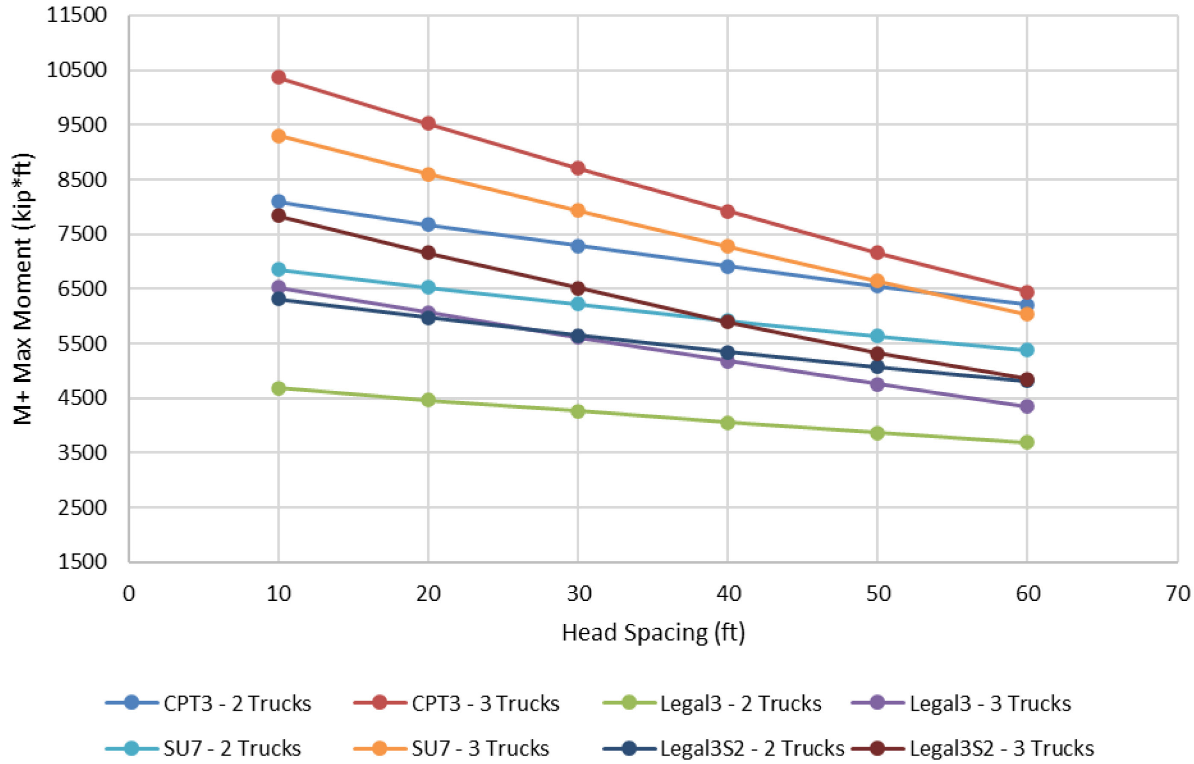

Figure 4.14: Effect of Head Spacing on Max Positive Bending Moment of Two and Three-Truck Platoons

Additional figures looking at the effect of head spacing for averages, maximums, and truck platooning ratios for positive and negative moments and shear can be found in Appendix B, Figures B65 – B74.

Focusing on bridge 708, one of the worst case three span bridges with span lengths 262 - 262 - 184 feet, a targeted study was conducted looking at head spacing across truck types while excluding data from all other bridges. Analyzing this isolated case reaffirmed the trends observed in the average and maximum graphs, lending further support to the significance of head spacing in determining internal forces under platooning scenarios (Figures 4.15 to 4.17).

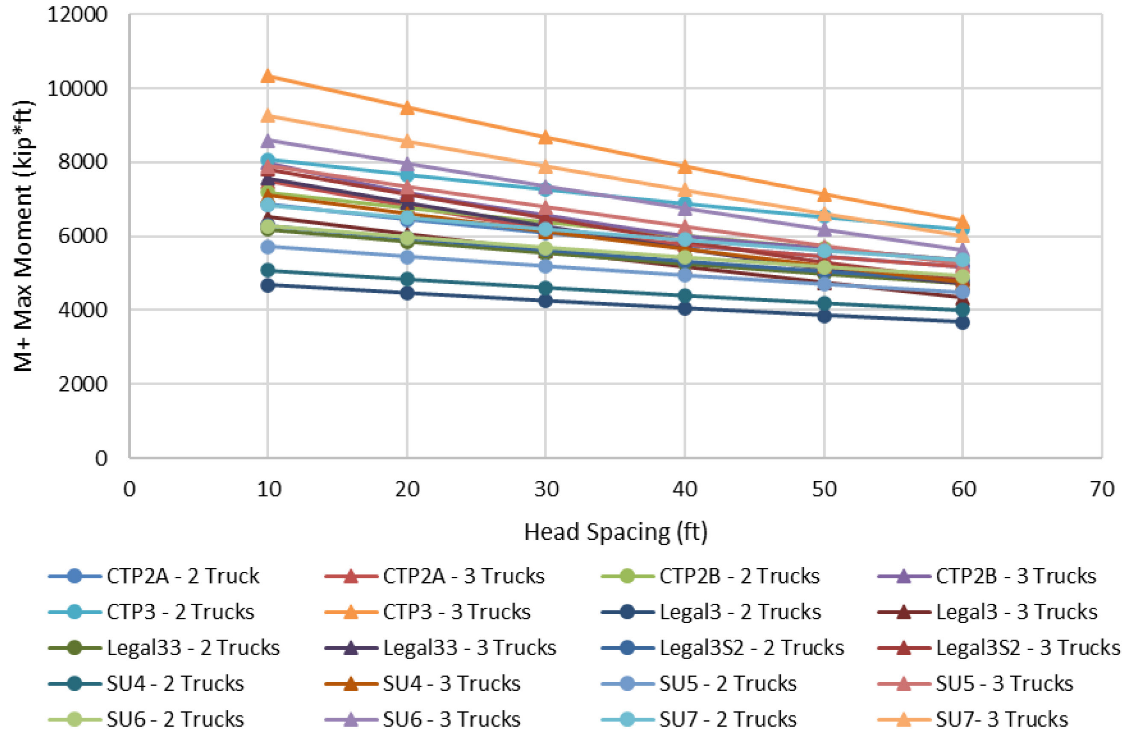

Figure 4.15: Effect of Head Spacing on Bridge 708 for the Max Positive Bending Moment

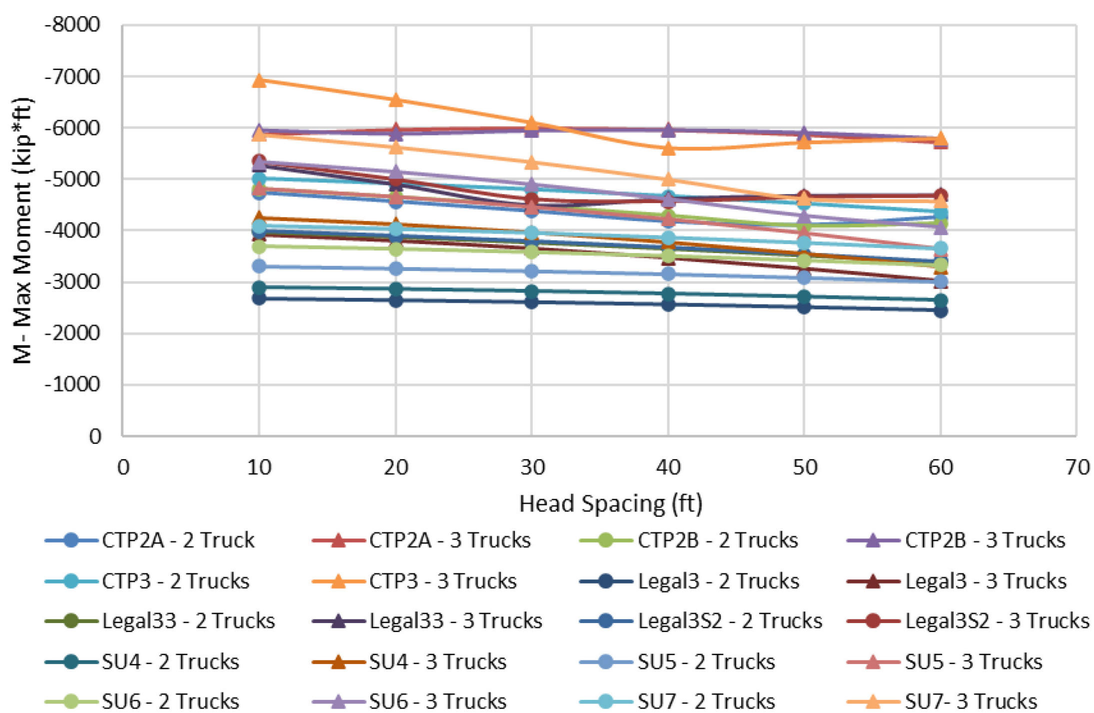

Figure 4.16: Effect of Head on Bridge 708 for the Max Negative Bending Moment

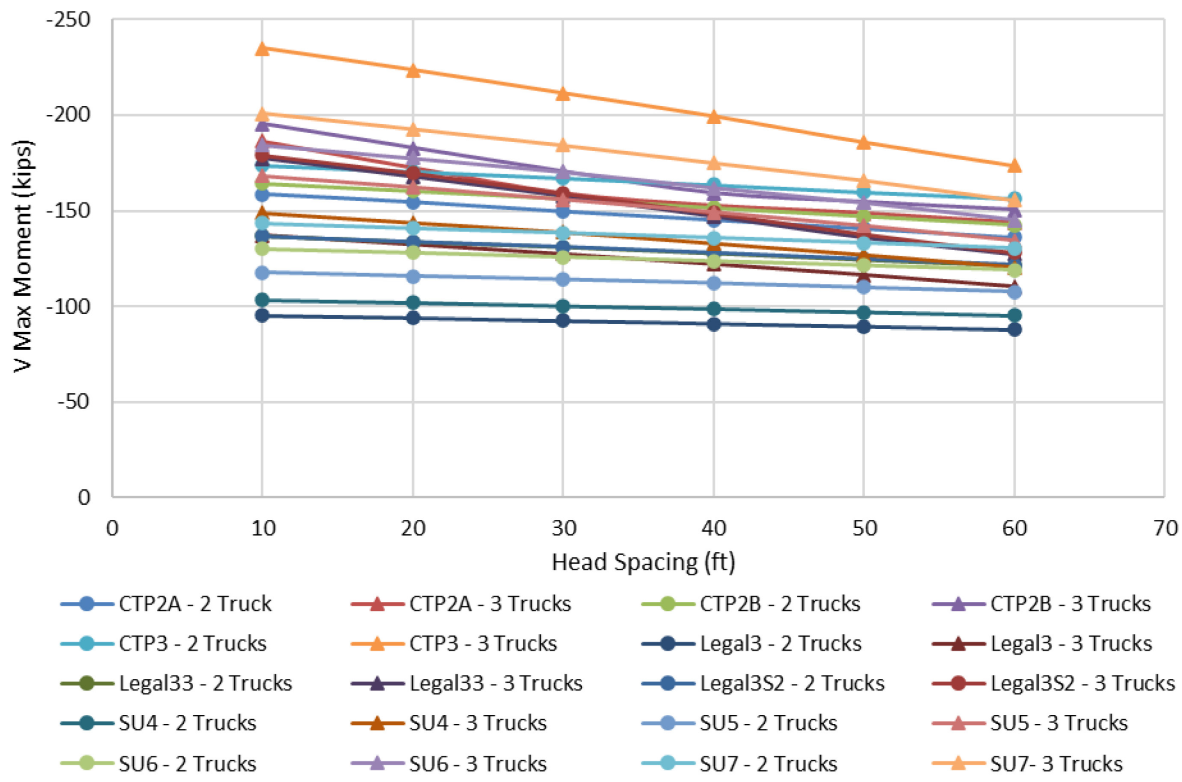

Figure 4.17: Effect of Head on Bridge 708 for the Max Shear Force

Removing data from all bridges to focus solely on this single bridge, we cleaned up the graphs to highlight Type OR CTP-3, OR Type 3 Legal, OR Type 3S2 Legal, and OR SU7. The patterns observed in the average and maximum graphs remained consistent, even in this isolated case (Figures 4.18 to 4.20).

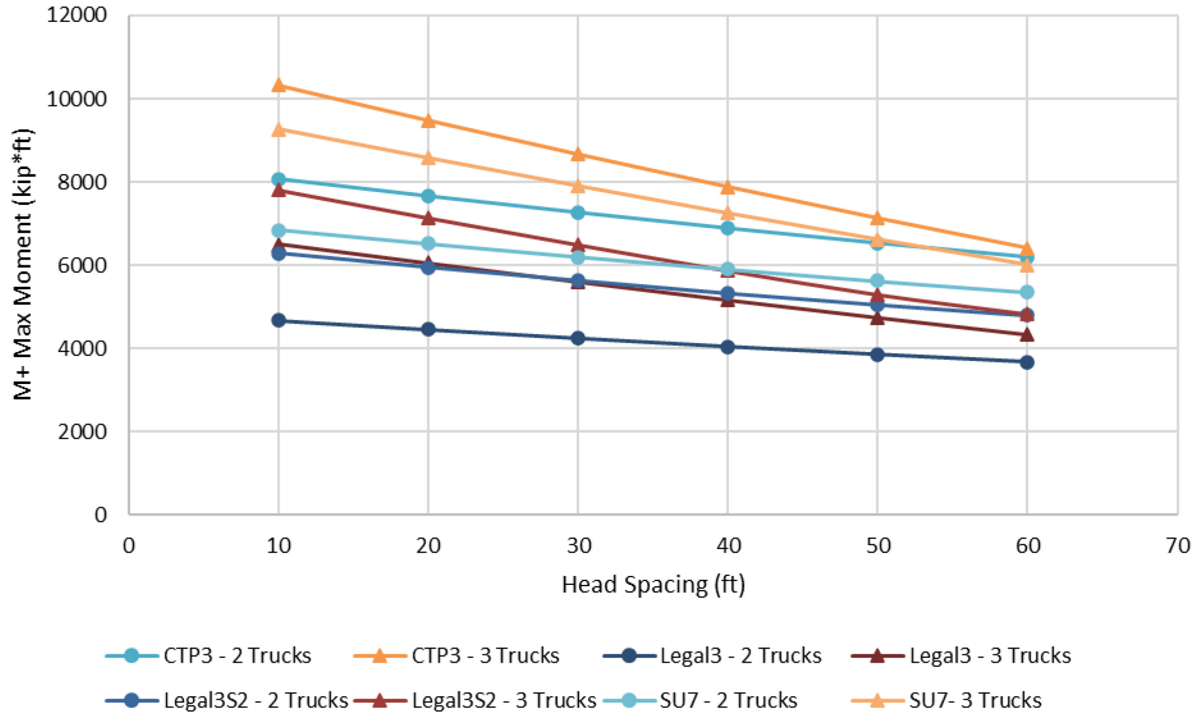

Figure 4.18: Effect of Head on Bridge 708 for the Max Positive Bending Moment - Isolating Specific Truck Types

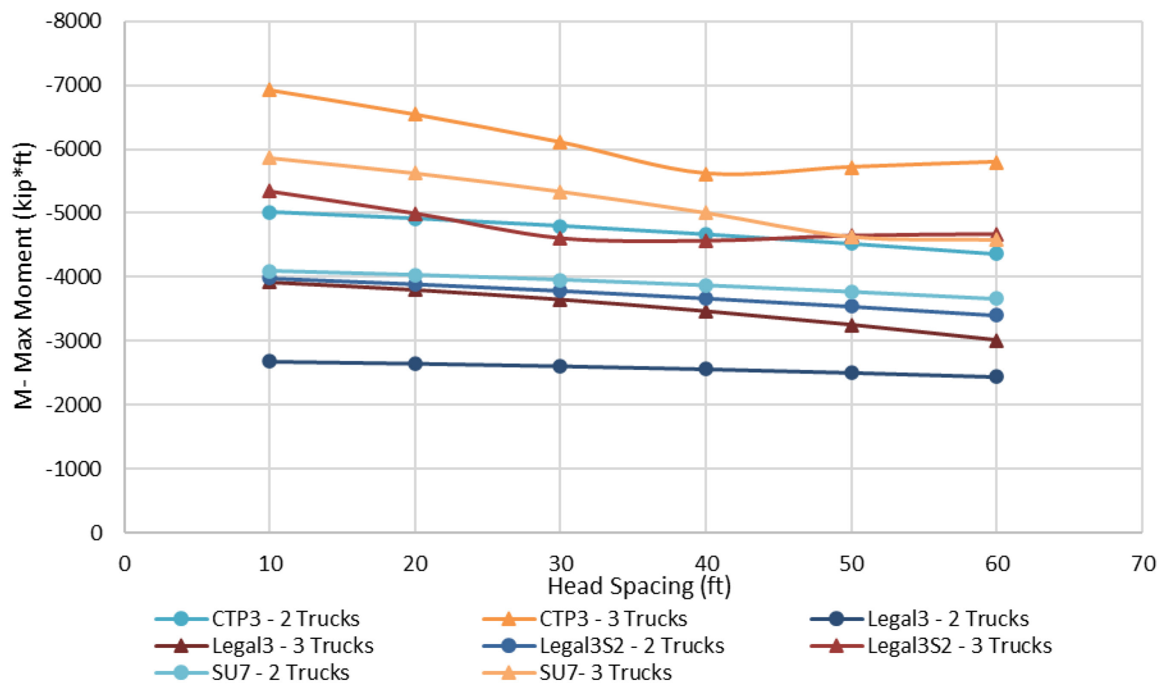

Figure 4.19: Effect of Head on Bridge 708 for the Max Negative Bending Moment – Isolating Specific Truck Types

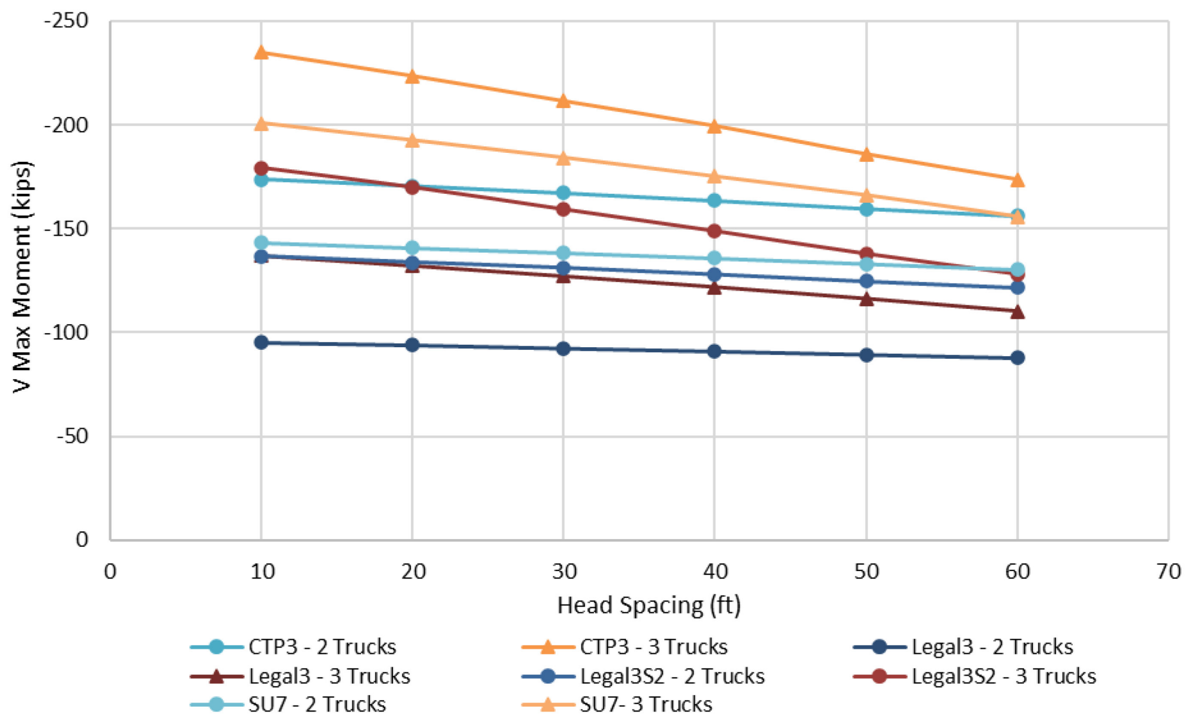

Figure 4.20: Effect of Head on Bridge 708 for the Max Shear Force - Isolating Specific Truck Types

It is worth noting that the dip in the negative moment graphs, Figure 4.19, can likely be attributed to the size of the three-span bridge and the increasing head spacing. The distributed load of the three-trucks contributes to an increasing negative moment due to their specific locations on the bridge. This effect could be influenced by the length of the trucks, as evident in OR Type 3 Legal three-truck platoon, being one of the shortest trucks, which does not show the dip. Conversely, the OR Type 3S2 Legal trucks, being one of the longest, shows a dip starting at the 30-ft head spacing. These findings underscore the importance of head spacing and its interaction with truck types in understanding load effects under platooning scenarios.

4.3 CASE STUDY 1: EFFECT OF HEAD SPACING FOR TWO MOST COMMON BRIDGE CONFIGURATIONS

In this case study, the effect of head spacing on internal force ratios for the two most common bridge configurations (per Appendix A) is studied:

- Single-span bridge with a span length of 15 m (49.2 ft)
- Three-span bridge with span lengths of 15 m – 20 m – 15 m (49.2 ft – 65.6 ft – 49.2 ft)

Two truck types that are most likely to be platooned in the near term are considered:

- OR legal truck Type 3S2
- OR continuous trip permit (CTP) truck CTP-3

Filters were applied to the summary dataset to only include the bridge configuration and truck types listed above. Using this reduced dataset, internal force ratios were extracted and are shown in Tables 4.3 through 4.6 seperately for each bridge and truck platoon configuration. Internal force ratios are based on Equation 1 with the OR legal truck Type 3S2 as reference. The following ranges were distinguished by color coding the tabulated ratios:

Green	Ratio < 1.10
Orange	1.10 ≤ Ratio < 1.20
Red	Ratio ≥ 1.20

In Tables 4.3 and 4.4, the internal force ratios for the single-span bridge (Span length = 15 m) are shown for the OR legal Type 3S2 and CPT3 truck platoon configurations, respectively. It can be observed that for the former, as long as the head spacing is kept to at least 30 ft, the increase in the internal forces are less than 5% compared to a single OR legal Type 3S2 truck. If the OR CPT-3 truck is platooned, the increase in the internal forces is at least 20%.

Table 4.3: Or Legal Type 3s2 Truck Platoon Configurations On Single-Span Bridge (Reference: Or Legal Truck Type 3s2)

Positive bending moment		**Shear force**	
Truck platoon configuration	**Ratio**	**Truck platton configuration**	**Ratio**
Legal3S2_3_10	1.221	Legal3S2_3_10	1.386
Legal3S2_2_10	1.220	Legal3S2_2_10	1.385
Legal3S2_2_50	1.001	Legal3S2_3_20	1.222
Legal3S2_2_60	1.001	Legal3S2_2_20	1.219
Legal3S2_3_60	1.001	Legal3S2_2_30	1.049
Legal3S2_2_40	1.000	Legal3S2_3_30	1.047
Legal3S2_3_40	1.000	Legal3S2_3_60	1.000
Legal3S2_3_50	1.000	Legal3S2_1_0	1.000
Legal3S2_2_20	1.000	Legal3S2_2_60	1.000
Legal3S2_2_30	1.000	Legal3S2_3_50	0.999
Legal3S2_1_0	1.000	Legal3S2_2_50	0.999
Legal3S2_3_30	1.000	Legal3S2_3_40	0.998
Legal3S2_3_20	1.000	Legal3S2_2_40	0.997

Table 4.4: OR CPT-3 Truck Platoon Configurations On Single-Span Bridge (Reference: OR Legal Truck Type 3S2). Ratios < 1.10 Are Highlighted In Green

Positive bending moment		Shear force	
Truck platoon configuration	Ratio	Truck platton configuration	Ratio
CTP3_2_10	1.416	CTP3_3_10	1.681
CTP3_3_10	1.416	CTP3_2_10	1.678
CTP3_2_30	1.203	CTP3_2_20	1.460
CTP3_2_40	1.203	CTP3_3_20	1.458
CTP3_2_60	1.203	CTP3_3_60	1.446
CTP3_3_40	1.203	CTP3_3_40	1.446
CTP3_2_50	1.203	CTP3_3_30	1.446
CTP3_1_0	1.203	CTP3_2_60	1.445
CTP3_2_20	1.203	CTP3_3_50	1.444
CTP3_3_30	1.203	CTP3_1_0	1.443
CTP3_3_60	1.203	CTP3_2_40	1.441
CTP3_3_50	1.203	CTP3_2_30	1.440
CTP3_3_20	1.203	CTP3_2_50	1.440

In Tables 4.5 and 4.6, the internal force ratios for the three-span bridge (Span lengths = 15 m – 20 m – 15 m) are shown for the OR legal Type 3S2 and CPT3 truck platoon configurations, respectively. It can oberved that for the former, as long as the head spacing is at least 30 ft, the increase in the internal forces are less than 10% compared to a single OR legal Type 3S2 truck. If the OR CPT-3 truck is platooned, the increase in the internal forces is at least 12% (for negative bending moment).

Table 4.5: OR Legal Type 3S2 Truck Platoon Configurations On Three-Span Bridge (Reference: OR Legal Truck Type 3S2)

Positive bending moment		Negative bending moment		Shear force	
Truck platoon configuration	Ratio	Truck platton configuration	Ratio	Truck platton configuration	Ratio
Legal3S2_2_10	1.034	Legal3S2_3_10	1.509	Legal3S2_3_10	1.391
Legal3S2_3_10	1.025	Legal3S2_2_10	1.374	Legal3S2_2_10	1.390
Legal3S2_2_40	1.001	Legal3S2_2_20	1.175	Legal3S2_3_20	1.184
Legal3S2_3_60	1.001	Legal3S2_3_20	1.175	Legal3S2_2_20	1.182
Legal3S2_3_20	1.000	Legal3S2_2_30	1.085	Legal3S2_3_30	1.045
Legal3S2_3_50	1.000	Legal3S2_3_30	1.085	Legal3S2_2_30	1.044
Legal3S2_2_60	1.000	Legal3S2_2_40	1.007	Legal3S2_2_40	1.018
Legal3S2_2_50	1.000	Legal3S2_3_40	1.007	Legal3S2_3_40	1.017
Legal3S2_2_30	1.000	Legal3S2_1_0	1.000	Legal3S2_2_60	1.000
Legal3S2_3_40	1.000	Legal3S2_2_50	1.000	Legal3S2_1_0	1.000
Legal3S2_3_30	1.000	Legal3S2_3_50	1.000	Legal3S2_2_50	0.998
Legal3S2_1_0	1.000	Legal3S2_2_60	1.000	Legal3S2_3_50	0.998
Legal3S2_2_20	1.000	Legal3S2_3_60	1.000	Legal3S2_3_60	0.998

Table 4.6: OR CPT-3 Truck Platoon Configurations On Three-Span Bridge (Reference: OR Legal Truck Type 3S2). Ratios < 1.10 Are Highlighted In Green

Positive bending moment		Negative bending moment		Shear force	
Truck platoon configuration	**Ratio**	**Truck platton configuration**	**Ratio**	**Truck platton configuration**	**Ratio**
CTP3_2_60	1.384	CTP3_3_10	1.961	CTP3_2_10	1.801
CTP3_1_0	1.384	CTP3_2_10	1.755	CTP3_3_10	1.799
CTP3_3_60	1.383	CTP3_2_20	1.622	CTP3_3_20	1.515
CTP3_3_50	1.369	CTP3_3_20	1.622	CTP3_2_20	1.513
CTP3_2_50	1.369	CTP3_2_30	1.545	CTP3_2_30	1.475
CTP3_2_10	1.363	CTP3_3_30	1.545	CTP3_3_30	1.473
CTP3_3_40	1.329	CTP3_2_40	1.412	CTP3_2_40	1.446
CTP3_2_40	1.329	CTP3_3_40	1.412	CTP3_3_40	1.438
CTP3_3_10	1.296	CTP3_3_50	1.219	CTP3_1_0	1.433
CTP3_2_30	1.246	CTP3_2_50	1.219	CTP3_3_50	1.432
CTP3_3_30	1.246	CTP3_1_0	1.118	CTP3_2_60	1.432
CTP3_2_20	1.217	CTP3_2_60	1.118	CTP3_2_50	1.431
CTP3_3_20	1.216	CTP3_3_60	1.118	CTP3_3_60	1.428

Because of the complexity of the bridge and truck platoon configurations, and their combinations, these tables need to be created individually, as needed. Also, to capture the true effect of truck platooning on the bridge network, load ratings should be conducted on a network level. An example of how approximate rating factors for LRFR load rating can be computed is provided in Section 4.4.

4.4 CASE STUDY 2: LOAD RATING OF AN IN-SERVICE BRIDGE

To understand how platooning could affect the rating factor (RF) of an in-service bridge, the live load ratios obtained from the summary dataset were applied to the LRFR strength equation for the rating factor (Figure 4.21), where Capacity, Dead Load Effect, and Live Load Effect are internal forces, i.e., bending moment or shear force, evaluated at a specific location along the length of the bridge (FHWA, 2018). Strength reduction factors, φ and load factors, γ, are shown for reference. Bridge 20026, an existing in-service bridge in Oregon, was selected for this case study. Bridge 20026 is a prestressed Bulb-T girder bridge comprising of two spans. The elevation view is depicted in Figure 4.22, where the first and second span measure 91 feet 10 inches and 142 feet 9 inches, respectively.

$$RF = \frac{\overbrace{\varphi_C \varphi_S \varphi\,(R_n)}^{\text{Capacity}} - \overbrace{(\gamma_{DC})(DC) - (\gamma_{DW})\,(DW)}^{\text{Dead Load Effect}}}{\underbrace{(\gamma_L)(LL+IM)}_{\text{Live Load Effect}}}$$

Figure 4.21: Equation used to calculate rating factor (RF). From The Manual for Bridge Evaluation (FHWA, 2018)

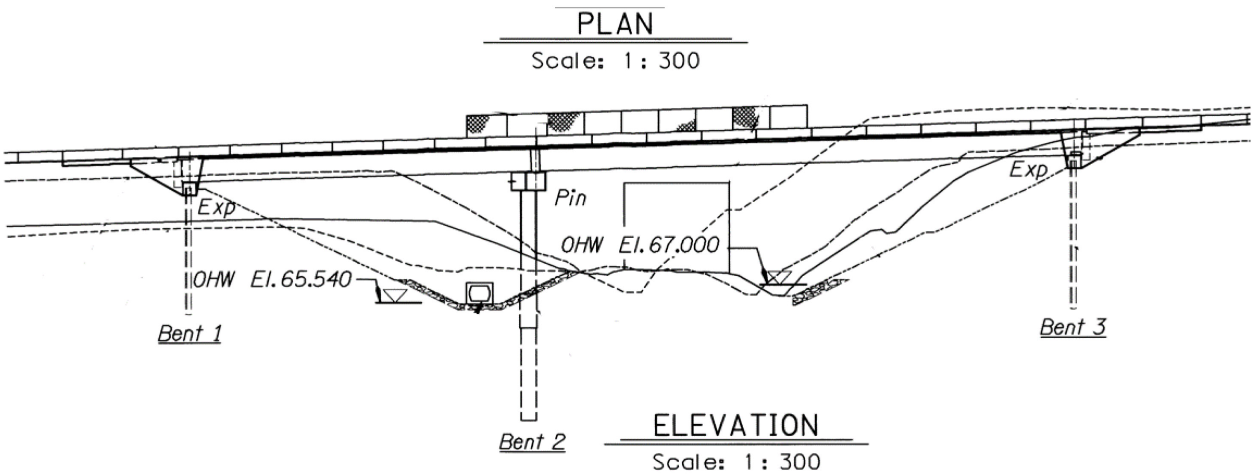

Figure 4.22: Elevation View of Bridge 2026

By utilizing the "Bridge Section Tier 2 Load Rating Summary Report" from ODOT (Appendix B, Figure B75) to calculate capacity and employing the "Wyoming Department of Transportation System Rating and Analysis of Structural Systems" (BRASS) files for Bridge 20026 to calculate the dead and live loads, the current RF was determined using the LRFR Strength Equation, equation 1. This calculation was verified against the "Bridge Section Tier 2 Load Rating Summary Report". This bridge has a current inventory and operating RF of 1.52 and 2.51, respectively. Herein, only the operating RF was computed and is compared.

To calculate an updated RF, a bridge with similar span lengths needed to be selected from the established summary dataset. Upon comparing the span lengths of Bridge 20026 with the summary dataset, Bridge 35 was found to be the closest match. The first span of Bridge 35 measured 131 feet, while the second spanned a length of 98.2 feet.

Next, internal force ratios were derived from single-truck versus two and three-truck platoons, considering different head spacings ranging from 10 to 60 feet. These ratios were calculated for various truck types, including OR Type 3 Legal, OR Type 3S2 Legal, Type 3-3 Legal, OR SU4, OR SU5, OR SU6, OR SU7, Type OR CTP-2A, Type OR CTP-2B, and Type OR CTP-3. However, in this case, the ratios were not obtained from the maximum positive moment for the entire bridge. Instead, they were based on the maximum positive moment per span length that corresponded to the span length of Bridge 20026. This adjustment was necessary because the live load rating created moments that were controlled by different spans for Type OR CTP-2A and Type OR CTP-2B. The updated RF were then calculated by applying the above internal force ratios to the live load in Equation 3. The updated RF were then plotted vs. head spacing and can be seen in Figures 4.22 and 4.23.

Some of the built-in assumptions of this approach regarding platooned trucks vs. their single truck versions are that they have the same:

- live load factors, γ_L,
- live load distribution factors, *DF*, and

- impact factors, *IM*.

These assumptions are necessary because no traffic data are currently available for platooned trucks; they are at this point entirely hypothetical.

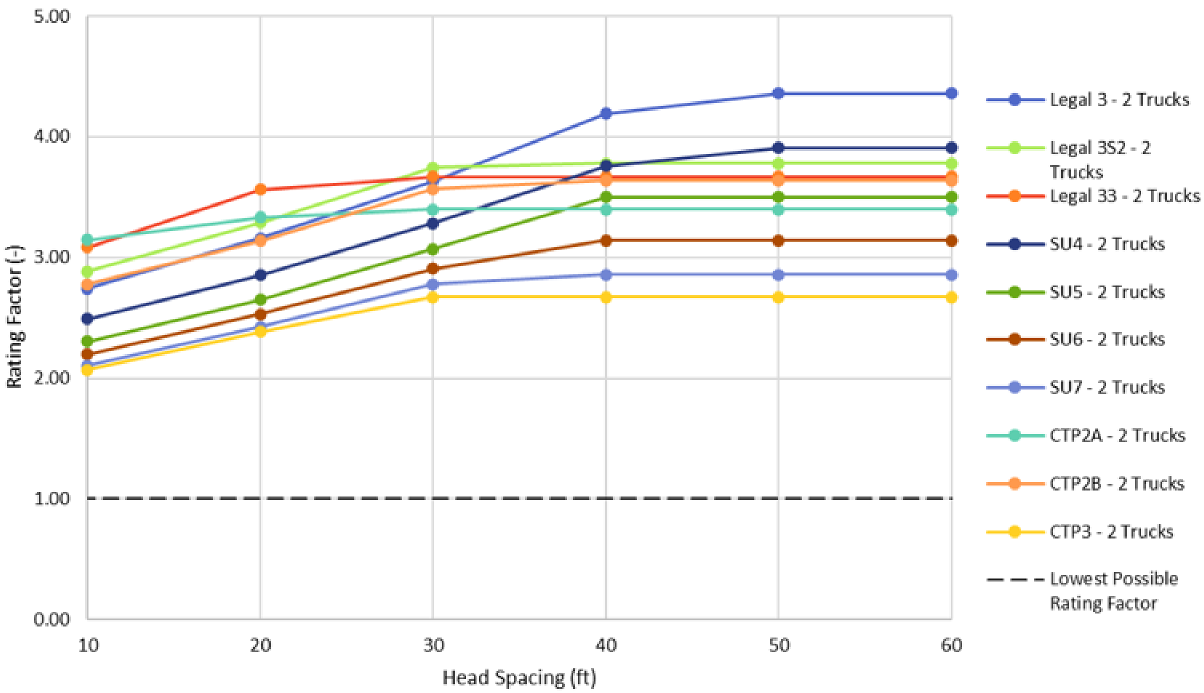

Figure 4.23: Rating Factor vs. Head Spacing for Two-Truck Platoons for Positive Bending Moment

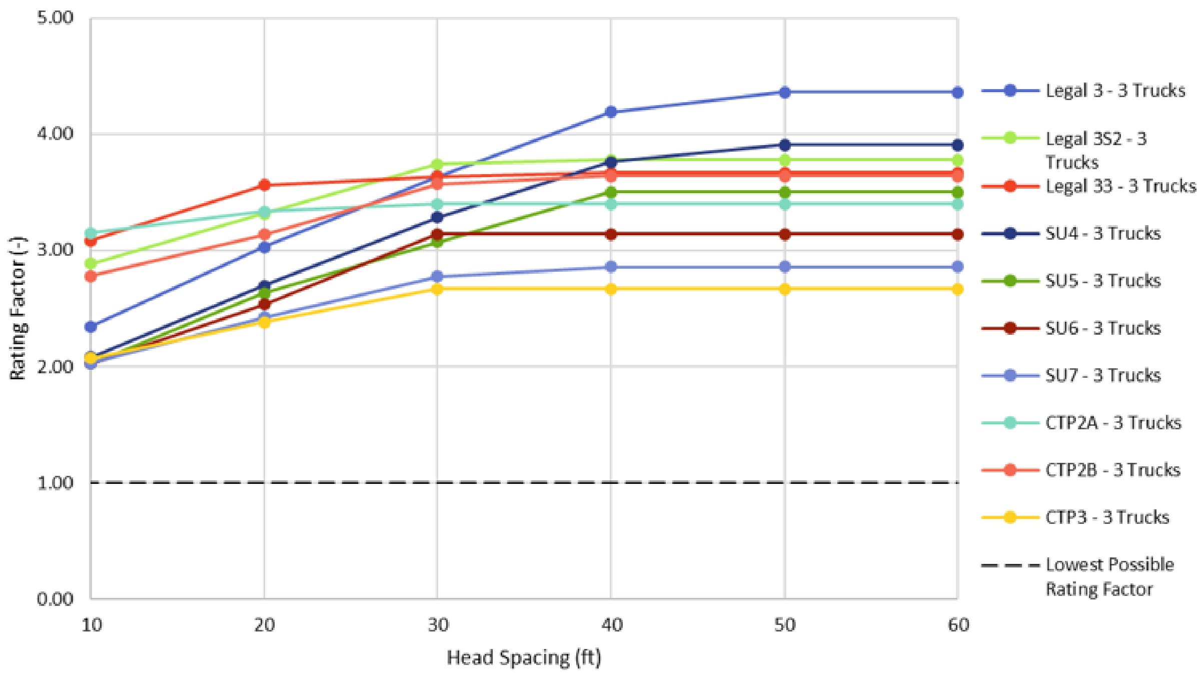

Figure 4.24: Rating Factor vs. Head Spacing for Three-Truck Platoons for Positive Bending Moment

To conclude, it can be observed that truck platooning consistently resulted in a decrease in the rating factor across all cases. While the reduction of the RF is significant for this bridge, the RF never dropped below 2.0, the reason being that this bridge is overdesigned. However, the updated RF using platooned trucks is still notably lower than the current operating RF of 2.51. By referring to Figures 4.22 and 4.23, it becomes evident that once the trucks are spaced at least 50 feet apart, the RF remains essentially flat and head spacing does not substantially influence the RF in most scenarios. This trend holds true for both two-truck and three-truck platoons. Individual truck types and their rating factors are available in Appendix B, Figures B76-B85.

5.0 SUMMARY AND CONCLUSIONS

The emerging technology of truck platooning holds immense potential for revolutionizing the transportation industry by enhancing fuel efficiency, traffic safety, and traffic flow in long-haul trucking. The implementation of automated driving technologies to facilitate truck platooning brings forth the prospect of optimized traffic management and improved driver comfort during extended journeys.

In the context of Oregon's transportation network, recent legislative changes, such as House Bill 4059, Section 40, have effectively permitted truck platooning by waiving headspace requirements for vehicles equipped with "connected automated braking systems." While this presents new opportunities for efficient freight transportation, the distinct behaviors of different truck types within platoons can substantially impact internal forces.

The research findings underscore that specific conditions can lead to notably higher internal load effects from platooned trucks. This highlights potential concerns regarding the integrity and safety of bridges, particularly in cases involving the use of Type OR CTP-3 and OR SU7 truck platoons, which have emerged as the predominant truck types associated with the highest frequency of elevated internal force ratios. Additionally, bridges featuring certain configurations, such as longer spans, may encounter challenges when subjected to truck platooning. This trend is evident in the analysis, where bridges with longer spans consistently exhibit the highest ratios. This pattern is particularly evident in the multi-span analysis, where a subset of bridges with the first two spans measuring 262 feet in length (bridge numbers 702-709) represents the worst-case scenario overall. Interestingly, the individual graph depicting the OR Type 3S2 Legal negative bending moment ratio in Figure 4.8 reveals that some shorter span bridges also exhibit elevated ratios. This phenomenon can likely be attributed to the longer platoon lengths of the OR Type 3S2 Legal configurations when compared to certain higher load and shorter length trucks. It is worth noting that the introduction of truck platooning poses a potential risk of structural inadequacy for bridges with lower rating factors (RF). These factors are often influenced by economic considerations, including cost, materials, and maintenance.

Two case studies showcase how the products of SPR-848 can be implemented to provide policies. The first case study looked at the two most common bridge configurations and most likely platooned truck types and how minimum head spacings can be determined. To capture the true effect of truck platooning on a bridge, however, a load rating needs to be conducted, which is shown in the second case study. With a load rating, the capacity of the bridge is considered, allowing to determine which truck platoon configurations a bridge can handle.

As further exploration and analysis are essential for a comprehensive understanding of the intricate interactions between truck platooning and the effect on internal forces, future research should address scenarios involving truck platoons at tight spacings (less than 30 feet) of more than three trucks of Type OR CTP-3 and OR SU7 and analyze bridge spans exceeding lengths of 262 feet, if applicable. This endeavor will facilitate informed policy recommendations and load rating updates that ensure the safe and sustainable integration of truck platooning within Oregon’s existing transportation infrastructure. In navigating the evolving landscape of transportation technologies, it is imperative to strike a balance between innovation and structural safety to foster a resilient and efficient future for freight movement. Finally, the impacts of truck platooning on the design of new bridges should be explored, one example being the impact of truck platooning on the replacement of the I-5 Bridge crossing the Columbia River in Portland.

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APPENDIX A

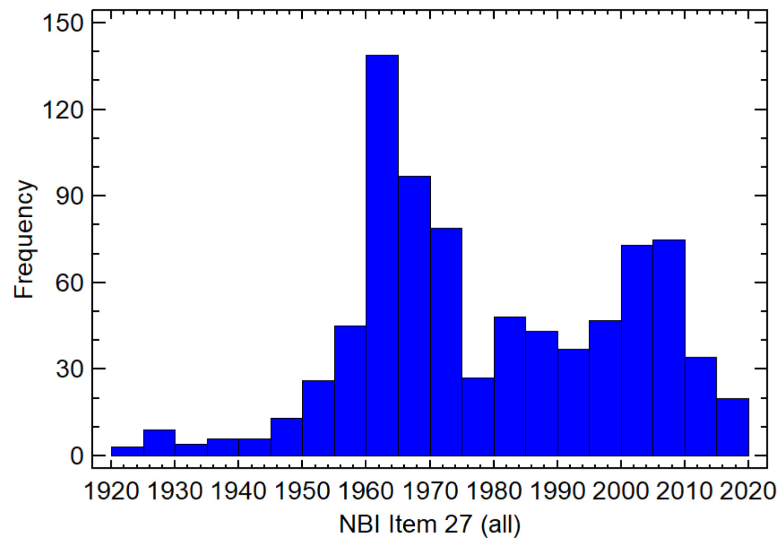


Figure A1. Histogram of NBI Item 27: Year built (yr).

Table A1. Frequencies of NBI Item 27: Year built (yr).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	1920		1	0.0012	1	0.0012
1	1920	1925.0	1922.5	3	0.0036	4	0.0048
2	1925	1930.0	1927.5	9	0.0108	13	0.0156
3	1930	1935.0	1932.5	4	0.0048	17	0.0204
4	1935	1940.0	1937.5	6	0.0072	23	0.0276
5	1940	1945.0	1942.5	6	0.0072	29	0.0349
6	1945	1950.0	1947.5	13	0.0156	42	0.0505
7	1950	1955.0	1952.5	26	0.0313	68	0.0817
8	1955	1960.0	1957.5	45	0.0541	113	0.1358
9	1960	1965.0	1962.5	139	0.1671	252	0.3029
10	1965	1970.0	1967.5	97	0.1166	349	0.4195
11	1970	1975.0	1972.5	79	0.0950	428	0.5144
12	1975	1980.0	1977.5	27	0.0325	455	0.5469
13	1980	1985.0	1982.5	48	0.0577	503	0.6046
14	1985	1990.0	1987.5	43	0.0517	546	0.6563
15	1990	1995.0	1992.5	37	0.0445	583	0.7007
16	1995	2000.0	1997.5	47	0.0565	630	0.7572
17	2000	2005.0	2002.5	73	0.0877	703	0.8450
18	2005	2010.0	2007.5	75	0.0901	778	0.9351
19	2010	2015.0	2012.5	34	0.0409	812	0.9760
20	2015	2020.0	2017.5	20	0.0240	832	1.0000
	above	2020		0	0.0000	832	1.0000

Mean = 1979.86   Standard deviation = 20.9768

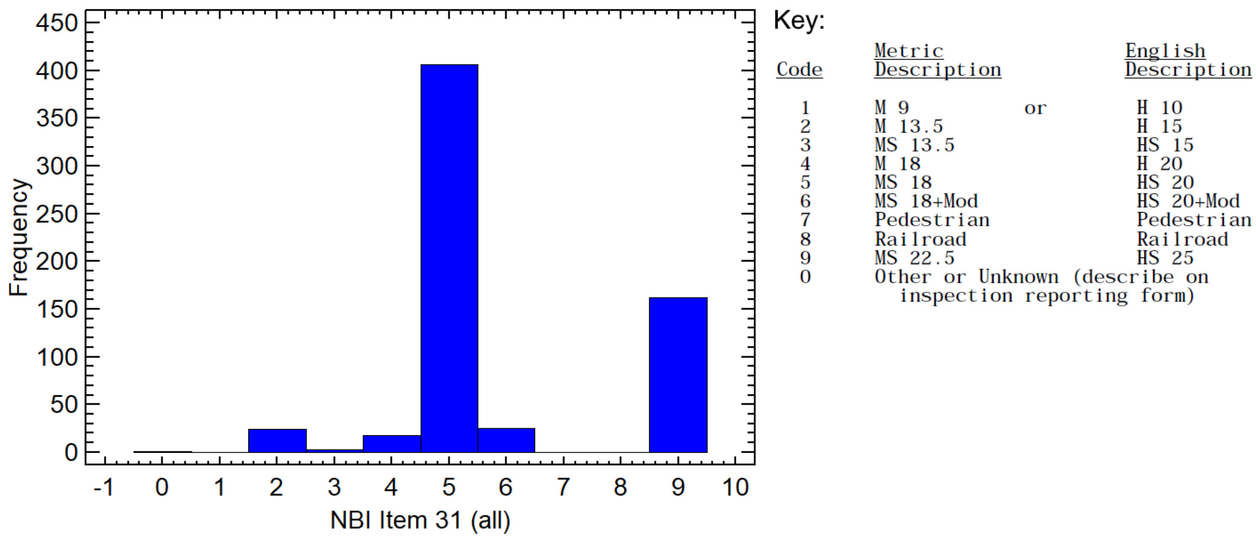


Figure A2. Histogram of NBI Item 31: Design load (-).

Table A2. Frequencies of NBI Item 31: Design load (-).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	-0.5		0	0.0000	0	0.0000
1	-0.5	0.5	0	1	0.0016	1	0.0016
2	0.5	1.5	1.0	0	0.0000	1	0.0016
3	1.5	2.5	2.0	24	0.0376	25	0.0391
4	2.5	3.5	3.0	3	0.0047	28	0.0438
5	3.5	4.5	4.0	18	0.0282	46	0.0720
6	4.5	5.5	5.0	406	0.6354	452	0.7074
7	5.5	6.5	6.0	25	0.0391	477	0.7465
8	6.5	7.5	7.0	0	0.0000	477	0.7465
9	7.5	8.5	8.0	0	0.0000	477	0.7465
	above	8.5		162	0.2535	639	1.0000

Mean = 5.89515 Standard deviation = 1.92979

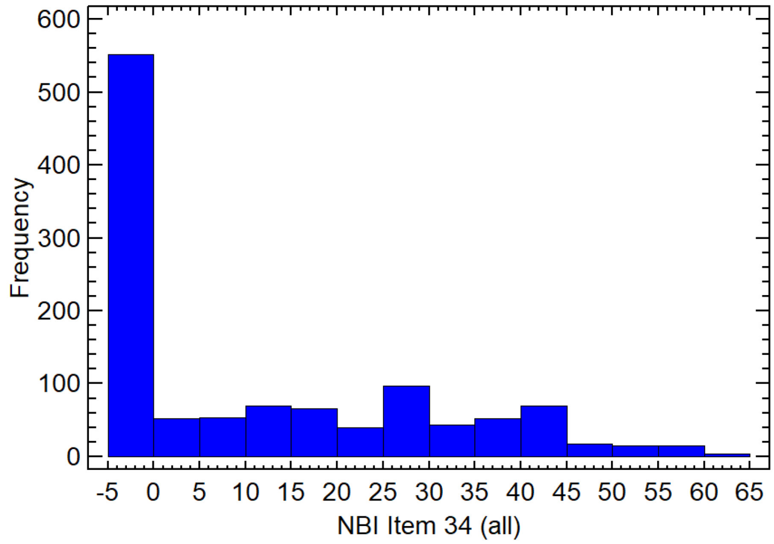


Figure A3. Histogram of NBI Item 34: Skew (Degrees).

Table A3. Frequencies of NBI Item 34: Skew (Degrees).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	-4		0	0.0000	0	0.0000
1	-4	0	-2.5	552	0.4698	552	0.4698
2	0	5.0	2.5	52	0.0443	604	0.5140
3	5	10.0	7.5	53	0.0451	657	0.5591
4	10	15.0	12.5	69	0.0587	726	0.6179
5	15	20.0	17.5	66	0.0562	792	0.6740
6	20	25.0	22.5	40	0.0340	832	0.7081
7	25	30.0	27.5	97	0.0826	929	0.7906
8	30	35.0	32.5	43	0.0366	972	0.8272
9	35	40.0	37.5	52	0.0443	1024	0.8715
10	40	45.0	42.5	69	0.0587	1093	0.9302
11	45	50.0	47.5	17	0.0145	1110	0.9447
12	50	55.0	52.5	15	0.0128	1125	0.9574
13	55	60.0	57.5	15	0.0128	1140	0.9702
14	60	65.0	62.5	4	0.0034	1144	0.9736
	above	65		31	0.0264	1175	1.0000

Mean = 15.9055 Standard deviation = 21.532

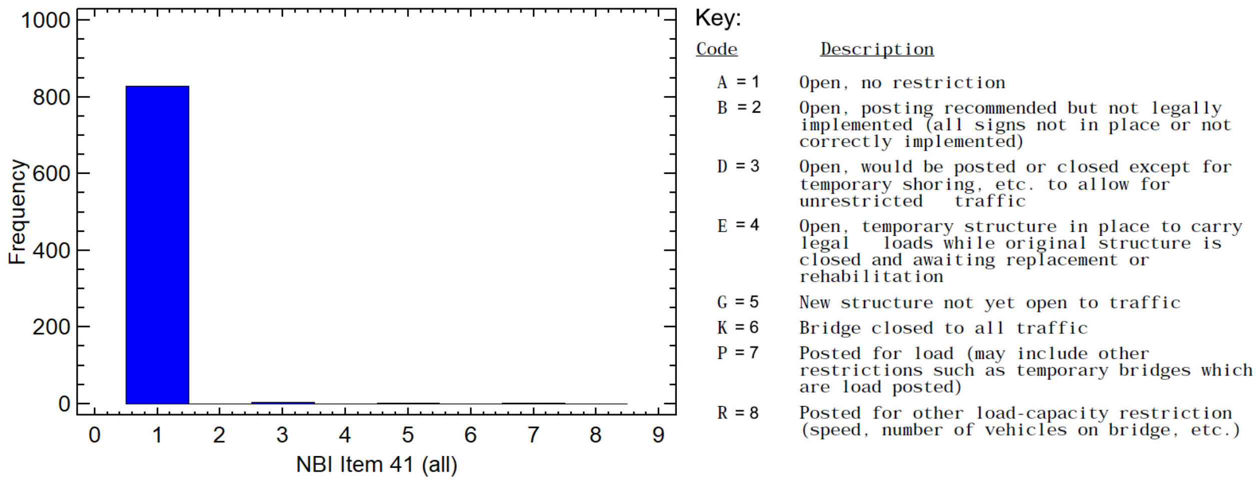


Figure A4. Histogram of NBI Item 41: Structure open, posted, or closed to traffic (-).

Table A4. Frequencies of NBI Item 41: Structure open, posted, or closed to traffic (-).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	-0.5		0	0.0000	0	0.0000
1	-0.5	0.5	0	0	0.0000	0	0.0000
2	0.5	1.5	1.0	829	0.9940	829	0.9940
3	1.5	2.5	2.0	0	0.0000	829	0.9940
4	2.5	3.5	3.0	3	0.0036	832	0.9976
5	3.5	4.5	4.0	0	0.0000	832	0.9976
6	4.5	5.5	5.0	1	0.0012	833	0.9988
7	5.5	6.5	6.0	0	0.0000	833	0.9988
8	6.5	7.5	7.0	1	0.0012	834	1.0000
9	7.5	8.5	8.0	0	0.0000	834	1.0000
	above	8.5		0	0.0000	834	1.0000

Mean = 1.01918 Standard deviation = 0.276518

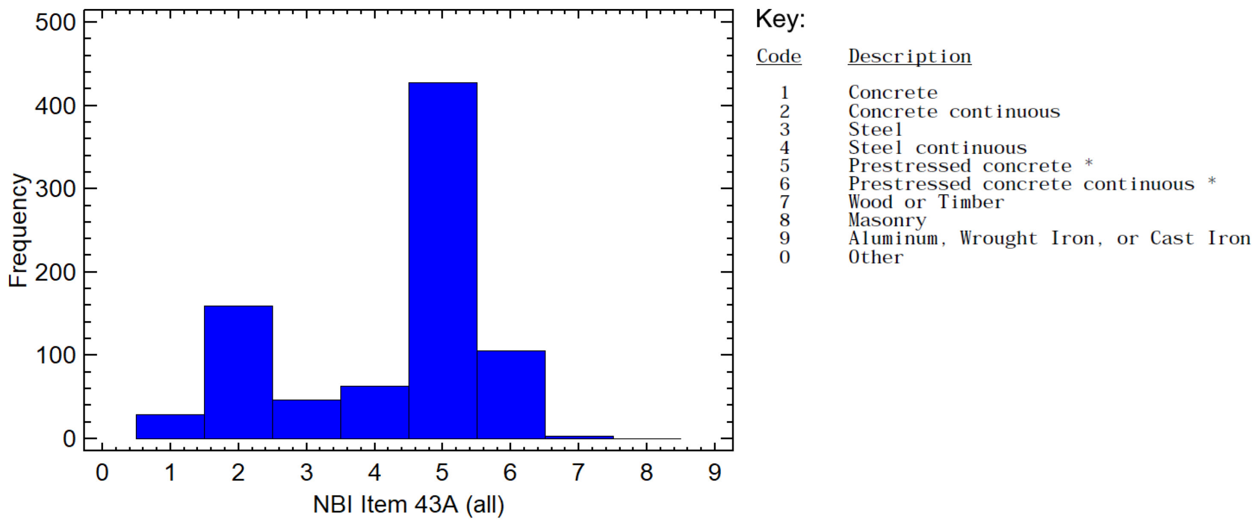
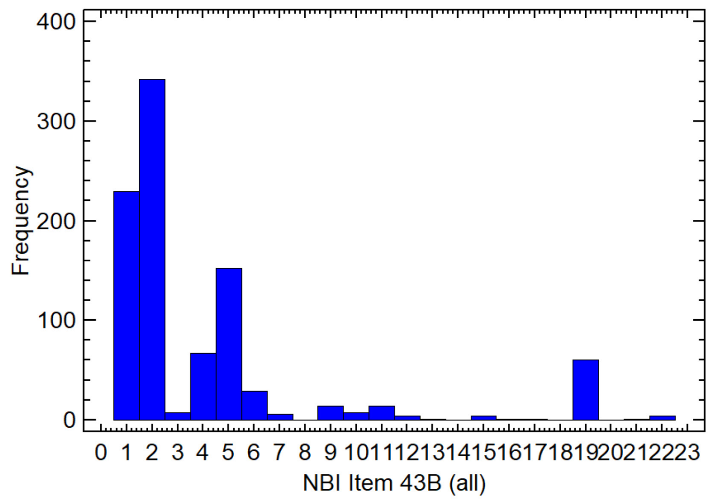


Figure A5. Histogram of NBI Item 43A: Kind of material and/or design (-).

Table A5. Frequencies of NBI Item 43A: Kind of material and/or design* (-).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	-0.5		0	0.0000	0	0.0000
1	-0.5	0.5	0	0	0.0000	0	0.0000
2	0.5	1.5	1.0	29	0.0347	29	0.0347
3	1.5	2.5	2.0	159	0.1904	188	0.2251
4	2.5	3.5	3.0	47	0.0563	235	0.2814
5	3.5	4.5	4.0	63	0.0754	298	0.3569
6	4.5	5.5	5.0	428	0.5126	726	0.8695
7	5.5	6.5	6.0	106	0.1269	832	0.9964
8	6.5	7.5	7.0	3	0.0036	835	1.0000
9	7.5	8.5	8.0	0	0.0000	835	1.0000
	above	8.5		0	0.0000	835	1.0000

Mean = 4.23593 Standard deviation = 1.45949



Key:

Code	Description
01	Slab
02	Stringer/Multi-beam or Girder
03	Girder and Floorbeam System
04	Tee Beam
05	Box Beam or Girders - Multiple
06	Box Beam or Girders - Single or Spread
07	Frame (except frame culverts)
08	Orthotropic
09	Truss - Deck
10	Truss - Thru
11	Arch - Deck
12	Arch - Thru
13	Suspension
14	Stayed Girder
15	Movable - Lift
16	Movable - Bascule
17	Movable - Swing
18	Tunnel
19	Culvert (includes frame culverts)
20 *	Mixed types
21	Segmental Box Girder
22	Channel Beam
00	Other

Figure A6. Histogram of NBI Item 43B: Type of design and/or construction (-).

Table A6. Frequencies of NBI Item 43B: Type of design and/or construction (-).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	-0.5		0	0.0000	0	0.0000
1	-0.5	0.5	0	0	0.0000	0	0.0000
2	0.5	1.5	1.0	229	0.2428	229	0.2428
3	1.5	2.5	2.0	342	0.3627	571	0.6055
4	2.5	3.5	3.0	7	0.0074	578	0.6129
5	3.5	4.5	4.0	67	0.0710	645	0.6840
6	4.5	5.5	5.0	152	0.1612	797	0.8452
7	5.5	6.5	6.0	29	0.0308	826	0.8759
8	6.5	7.5	7.0	6	0.0064	832	0.8823
9	7.5	8.5	8.0	0	0.0000	832	0.8823
10	8.5	9.5	9.0	14	0.0148	846	0.8971
11	9.5	10.5	10.0	7	0.0074	853	0.9046
12	10.5	11.5	11.0	14	0.0148	867	0.9194
13	11.5	12.5	12.0	4	0.0042	871	0.9236
14	12.5	13.5	13.0	1	0.0011	872	0.9247
15	13.5	14.5	14.0	0	0.0000	872	0.9247
16	14.5	15.5	15.0	4	0.0042	876	0.9290
17	15.5	16.5	16.0	1	0.0011	877	0.9300
18	16.5	17.5	17.0	1	0.0011	878	0.9311
19	17.5	18.5	18.0	0	0.0000	878	0.9311
20	18.5	19.5	19.0	60	0.0636	938	0.9947
21	19.5	20.5	20.0	0	0.0000	938	0.9947
22	20.5	21.5	21.0	1	0.0011	939	0.9958
23	21.5	22.5	22.0	4	0.0042	943	1.0000
	above	22.5		0	0.0000	943	1.0000

Mean = 4.16861 Standard deviation = 4.74825

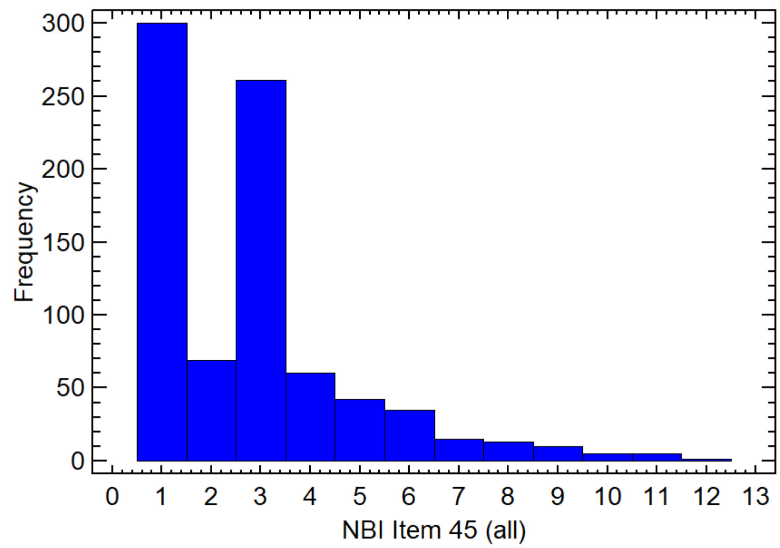


Figure A7. Histogram of NBI Item 45: Number of spans in main unit (-).

Table A7. Frequencies of NBI Item 45: Number of spans in main unit (-).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	-0.5		0	0.0000	0	0.0000
1	-0.5	0.5	0	0	0.0000	0	0.0000
2	0.5	1.5	1.0	300	0.3606	300	0.3606
3	1.5	2.5	2.0	69	0.0829	369	0.4435
4	2.5	3.5	3.0	261	0.3137	630	0.7572
5	3.5	4.5	4.0	60	0.0721	690	0.8293
6	4.5	5.5	5.0	42	0.0505	732	0.8798
7	5.5	6.5	6.0	35	0.0421	767	0.9219
8	6.5	7.5	7.0	15	0.0180	782	0.9399
9	7.5	8.5	8.0	13	0.0156	795	0.9555
10	8.5	9.5	9.0	10	0.0120	805	0.9675
11	9.5	10.5	10.0	5	0.0060	810	0.9736
12	10.5	11.5	11.0	5	0.0060	815	0.9796
13	11.5	12.5	12.0	1	0.0012	816	0.9808
	above	12.5		16	0.0192	832	1.0000

Mean = 3.23197   Standard deviation = 5.50311

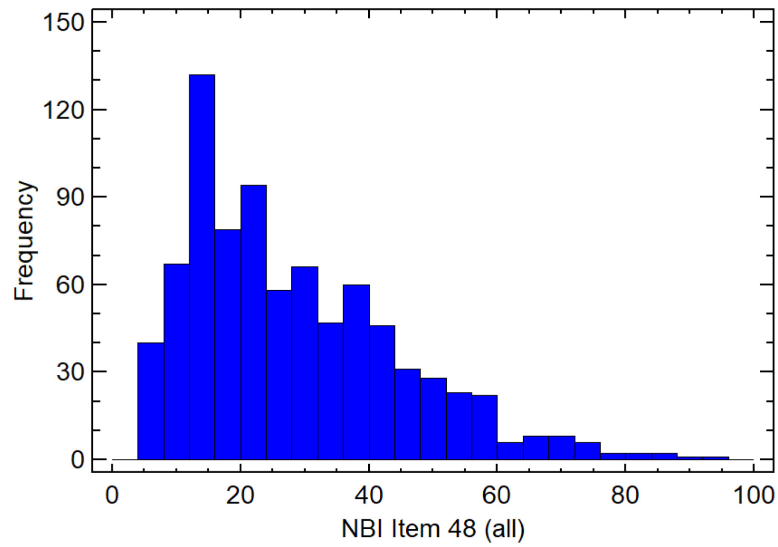


Figure A8. Histogram of NBI Item 48: Length of maximum span (all spans) (m).

Table A8. Frequencies of NBI Item 48: Length of maximum span (all spans) (m).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	0		1	0.0012	1	0.0012
1	0	4.0	2.0	0	0.0000	1	0.0012
2	4	8.0	6.0	40	0.0481	41	0.0493
3	8	12.0	10.0	67	0.0805	108	0.1298
4	12	16.0	14.0	132	0.1587	240	0.2885
5	16	20.0	18.0	79	0.0950	319	0.3834
6	20	24.0	22.0	94	0.1130	413	0.4964
7	24	28.0	26.0	58	0.0697	471	0.5661
8	28	32.0	30.0	66	0.0793	537	0.6454
9	32	36.0	34.0	47	0.0565	584	0.7019
10	36	40.0	38.0	60	0.0721	644	0.7740
11	40	44.0	42.0	46	0.0553	690	0.8293
12	44	48.0	46.0	31	0.0373	721	0.8666
13	48	52.0	50.0	28	0.0337	749	0.9002
14	52	56.0	54.0	23	0.0276	772	0.9279
15	56	60.0	58.0	22	0.0264	794	0.9543
16	60	64.0	62.0	6	0.0072	800	0.9615
17	64	68.0	66.0	8	0.0096	808	0.9712
18	68	72.0	70.0	8	0.0096	816	0.9808
19	72	76.0	74.0	6	0.0072	822	0.9880
20	76	80.0	78.0	2	0.0024	824	0.9904
21	80	84.0	82.0	2	0.0024	826	0.9928
22	84	88.0	86.0	2	0.0024	828	0.9952
23	88	92.0	90.0	1	0.0012	829	0.9964
24	92	96.0	94.0	1	0.0012	830	0.9976
25	96	100.0	98.0	0	0.0000	830	0.9976
	above	100		2	0.0024	832	1.0000

Mean = 29.4139   Standard deviation = 30.4938

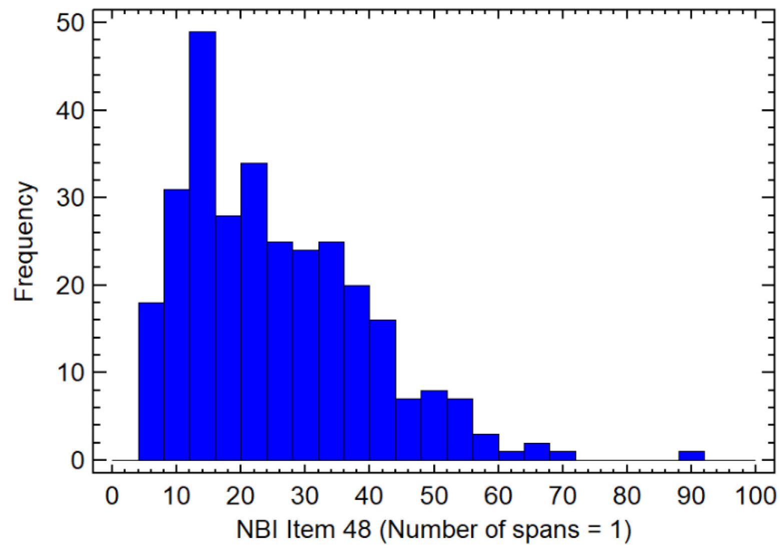


Figure A9. Histogram of NBI Item 48: Length of maximum span (# of spans = 1) (m).

Table A9. Frequencies of NBI Item 48: Length of maximum span (# of spans = 1) (m).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	0		0	0.0000	0	0.0000
1	0	4.0	2.0	0	0.0000	0	0.0000
2	4	8.0	6.0	18	0.0600	18	0.0600
3	8	12.0	10.0	31	0.1033	49	0.1633
4	12	16.0	14.0	49	0.1633	98	0.3267
5	16	20.0	18.0	28	0.0933	126	0.4200
6	20	24.0	22.0	34	0.1133	160	0.5333
7	24	28.0	26.0	25	0.0833	185	0.6167
8	28	32.0	30.0	24	0.0800	209	0.6967
9	32	36.0	34.0	25	0.0833	234	0.7800
10	36	40.0	38.0	20	0.0667	254	0.8467
11	40	44.0	42.0	16	0.0533	270	0.9000
12	44	48.0	46.0	7	0.0233	277	0.9233
13	48	52.0	50.0	8	0.0267	285	0.9500
14	52	56.0	54.0	7	0.0233	292	0.9733
15	56	60.0	58.0	3	0.0100	295	0.9833
16	60	64.0	62.0	1	0.0033	296	0.9867
17	64	68.0	66.0	2	0.0067	298	0.9933
18	68	72.0	70.0	1	0.0033	299	0.9967
19	72	76.0	74.0	0	0.0000	299	0.9967
20	76	80.0	78.0	0	0.0000	299	0.9967
21	80	84.0	82.0	0	0.0000	299	0.9967
22	84	88.0	86.0	0	0.0000	299	0.9967
23	88	92.0	90.0	1	0.0033	300	1.0000
24	92	96.0	94.0	0	0.0000	300	1.0000
25	96	100.0	98.0	0	0.0000	300	1.0000
	above	100		0	0.0000	300	1.0000

Mean = 25.569   Standard deviation = 14.1211

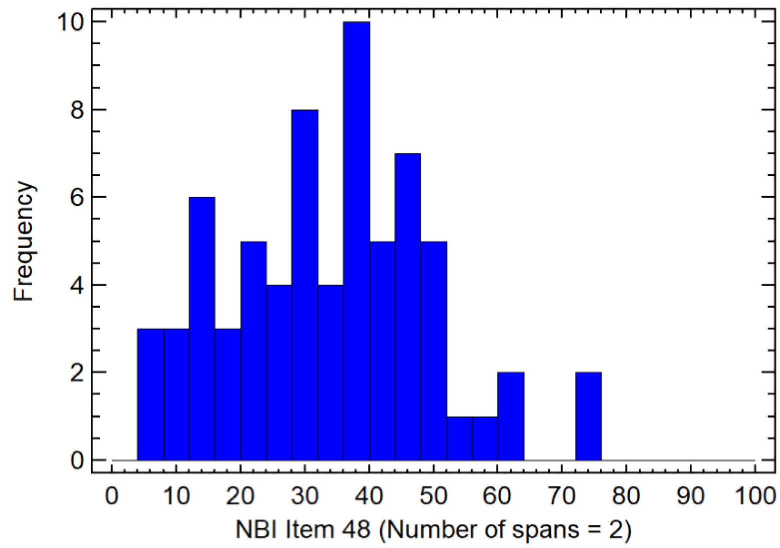


Figure A10. Histogram of NBI Item 48: Length of maximum span (# of spans = 2) (m).

Table A10. Frequencies of NBI Item 48: Length of maximum span (# of spans = 2) (m).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	0		0	0.0000	0	0.0000
1	0	4.0	2.0	0	0.0000	0	0.0000
2	4	8.0	6.0	3	0.0435	3	0.0435
3	8	12.0	10.0	3	0.0435	6	0.0870
4	12	16.0	14.0	6	0.0870	12	0.1739
5	16	20.0	18.0	3	0.0435	15	0.2174
6	20	24.0	22.0	5	0.0725	20	0.2899
7	24	28.0	26.0	4	0.0580	24	0.3478
8	28	32.0	30.0	8	0.1159	32	0.4638
9	32	36.0	34.0	4	0.0580	36	0.5217
10	36	40.0	38.0	10	0.1449	46	0.6667
11	40	44.0	42.0	5	0.0725	51	0.7391
12	44	48.0	46.0	7	0.1014	58	0.8406
13	48	52.0	50.0	5	0.0725	63	0.9130
14	52	56.0	54.0	1	0.0145	64	0.9275
15	56	60.0	58.0	1	0.0145	65	0.9420
16	60	64.0	62.0	2	0.0290	67	0.9710
17	64	68.0	66.0	0	0.0000	67	0.9710
18	68	72.0	70.0	0	0.0000	67	0.9710
19	72	76.0	74.0	2	0.0290	69	1.0000
20	76	80.0	78.0	0	0.0000	69	1.0000
21	80	84.0	82.0	0	0.0000	69	1.0000
22	84	88.0	86.0	0	0.0000	69	1.0000
23	88	92.0	90.0	0	0.0000	69	1.0000
24	92	96.0	94.0	0	0.0000	69	1.0000
25	96	100.0	98.0	0	0.0000	69	1.0000
	above	100		0	0.0000	69	1.0000

Mean = 33.8159   Standard deviation = 15.6458

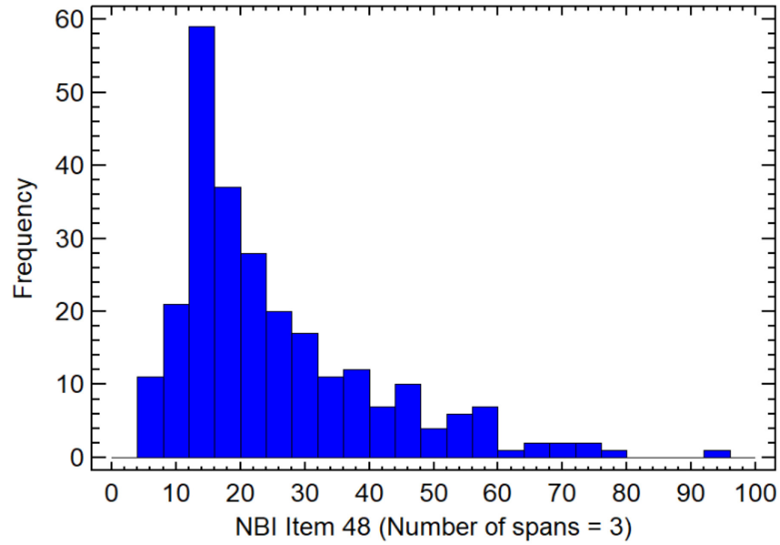


Figure A11. Histogram of NBI Item 48: Length of maximum span (# of spans = 3) (m).

Table A11. Frequencies of NBI Item 48: Length of maximum span (# of spans = 3) (m).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	0		1	0.0038	1	0.0038
1	0	4.0	2.0	0	0.0000	1	0.0038
2	4	8.0	6.0	11	0.0421	12	0.0460
3	8	12.0	10.0	21	0.0805	33	0.1264
4	12	16.0	14.0	59	0.2261	92	0.3525
5	16	20.0	18.0	37	0.1418	129	0.4943
6	20	24.0	22.0	28	0.1073	157	0.6015
7	24	28.0	26.0	20	0.0766	177	0.6782
8	28	32.0	30.0	17	0.0651	194	0.7433
9	32	36.0	34.0	11	0.0421	205	0.7854
10	36	40.0	38.0	12	0.0460	217	0.8314
11	40	44.0	42.0	7	0.0268	224	0.8582
12	44	48.0	46.0	10	0.0383	234	0.8966
13	48	52.0	50.0	4	0.0153	238	0.9119
14	52	56.0	54.0	6	0.0230	244	0.9349
15	56	60.0	58.0	7	0.0268	251	0.9617
16	60	64.0	62.0	1	0.0038	252	0.9655
17	64	68.0	66.0	2	0.0077	254	0.9732
18	68	72.0	70.0	2	0.0077	256	0.9808
19	72	76.0	74.0	2	0.0077	258	0.9885
20	76	80.0	78.0	1	0.0038	259	0.9923
21	80	84.0	82.0	0	0.0000	259	0.9923
22	84	88.0	86.0	0	0.0000	259	0.9923
23	88	92.0	90.0	0	0.0000	259	0.9923
24	92	96.0	94.0	1	0.0038	260	0.9962
25	96	100.0	98.0	0	0.0000	260	0.9962
	above	100		1	0.0038	261	1.0000

Mean = 25.772   Standard deviation = 16.9927

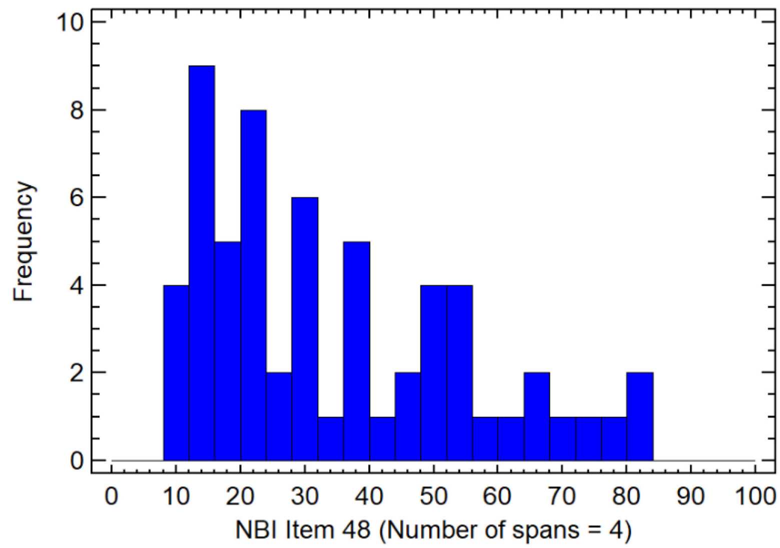


Figure A12. Histogram of NBI Item 48: Length of maximum span (# of spans = 4) (m).

Table A12. Frequencies of NBI Item 48: Length of maximum span (# of spans = 4) (m).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	0		0	0.0000	0	0.0000
1	0	4.0	2.0	0	0.0000	0	0.0000
2	4	8.0	6.0	0	0.0000	0	0.0000
3	8	12.0	10.0	4	0.0667	4	0.0667
4	12	16.0	14.0	9	0.1500	13	0.2167
5	16	20.0	18.0	5	0.0833	18	0.3000
6	20	24.0	22.0	8	0.1333	26	0.4333
7	24	28.0	26.0	2	0.0333	28	0.4667
8	28	32.0	30.0	6	0.1000	34	0.5667
9	32	36.0	34.0	1	0.0167	35	0.5833
10	36	40.0	38.0	5	0.0833	40	0.6667
11	40	44.0	42.0	1	0.0167	41	0.6833
12	44	48.0	46.0	2	0.0333	43	0.7167
13	48	52.0	50.0	4	0.0667	47	0.7833
14	52	56.0	54.0	4	0.0667	51	0.8500
15	56	60.0	58.0	1	0.0167	52	0.8667
16	60	64.0	62.0	1	0.0167	53	0.8833
17	64	68.0	66.0	2	0.0333	55	0.9167
18	68	72.0	70.0	1	0.0167	56	0.9333
19	72	76.0	74.0	1	0.0167	57	0.9500
20	76	80.0	78.0	1	0.0167	58	0.9667
21	80	84.0	82.0	2	0.0333	60	1.0000
22	84	88.0	86.0	0	0.0000	60	1.0000
23	88	92.0	90.0	0	0.0000	60	1.0000
24	92	96.0	94.0	0	0.0000	60	1.0000
25	96	100.0	98.0	0	0.0000	60	1.0000
	above	100		0	0.0000	60	1.0000

Mean = 34.7667   Standard deviation = 20.2663

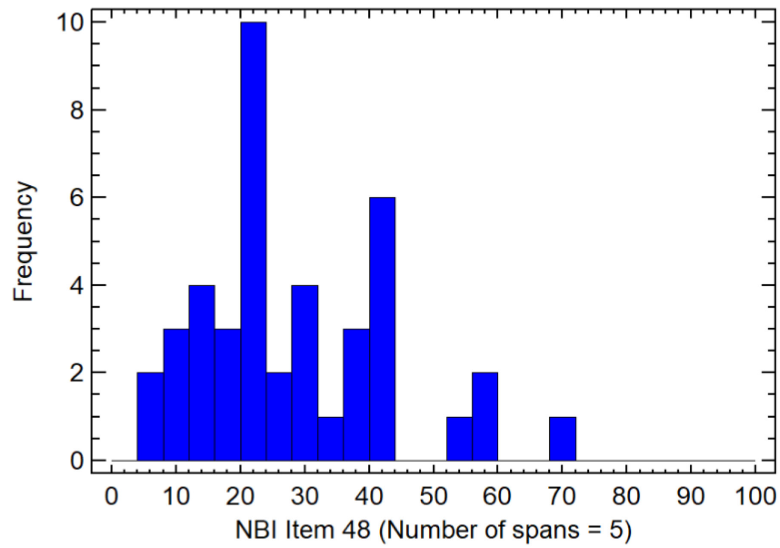


Figure A13. Histogram of NBI Item 48: Length of maximum span (# of spans = 5) (m).

Table A13. Frequencies of NBI Item 48: Length of maximum span (# of spans = 5) (m).

Class	***Lower Limit***	***Upper Limit***	***Midpoint***	***Frequency***	***Relative Frequency***	***Cumulative Frequency***	***Cum. Rel. Frequency***
	at or below	0		0	0.0000	0	0.0000
1	0	4.0	2.0	0	0.0000	0	0.0000
2	4	8.0	6.0	2	0.0476	2	0.0476
3	8	12.0	10.0	3	0.0714	5	0.1190
4	12	16.0	14.0	4	0.0952	9	0.2143
5	16	20.0	18.0	3	0.0714	12	0.2857
6	20	24.0	22.0	10	0.2381	22	0.5238
7	24	28.0	26.0	2	0.0476	24	0.5714
8	28	32.0	30.0	4	0.0952	28	0.6667
9	32	36.0	34.0	1	0.0238	29	0.6905
10	36	40.0	38.0	3	0.0714	32	0.7619
11	40	44.0	42.0	6	0.1429	38	0.9048
12	44	48.0	46.0	0	0.0000	38	0.9048
13	48	52.0	50.0	0	0.0000	38	0.9048
14	52	56.0	54.0	1	0.0238	39	0.9286
15	56	60.0	58.0	2	0.0476	41	0.9762
16	60	64.0	62.0	0	0.0000	41	0.9762
17	64	68.0	66.0	0	0.0000	41	0.9762
18	68	72.0	70.0	1	0.0238	42	1.0000
19	72	76.0	74.0	0	0.0000	42	1.0000
20	76	80.0	78.0	0	0.0000	42	1.0000
21	80	84.0	82.0	0	0.0000	42	1.0000
22	84	88.0	86.0	0	0.0000	42	1.0000
23	88	92.0	90.0	0	0.0000	42	1.0000
24	92	96.0	94.0	0	0.0000	42	1.0000
25	96	100.0	98.0	0	0.0000	42	1.0000
	above	100		0	0.0000	42	1.0000

Mean = 28.5738   Standard deviation = 15.1319

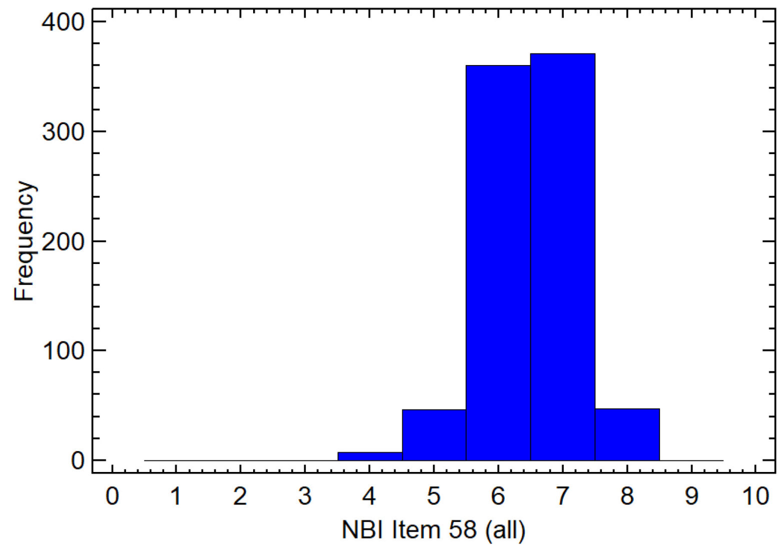


Figure A14. Histogram of NBI Item 58: Deck condition rating (-).

Table A14. Frequencies of NBI Item 58: Deck condition rating (-).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	-0.5		0	0.0000	0	0.0000
1	-0.5	0.5	0	0	0.0000	0	0.0000
2	0.5	1.5	1.0	0	0.0000	0	0.0000
3	1.5	2.5	2.0	0	0.0000	0	0.0000
4	2.5	3.5	3.0	0	0.0000	0	0.0000
5	3.5	4.5	4.0	7	0.0084	7	0.0084
6	4.5	5.5	5.0	46	0.0554	53	0.0638
7	5.5	6.5	6.0	360	0.4332	413	0.4970
8	6.5	7.5	7.0	371	0.4465	784	0.9434
9	7.5	8.5	8.0	47	0.0566	831	1.0000
10	8.5	9.5	9.0	0	0.0000	831	1.0000
	above	9.5		0	0.0000	831	1.0000

Mean = 6.48736   Standard deviation = 0.724459

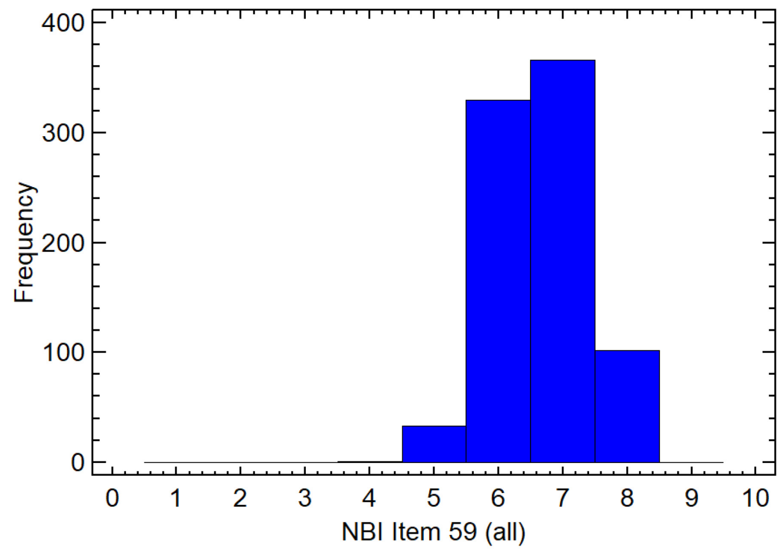


Figure A15. Histogram of NBI Item 59: Superstructure condition rating (-).

Table A15. Frequencies of NBI Item 59: Superstructure condition rating (-).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	-0.5		0	0.0000	0	0.0000
1	-0.5	0.5	0	0	0.0000	0	0.0000
2	0.5	1.5	1.0	0	0.0000	0	0.0000
3	1.5	2.5	2.0	0	0.0000	0	0.0000
4	2.5	3.5	3.0	0	0.0000	0	0.0000
5	3.5	4.5	4.0	1	0.0012	1	0.0012
6	4.5	5.5	5.0	33	0.0397	34	0.0409
7	5.5	6.5	6.0	330	0.3966	364	0.4375
8	6.5	7.5	7.0	366	0.4399	730	0.8774
9	7.5	8.5	8.0	102	0.1226	832	1.0000
10	8.5	9.5	9.0	0	0.0000	832	1.0000
	above	9.5		0	0.0000	832	1.0000

Mean = 6.64303   Standard deviation = 0.749633

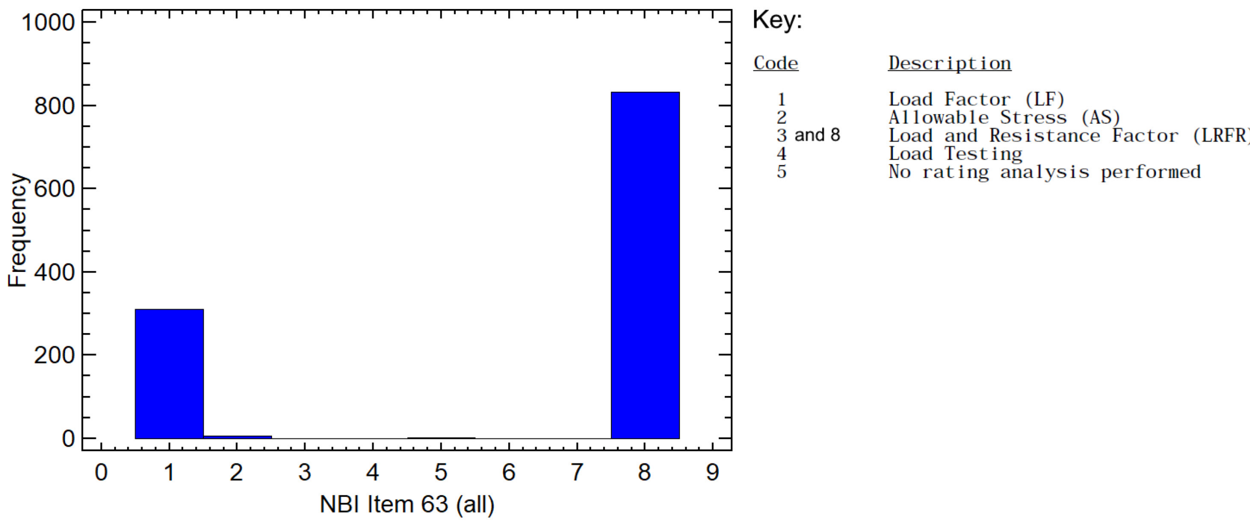


Figure A16. Histogram of NBI Item 63: Method used to determine operating rating (-).

Table A16. Frequencies of NBI Item 63: Method used to determine operating rating (-).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	-0.5		0	0.0000	0	0.0000
1	-0.5	0.5	0	3	0.0026	3	0.0026
2	0.5	1.5	1.0	310	0.2691	313	0.2717
3	1.5	2.5	2.0	5	0.0043	318	0.2760
4	2.5	3.5	3.0	0	0.0000	318	0.2760
5	3.5	4.5	4.0	0	0.0000	318	0.2760
6	4.5	5.5	5.0	2	0.0017	320	0.2778
7	5.5	6.5	6.0	0	0.0000	320	0.2778
8	6.5	7.5	7.0	0	0.0000	320	0.2778
9	7.5	8.5	8.0	832	0.7222	1152	1.0000
	above	8.5		0	0.0000	1152	1.0000

Mean = 6.06424   Standard deviation = 3.1282

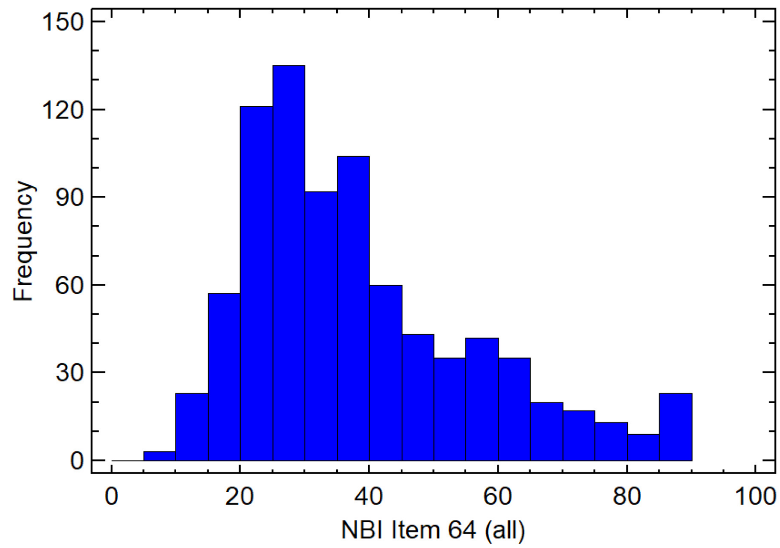


Figure A17. Histogram of NBI Item 64: Operating rating (-).

Table A17. Frequencies of NBI Item 64: Operating rating (-).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	0		0	0.0000	0	0.0000
1	0	5.0	2.5	0	0.0000	0	0.0000
2	5	10.0	7.5	3	0.0036	3	0.0036
3	10	15.0	12.5	23	0.0276	26	0.0313
4	15	20.0	17.5	57	0.0685	83	0.0998
5	20	25.0	22.5	121	0.1454	204	0.2452
6	25	30.0	27.5	135	0.1623	339	0.4075
7	30	35.0	32.5	92	0.1106	431	0.5180
8	35	40.0	37.5	104	0.1250	535	0.6430
9	40	45.0	42.5	60	0.0721	595	0.7151
10	45	50.0	47.5	43	0.0517	638	0.7668
11	50	55.0	52.5	35	0.0421	673	0.8089
12	55	60.0	57.5	42	0.0505	715	0.8594
13	60	65.0	62.5	35	0.0421	750	0.9014
14	65	70.0	67.5	20	0.0240	770	0.9255
15	70	75.0	72.5	17	0.0204	787	0.9459
16	75	80.0	77.5	13	0.0156	800	0.9615
17	80	85.0	82.5	9	0.0108	809	0.9724
18	85	90.0	87.5	23	0.0276	832	1.0000
	above	90		0	0.0000	832	1.0000

Mean = 38.6221 Standard deviation = 18.11

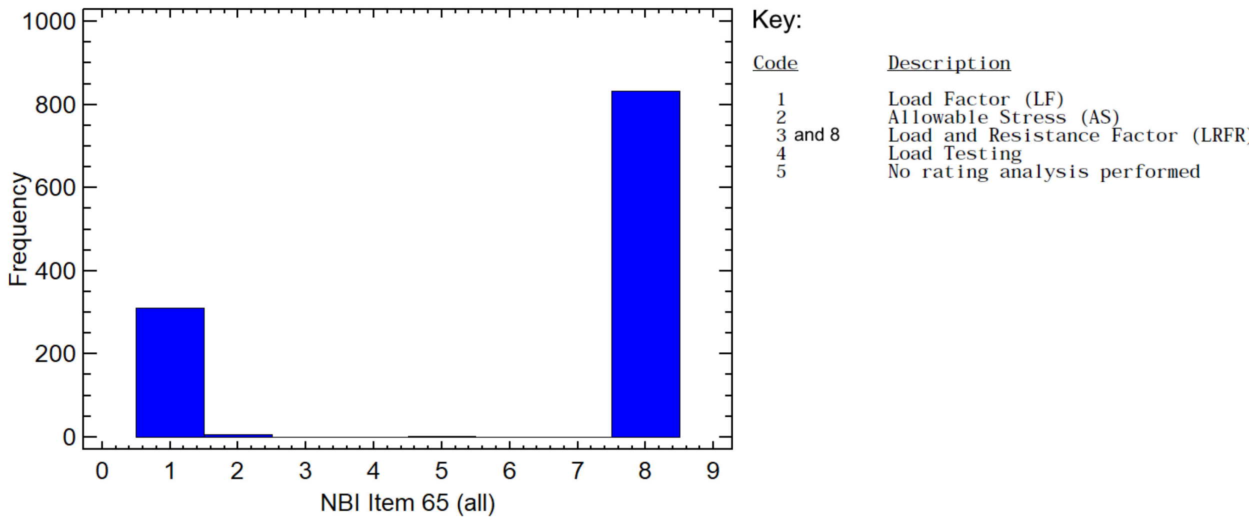


Figure A18. Histogram of NBI Item 65: Method used to determine inventory rating (-).

Table A18. Frequencies of NBI Item 65: Method used to determine inventory rating (-).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	-0.5		0	0.0000	0	0.0000
1	-0.5	0.5	0	3	0.0026	3	0.0026
2	0.5	1.5	1.0	310	0.2691	313	0.2717
3	1.5	2.5	2.0	5	0.0043	318	0.2760
4	2.5	3.5	3.0	0	0.0000	318	0.2760
5	3.5	4.5	4.0	0	0.0000	318	0.2760
6	4.5	5.5	5.0	2	0.0017	320	0.2778
7	5.5	6.5	6.0	0	0.0000	320	0.2778
8	6.5	7.5	7.0	0	0.0000	320	0.2778
9	7.5	8.5	8.0	832	0.7222	1152	1.0000
	above	8.5		0	0.0000	1152	1.0000

Mean = 6.06424 Standard deviation = 3.1282

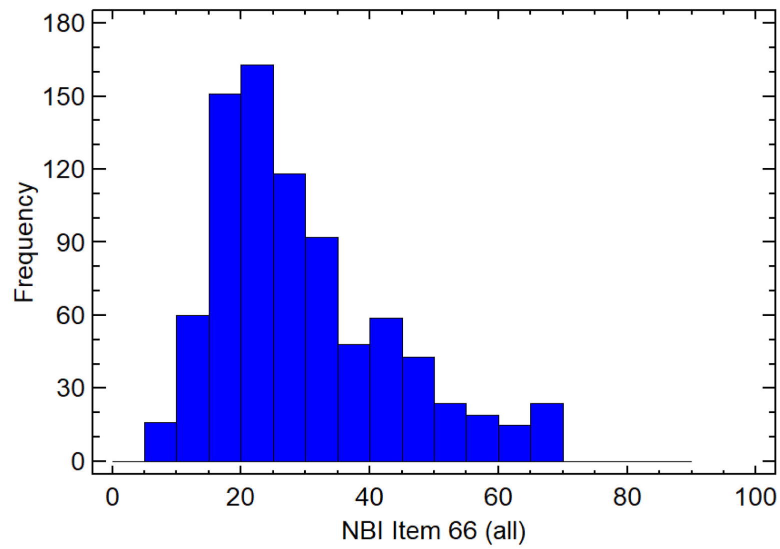


Figure A19. Histogram of NBI Item 66: Inventory rating (-).

Table A19. Frequencies of NBI Item 66: Inventory rating (-).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	0		0	0.0000	0	0.0000
1	0	5.0	2.5	0	0.0000	0	0.0000
2	5	10.0	7.5	16	0.0192	16	0.0192
3	10	15.0	12.5	60	0.0721	76	0.0913
4	15	20.0	17.5	151	0.1815	227	0.2728
5	20	25.0	22.5	163	0.1959	390	0.4688
6	25	30.0	27.5	118	0.1418	508	0.6106
7	30	35.0	32.5	92	0.1106	600	0.7212
8	35	40.0	37.5	48	0.0577	648	0.7788
9	40	45.0	42.5	59	0.0709	707	0.8498
10	45	50.0	47.5	43	0.0517	750	0.9014
11	50	55.0	52.5	24	0.0288	774	0.9303
12	55	60.0	57.5	19	0.0228	793	0.9531
13	60	65.0	62.5	15	0.0180	808	0.9712
14	65	70.0	67.5	24	0.0288	832	1.0000
15	70	75.0	72.5	0	0.0000	832	1.0000
16	75	80.0	77.5	0	0.0000	832	1.0000
17	80	85.0	82.5	0	0.0000	832	1.0000
18	85	90.0	87.5	0	0.0000	832	1.0000
	above	90		0	0.0000	832	1.0000

Mean = 29.7944   Standard deviation = 13.9606

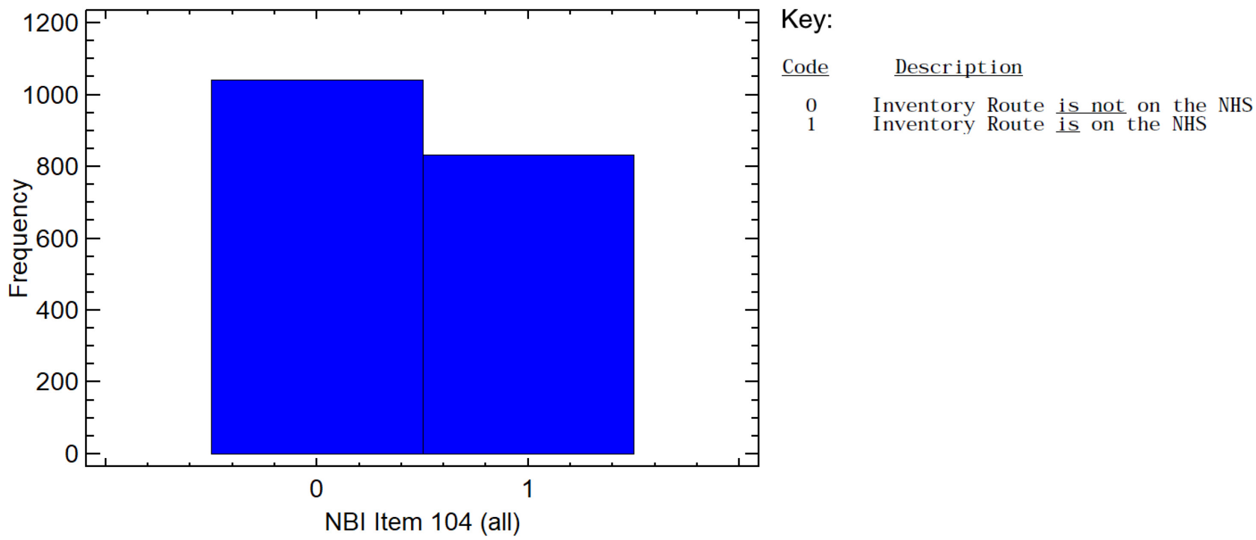


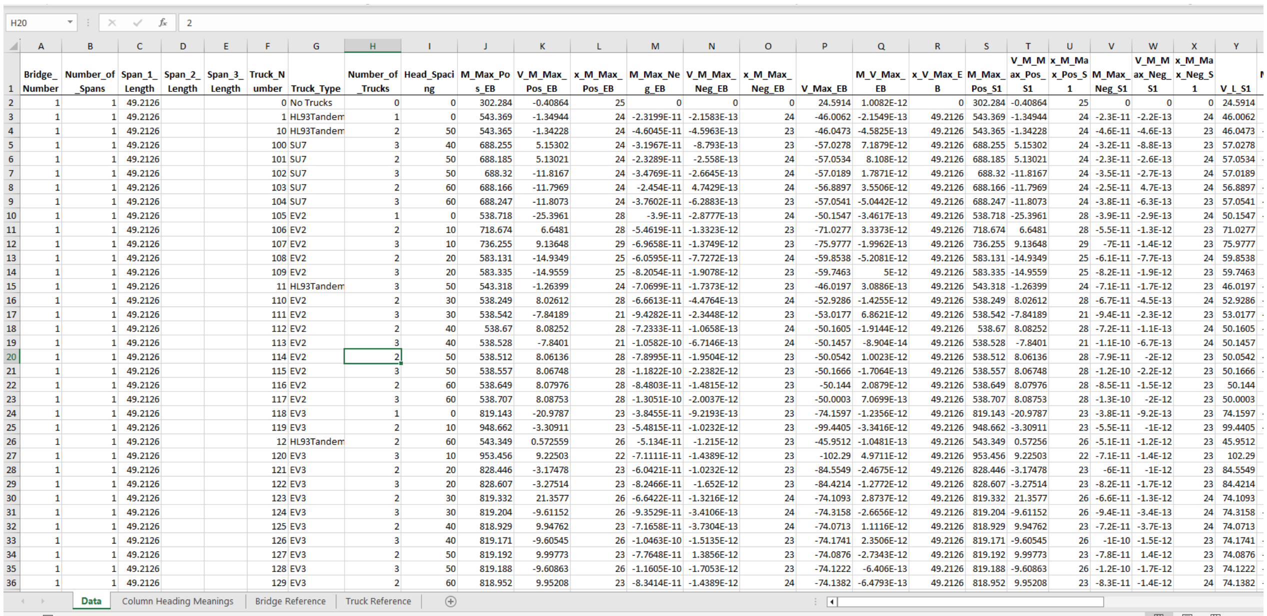
Figure A20. Histogram of NBI Item 104: Highway system of the inventory route (-).

Table A20. Frequencies of NBI Item 104: Highway system of the inventory route (-).

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
	at or below	-0.5		0	0.0000	0	0.0000
1	-0.5	0.5	0	1041	0.5558	1041	0.5558
2	0.5	1.5	1.0	832	0.4442	1873	1.0000
	above	1.5		0	0.0000	1873	1.0000

Mean = 0.444207 Standard deviation = 0.49701

APPENDIX B



Row	Bridge_Number	Number_of_Spans	Span_1_Length	Span_2_Length	Span_3_Length	Truck_Number	Truck_Type	Number_of_Trucks	Head_Spacing	M_Max_Pos_EB	V_M_Max_Pos_EB	x_M_Max_Pos_EB
2	1	1	49.2126			0	No Trucks	0	0	302.284	-0.40864	25
3	1	1	49.2126			1	HL93Tandem	1	0	543.369	-1.34944	24
4	1	1	49.2126			10	HL93Tandem	2	50	543.365	-1.34228	24
5	1	1	49.2126			100	SU7	3	40	688.255	5.15302	24
6	1	1	49.2126			101	SU7	2	50	688.185	5.13021	24
7	1	1	49.2126			102	SU7	3	50	688.32	-11.8167	24
8	1	1	49.2126			103	SU7	2	60	688.166	-11.7969	24
9	1	1	49.2126			104	SU7	3	60	688.247	-11.8073	24
10	1	1	49.2126			105	EV2	1	0	538.718	-25.3961	28
11	1	1	49.2126			106	EV2	2	10	718.674	6.6481	28
12	1	1	49.2126			107	EV2	3	10	736.255	9.13648	29
13	1	1	49.2126			108	EV2	2	20	583.131	-14.9349	25
14	1	1	49.2126			109	EV2	3	20	583.335	-14.9559	25
15	1	1	49.2126			11	HL93Tandem	3	50	543.318	-1.26399	24
16	1	1	49.2126			110	EV2	2	30	538.249	8.02612	28
17	1	1	49.2126			111	EV2	3	30	538.542	-7.84189	21
18	1	1	49.2126			112	EV2	2	40	538.67	8.08252	28
19	1	1	49.2126			113	EV2	3	40	538.528	-7.8401	21
20	1	1	49.2126			114	EV2	2	50	538.512	8.06136	28
21	1	1	49.2126			115	EV2	3	50	538.557	8.06748	28
22	1	1	49.2126			116	EV2	2	60	538.649	8.07976	28
23	1	1	49.2126			117	EV2	3	60	538.707	8.08753	28
24	1	1	49.2126			118	EV3	1	0	819.143	-20.9787	23
25	1	1	49.2126			119	EV3	2	10	948.662	-3.30911	23
26	1	1	49.2126			12	HL93Tandem	2	60	543.349	0.572559	26
27	1	1	49.2126			120	EV3	3	10	953.456	9.22503	22
28	1	1	49.2126			121	EV3	2	20	828.446	-3.17478	23
29	1	1	49.2126			122	EV3	3	20	828.607	-3.27514	23
30	1	1	49.2126			123	EV3	2	30	819.332	21.3577	26
31	1	1	49.2126			124	EV3	3	30	819.204	-9.61152	26
32	1	1	49.2126			125	EV3	2	40	818.929	9.94762	23
33	1	1	49.2126			126	EV3	3	40	819.171	-9.60545	26
34	1	1	49.2126			127	EV3	2	50	819.192	9.99773	23
35	1	1	49.2126			128	EV3	3	50	819.188	-9.60863	26
36	1	1	49.2126			129	EV3	2	60	818.952	9.95208	23

Row	M_Max_Neg_EB	V_M_Max_Neg_EB	x_M_Max_Neg_EB	V_Max_EB	M_V_Max_EB	x_V_Max_EB	M_Max_Pos_S1	V_M_Max_Pos_S1	x_M_Max_Pos_S1	M_Max_Neg_S1	V_M_Max_Neg_S1	x_M_Max_Neg_S1	V_L_S1
2	0	0	0	24.5914	1.0082E-12	0	302.284	-0.40864	25	0	0	0	24.5914
3	-2.3199E-11	-2.1583E-13	24	-46.0062	-2.1549E-13	49.2126	543.369	-1.34944	24	-2.3E-11	-2.2E-13	24	46.0062
4	-4.6045E-11	-4.5963E-13	23	-46.0473	-4.5825E-13	49.2126	543.365	-1.34228	24	-4.6E-11	-4.6E-13	23	46.0473
5	-3.1967E-11	-8.793E-13	23	-57.0278	7.1879E-12	49.2126	688.255	5.15302	24	-3.2E-11	-8.8E-13	23	57.0278
6	-2.3289E-11	-2.558E-13	24	-57.0534	8.108E-12	49.2126	688.185	5.13021	24	-2.3E-11	-2.6E-13	24	57.0534
7	-3.4769E-11	-2.6645E-13	24	-57.0189	1.7871E-12	49.2126	688.32	-11.8167	24	-3.5E-11	-2.7E-13	24	57.0189
8	-2.454E-11	4.7429E-13	24	-56.8897	3.5506E-12	49.2126	688.166	-11.7969	24	-2.5E-11	4.7E-13	24	56.8897
9	-3.7602E-11	-6.2883E-13	23	-57.0541	-5.0442E-12	49.2126	688.247	-11.8073	24	-3.8E-11	-6.3E-13	23	57.0541
10	-3.9E-11	-2.8777E-13	24	-50.1547	-3.4617E-13	49.2126	538.718	-25.3961	28	-3.9E-11	-2.9E-13	24	50.1547
11	-5.4619E-11	-1.3323E-12	23	-71.0277	3.3373E-12	49.2126	718.674	6.6481	28	-5.5E-11	-1.3E-12	23	71.0277
12	-6.9658E-11	-1.3749E-12	23	-75.9777	-1.9962E-13	49.2126	736.255	9.13648	29	-7E-11	-1.4E-12	23	75.9777
13	-6.0595E-11	-7.7272E-13	24	-59.8538	-5.2081E-12	49.2126	583.131	-14.9349	25	-6.1E-11	-7.7E-13	24	59.8538
14	-8.2054E-11	-1.9078E-12	23	-59.7463	5E-12	49.2126	583.335	-14.9559	25	-8.2E-11	-1.9E-12	23	59.7463
15	-7.0699E-11	-1.7373E-12	23	-46.0197	3.0886E-13	49.2126	543.318	-1.26399	24	-7.1E-11	-1.7E-12	23	46.0197
16	-6.6613E-11	-4.4764E-13	24	-52.9286	-1.4255E-12	49.2126	538.249	8.02612	28	-6.7E-11	-4.5E-13	24	52.9286
17	-9.4282E-11	-2.3448E-12	23	-53.0177	6.8621E-12	49.2126	538.542	-7.84189	21	-9.4E-11	-2.3E-12	23	53.0177
18	-7.2333E-11	-1.0658E-13	24	-50.1605	-1.9144E-12	49.2126	538.67	8.08252	28	-7.2E-11	-1.1E-13	24	50.1605
19	-1.0582E-10	-6.7146E-13	24	-50.1457	-8.904E-14	49.2126	538.528	-7.8401	21	-1.1E-10	-6.7E-13	24	50.1457
20	-7.8995E-11	-1.9504E-12	23	-50.0542	1.0023E-12	49.2126	538.512	8.06136	28	-7.9E-11	-2E-12	23	50.0542
21	-1.1822E-10	-2.2382E-12	23	-50.1666	-1.7064E-13	49.2126	538.557	8.06748	28	-1.2E-10	-2.2E-12	23	50.1666
22	-8.4803E-11	-1.4815E-12	23	-50.144	2.0879E-12	49.2126	538.649	8.07976	28	-8.5E-11	-1.5E-12	23	50.144
23	-1.3051E-10	-2.0037E-12	23	-50.0003	7.0699E-13	49.2126	538.707	8.08753	28	-1.3E-10	-2E-12	23	50.0003
24	-3.8455E-11	-9.2193E-13	23	-74.1597	-1.2356E-12	49.2126	819.143	-20.9787	23	-3.8E-11	-9.2E-13	23	74.1597
25	-5.4815E-11	-1.0232E-12	23	-99.4405	-3.3416E-12	49.2126	948.662	-3.30911	23	-5.5E-11	-1E-12	23	99.4405
26	-5.134E-11	-1.215E-12	23	-45.9512	-1.0481E-13	49.2126	543.349	0.57256	26	-5.1E-11	-1.2E-12	23	45.9512
27	-7.1111E-11	-1.4389E-12	23	-102.29	4.9711E-12	49.2126	953.456	9.22503	22	-7.1E-11	-1.4E-12	23	102.29
28	-6.0421E-11	-1.0232E-12	23	-84.5549	-2.4675E-12	49.2126	828.446	-3.17478	23	-6E-11	-1E-12	23	84.5549
29	-8.2466E-11	-1.652E-12	23	-84.4214	-1.2772E-12	49.2126	828.607	-3.27514	23	-8.2E-11	-1.7E-12	23	84.4214
30	-6.6422E-11	-1.3216E-12	24	-74.1093	2.8737E-12	49.2126	819.332	21.3577	26	-6.6E-11	-1.3E-12	24	74.1093
31	-9.3529E-11	-3.4106E-13	24	-74.3158	-2.6656E-12	49.2126	819.204	-9.61152	26	-9.4E-11	-3.4E-13	24	74.3158
32	-7.1658E-11	-3.7304E-13	24	-74.0713	1.1116E-12	49.2126	818.929	9.94762	23	-7.2E-11	-3.7E-13	24	74.0713
33	-1.0463E-10	-1.5135E-12	23	-74.1741	2.3506E-12	49.2126	819.171	-9.60545	26	-1E-10	-1.5E-12	23	74.1741
34	-7.7648E-11	1.3856E-12	23	-74.0876	-2.7343E-12	49.2126	819.192	9.99773	23	-7.8E-11	1.4E-12	23	74.0876
35	-1.1605E-10	-1.7053E-12	23	-74.1222	-6.406E-13	49.2126	819.188	-9.60863	26	-1.2E-10	-1.7E-12	23	74.1222
36	-8.3414E-11	-1.4389E-12	24	-74.1382	-6.4793E-13	49.2126	818.952	9.95208	23	-8.3E-11	-1.4E-12	24	74.1382

Figure B1. Spreadsheet with maximum internal forces for the entire bridge and all span lengths

Table B2. Bridge Number Reference Table – The length of each of the three spands in feet.

Bridge No.	Span Length 1	Span Length 2	Span Length 3
1	49.21259843	0	0
2	65.6167979	0	0
3	82.02099738	0	0
4	98.42519685	0	0
5	114.8293963	0	0
6	131.2335958	0	0
7	147.6377953	0	0
8	164.0419948	0	0
9	180.4461942	0	0
10	196.8503937	0	0
11	213.2545932	0	0
12	82.02099738	82.02099738	0
13	82.02099738	77.91994751	0
14	82.02099738	73.81889764	0
15	82.02099738	69.71784777	0
16	82.02099738	65.6167979	0
17	82.02099738	61.51574803	0
18	98.42519685	98.42519685	0
19	98.42519685	93.50393701	0
20	98.42519685	88.58267717	0
21	98.42519685	83.66141732	0
22	98.42519685	78.74015748	0
23	98.42519685	73.81889764	0
24	114.8293963	114.8293963	0
25	114.8293963	109.0879265	0
26	114.8293963	103.3464567	0
27	114.8293963	97.60498688	0
28	114.8293963	91.86351706	0
29	114.8293963	86.12204724	0
30	131.2335958	131.2335958	0
31	131.2335958	124.671916	0
32	131.2335958	118.1102362	0
33	131.2335958	111.5485564	0
34	131.2335958	104.9868766	0
35	131.2335958	98.42519685	0
36	147.6377953	147.6377953	0
37	147.6377953	140.2559055	0
38	147.6377953	132.8740157	0
39	147.6377953	125.492126	0
40	147.6377953	118.1102362	0
41	147.6377953	110.7283465	0
42	164.0419948	164.0419948	0
43	164.0419948	155.839895	0
44	164.0419948	147.6377953	0
45	164.0419948	139.4356955	0
46	164.0419948	131.2335958	0
47	164.0419948	123.0314961	0
48	180.4461942	180.4461942	0
49	180.4461942	171.4238845	0
50	180.4461942	162.4015748	0
51	180.4461942	153.3792651	0
52	180.4461942	144.3569554	0
53	180.4461942	135.3346457	0
54	196.8503937	196.8503937	0

Bridge No.	Span Length 1	Span Length 2	Span Length 3
55	196.8503937	187.007874	0
56	196.8503937	177.1653543	0
57	196.8503937	167.3228346	0
58	196.8503937	157.480315	0
59	196.8503937	147.6377953	0
60	213.2545932	213.2545932	0
61	213.2545932	202.5918635	0
62	213.2545932	191.9291339	0
63	213.2545932	181.2664042	0
64	213.2545932	170.6036745	0
65	213.2545932	159.9409449	0
66	229.6587927	229.6587927	0
67	229.6587927	218.175853	0
68	229.6587927	206.6929134	0
69	229.6587927	195.2099738	0
70	229.6587927	183.7270341	0
71	229.6587927	172.2440945	0
72	246.0629921	246.0629921	0
73	246.0629921	233.7598425	0
74	246.0629921	221.4566929	0
75	246.0629921	209.1535433	0
76	246.0629921	196.8503937	0
77	246.0629921	184.5472441	0
78	49.21259843	49.21259843	49.21259843
79	49.21259843	49.21259843	46.7519685
80	49.21259843	49.21259843	44.29133858
81	49.21259843	49.21259843	41.83070866
82	49.21259843	49.21259843	39.37007874

Bridge No.	Span Length 1	Span Length 2	Span Length 3
83	49.21259843	49.21259843	36.90944882
84	49.21259843	49.21259843	34.4488189
85	49.21259843	49.21259843	31.98818898
86	46.7519685	49.21259843	49.21259843
87	46.7519685	49.21259843	46.7519685
88	46.7519685	49.21259843	44.29133858
89	46.7519685	49.21259843	41.83070866
90	46.7519685	49.21259843	39.37007874
91	46.7519685	49.21259843	36.90944882
92	46.7519685	49.21259843	34.4488189
93	46.7519685	49.21259843	31.98818898
94	44.29133858	49.21259843	49.21259843
95	44.29133858	49.21259843	46.7519685
96	44.29133858	49.21259843	44.29133858
97	44.29133858	49.21259843	41.83070866
98	44.29133858	49.21259843	39.37007874
99	44.29133858	49.21259843	36.90944882
100	44.29133858	49.21259843	34.4488189
101	44.29133858	49.21259843	31.98818898
102	41.83070866	49.21259843	49.21259843
103	41.83070866	49.21259843	46.7519685
104	41.83070866	49.21259843	44.29133858
105	41.83070866	49.21259843	41.83070866
106	41.83070866	49.21259843	39.37007874
107	41.83070866	49.21259843	36.90944882
108	41.83070866	49.21259843	34.4488189
109	41.83070866	49.21259843	31.98818898
110	39.37007874	49.21259843	49.21259843

Bridge No.	Span Length 1	Span Length 2	Span Length 3
111	39.37007874	49.21259843	46.7519685
112	39.37007874	49.21259843	44.29133858
113	39.37007874	49.21259843	41.83070866
114	39.37007874	49.21259843	39.37007874
115	39.37007874	49.21259843	36.90944882
116	39.37007874	49.21259843	34.4488189
117	39.37007874	49.21259843	31.98818898
118	36.90944882	49.21259843	49.21259843
119	36.90944882	49.21259843	46.7519685
120	36.90944882	49.21259843	44.29133858
121	36.90944882	49.21259843	41.83070866
122	36.90944882	49.21259843	39.37007874
123	36.90944882	49.21259843	36.90944882
124	36.90944882	49.21259843	34.4488189
125	36.90944882	49.21259843	31.98818898
126	65.6167979	65.6167979	65.6167979
127	65.6167979	65.6167979	62.33595801
128	65.6167979	65.6167979	59.05511811
129	65.6167979	65.6167979	55.77427822
130	65.6167979	65.6167979	52.49343832
131	65.6167979	65.6167979	49.21259843
132	65.6167979	65.6167979	45.93175853
133	65.6167979	65.6167979	42.65091864
134	62.33595801	65.6167979	65.6167979
135	62.33595801	65.6167979	62.33595801
136	62.33595801	65.6167979	59.05511811
137	62.33595801	65.6167979	55.77427822
138	62.33595801	65.6167979	52.49343832

Bridge No.	Span Length 1	Span Length 2	Span Length 3
139	62.33595801	65.6167979	49.21259843
140	62.33595801	65.6167979	45.93175853
141	62.33595801	65.6167979	42.65091864
142	59.05511811	65.6167979	65.6167979
143	59.05511811	65.6167979	62.33595801
144	59.05511811	65.6167979	59.05511811
145	59.05511811	65.6167979	55.77427822
146	59.05511811	65.6167979	52.49343832
147	59.05511811	65.6167979	49.21259843
148	59.05511811	65.6167979	45.93175853
149	59.05511811	65.6167979	42.65091864
150	55.77427822	65.6167979	65.6167979
151	55.77427822	65.6167979	62.33595801
152	55.77427822	65.6167979	59.05511811
153	55.77427822	65.6167979	55.77427822
154	55.77427822	65.6167979	52.49343832
155	55.77427822	65.6167979	49.21259843
156	55.77427822	65.6167979	45.93175853
157	55.77427822	65.6167979	42.65091864
158	52.49343832	65.6167979	65.6167979
159	52.49343832	65.6167979	62.33595801
160	52.49343832	65.6167979	59.05511811
161	52.49343832	65.6167979	55.77427822
162	52.49343832	65.6167979	52.49343832
163	52.49343832	65.6167979	49.21259843
164	52.49343832	65.6167979	45.93175853
165	52.49343832	65.6167979	42.65091864
166	49.21259843	65.6167979	65.6167979

Bridge No.	Span Length 1	Span Length 2	Span Length 3
167	49.21259843	65.6167979	62.33595801
168	49.21259843	65.6167979	59.05511811
169	49.21259843	65.6167979	55.77427822
170	49.21259843	65.6167979	52.49343832
171	49.21259843	65.6167979	49.21259843
172	49.21259843	65.6167979	45.93175853
173	49.21259843	65.6167979	42.65091864
174	82.02099738	82.02099738	82.02099738
175	82.02099738	82.02099738	77.91994751
176	82.02099738	82.02099738	73.81889764
177	82.02099738	82.02099738	69.71784777
178	82.02099738	82.02099738	65.6167979
179	82.02099738	82.02099738	61.51574803
180	82.02099738	82.02099738	57.41469816
181	82.02099738	82.02099738	53.31364829
182	77.91994751	82.02099738	82.02099738
183	77.91994751	82.02099738	77.91994751
184	77.91994751	82.02099738	73.81889764
185	77.91994751	82.02099738	69.71784777
186	77.91994751	82.02099738	65.6167979
187	77.91994751	82.02099738	61.51574803
188	77.91994751	82.02099738	57.41469816
189	77.91994751	82.02099738	53.31364829
190	73.81889764	82.02099738	82.02099738
191	73.81889764	82.02099738	77.91994751
192	73.81889764	82.02099738	73.81889764
193	73.81889764	82.02099738	69.71784777
194	73.81889764	82.02099738	65.6167979

Bridge No.	Span Length 1	Span Length 2	Span Length 3
195	73.81889764	82.02099738	61.51574803
196	73.81889764	82.02099738	57.41469816
197	73.81889764	82.02099738	53.31364829
198	69.71784777	82.02099738	82.02099738
199	69.71784777	82.02099738	77.91994751
200	69.71784777	82.02099738	73.81889764
201	69.71784777	82.02099738	69.71784777
202	69.71784777	82.02099738	65.6167979
203	69.71784777	82.02099738	61.51574803
204	69.71784777	82.02099738	57.41469816
205	69.71784777	82.02099738	53.31364829
206	65.6167979	82.02099738	82.02099738
207	65.6167979	82.02099738	77.91994751
208	65.6167979	82.02099738	73.81889764
209	65.6167979	82.02099738	69.71784777
210	65.6167979	82.02099738	65.6167979
211	65.6167979	82.02099738	61.51574803
212	65.6167979	82.02099738	57.41469816
213	65.6167979	82.02099738	53.31364829
214	61.51574803	82.02099738	82.02099738
215	61.51574803	82.02099738	77.91994751
216	61.51574803	82.02099738	73.81889764
217	61.51574803	82.02099738	69.71784777
218	61.51574803	82.02099738	65.6167979
219	61.51574803	82.02099738	61.51574803
220	61.51574803	82.02099738	57.41469816
221	61.51574803	82.02099738	53.31364829
222	98.42519685	98.42519685	98.42519685

Bridge No.	Span Length 1	Span Length 2	Span Length 3
223	98.42519685	98.42519685	93.50393701
224	98.42519685	98.42519685	88.58267717
225	98.42519685	98.42519685	83.66141732
226	98.42519685	98.42519685	78.74015748
227	98.42519685	98.42519685	73.81889764
228	98.42519685	98.42519685	68.8976378
229	98.42519685	98.42519685	63.97637795
230	93.50393701	98.42519685	98.42519685
231	93.50393701	98.42519685	93.50393701
232	93.50393701	98.42519685	88.58267717
233	93.50393701	98.42519685	83.66141732
234	93.50393701	98.42519685	78.74015748
235	93.50393701	98.42519685	73.81889764
236	93.50393701	98.42519685	68.8976378
237	93.50393701	98.42519685	63.97637795
238	88.58267717	98.42519685	98.42519685
239	88.58267717	98.42519685	93.50393701
240	88.58267717	98.42519685	88.58267717
241	88.58267717	98.42519685	83.66141732
242	88.58267717	98.42519685	78.74015748
243	88.58267717	98.42519685	73.81889764
244	88.58267717	98.42519685	68.8976378
245	88.58267717	98.42519685	63.97637795
246	83.66141732	98.42519685	98.42519685
247	83.66141732	98.42519685	93.50393701
248	83.66141732	98.42519685	88.58267717
249	83.66141732	98.42519685	83.66141732
250	83.66141732	98.42519685	78.74015748

Bridge No.	Span Length 1	Span Length 2	Span Length 3
251	83.66141732	98.42519685	73.81889764
252	83.66141732	98.42519685	68.8976378
253	83.66141732	98.42519685	63.97637795
254	78.74015748	98.42519685	98.42519685
255	78.74015748	98.42519685	93.50393701
256	78.74015748	98.42519685	88.58267717
257	78.74015748	98.42519685	83.66141732
258	78.74015748	98.42519685	78.74015748
259	78.74015748	98.42519685	73.81889764
260	78.74015748	98.42519685	68.8976378
261	78.74015748	98.42519685	63.97637795
262	73.81889764	98.42519685	98.42519685
263	73.81889764	98.42519685	93.50393701
264	73.81889764	98.42519685	88.58267717
265	73.81889764	98.42519685	83.66141732
266	73.81889764	98.42519685	78.74015748
267	73.81889764	98.42519685	73.81889764
268	73.81889764	98.42519685	68.8976378
269	73.81889764	98.42519685	63.97637795
270	114.8293963	114.8293963	114.8293963
271	114.8293963	114.8293963	109.0879265
272	114.8293963	114.8293963	103.3464567
273	114.8293963	114.8293963	97.60498688
274	114.8293963	114.8293963	91.86351706
275	114.8293963	114.8293963	86.12204724
276	114.8293963	114.8293963	80.38057743
277	114.8293963	114.8293963	74.63910761
278	109.0879265	114.8293963	114.8293963

Bridge No.	Span Length 1	Span Length 2	Span Length 3
279	109.0879265	114.8293963	109.0879265
280	109.0879265	114.8293963	103.3464567
281	109.0879265	114.8293963	97.60498688
282	109.0879265	114.8293963	91.86351706
283	109.0879265	114.8293963	86.12204724
284	109.0879265	114.8293963	80.38057743
285	109.0879265	114.8293963	74.63910761
286	103.3464567	114.8293963	114.8293963
287	103.3464567	114.8293963	109.0879265
288	103.3464567	114.8293963	103.3464567
289	103.3464567	114.8293963	97.60498688
290	103.3464567	114.8293963	91.86351706
291	103.3464567	114.8293963	86.12204724
292	103.3464567	114.8293963	80.38057743
293	103.3464567	114.8293963	74.63910761
294	97.60498688	114.8293963	114.8293963
295	97.60498688	114.8293963	109.0879265
296	97.60498688	114.8293963	103.3464567
297	97.60498688	114.8293963	97.60498688
298	97.60498688	114.8293963	91.86351706
299	97.60498688	114.8293963	86.12204724
300	97.60498688	114.8293963	80.38057743
301	97.60498688	114.8293963	74.63910761
302	91.86351706	114.8293963	114.8293963
303	91.86351706	114.8293963	109.0879265
304	91.86351706	114.8293963	103.3464567
305	91.86351706	114.8293963	97.60498688
306	91.86351706	114.8293963	91.86351706
307	91.86351706	114.8293963	86.12204724
308	91.86351706	114.8293963	80.38057743
309	91.86351706	114.8293963	74.63910761
310	86.12204724	114.8293963	114.8293963
311	86.12204724	114.8293963	109.0879265
312	86.12204724	114.8293963	103.3464567
313	86.12204724	114.8293963	97.60498688
314	86.12204724	114.8293963	91.86351706
315	86.12204724	114.8293963	86.12204724
316	86.12204724	114.8293963	80.38057743
317	86.12204724	114.8293963	74.63910761
318	131.2335958	131.2335958	131.2335958
319	131.2335958	131.2335958	124.671916
320	131.2335958	131.2335958	118.1102362
321	131.2335958	131.2335958	111.5485564
322	131.2335958	131.2335958	104.9868766
323	131.2335958	131.2335958	98.42519685
324	131.2335958	131.2335958	91.86351706
325	131.2335958	131.2335958	85.30183727
326	124.671916	131.2335958	131.2335958
327	124.671916	131.2335958	124.671916
328	124.671916	131.2335958	118.1102362
329	124.671916	131.2335958	111.5485564
330	124.671916	131.2335958	104.9868766
331	124.671916	131.2335958	98.42519685
332	124.671916	131.2335958	91.86351706
333	124.671916	131.2335958	85.30183727
334	118.1102362	131.2335958	131.2335958

Bridge No.	Span Length 1	Span Length 2	Span Length 3
335	118.1102362	131.2335958	124.671916
336	118.1102362	131.2335958	118.1102362
337	118.1102362	131.2335958	111.5485564
338	118.1102362	131.2335958	104.9868766
339	118.1102362	131.2335958	98.42519685
340	118.1102362	131.2335958	91.86351706
341	118.1102362	131.2335958	85.30183727
342	111.5485564	131.2335958	131.2335958
343	111.5485564	131.2335958	124.671916
344	111.5485564	131.2335958	118.1102362
345	111.5485564	131.2335958	111.5485564
346	111.5485564	131.2335958	104.9868766
347	111.5485564	131.2335958	98.42519685
348	111.5485564	131.2335958	91.86351706
349	111.5485564	131.2335958	85.30183727
350	104.9868766	131.2335958	131.2335958
351	104.9868766	131.2335958	124.671916
352	104.9868766	131.2335958	118.1102362
353	104.9868766	131.2335958	111.5485564
354	104.9868766	131.2335958	104.9868766
355	104.9868766	131.2335958	98.42519685
356	104.9868766	131.2335958	91.86351706
357	104.9868766	131.2335958	85.30183727
358	98.42519685	131.2335958	131.2335958
359	98.42519685	131.2335958	124.671916
360	98.42519685	131.2335958	118.1102362
361	98.42519685	131.2335958	111.5485564
362	98.42519685	131.2335958	104.9868766

Bridge No.	Span Length 1	Span Length 2	Span Length 3
363	98.42519685	131.2335958	98.42519685
364	98.42519685	131.2335958	91.86351706
365	98.42519685	131.2335958	85.30183727
366	147.6377953	147.6377953	147.6377953
367	147.6377953	147.6377953	140.2559055
368	147.6377953	147.6377953	132.8740157
369	147.6377953	147.6377953	125.492126
370	147.6377953	147.6377953	118.1102362
371	147.6377953	147.6377953	110.7283465
372	147.6377953	147.6377953	103.3464567
373	147.6377953	147.6377953	95.96456693
374	140.2559055	147.6377953	147.6377953
375	140.2559055	147.6377953	140.2559055
376	140.2559055	147.6377953	132.8740157
377	140.2559055	147.6377953	125.492126
378	140.2559055	147.6377953	118.1102362
379	140.2559055	147.6377953	110.7283465
380	140.2559055	147.6377953	103.3464567
381	140.2559055	147.6377953	95.96456693
382	132.8740157	147.6377953	147.6377953
383	132.8740157	147.6377953	140.2559055
384	132.8740157	147.6377953	132.8740157
385	132.8740157	147.6377953	125.492126
386	132.8740157	147.6377953	118.1102362
387	132.8740157	147.6377953	110.7283465
388	132.8740157	147.6377953	103.3464567
389	132.8740157	147.6377953	95.96456693
390	125.492126	147.6377953	147.6377953

Bridge No.	Span Length 1	Span Length 2	Span Length 3
391	125.492126	147.6377953	140.2559055
392	125.492126	147.6377953	132.8740157
393	125.492126	147.6377953	125.492126
394	125.492126	147.6377953	118.1102362
395	125.492126	147.6377953	110.7283465
396	125.492126	147.6377953	103.3464567
397	125.492126	147.6377953	95.96456693
398	118.1102362	147.6377953	147.6377953
399	118.1102362	147.6377953	140.2559055
400	118.1102362	147.6377953	132.8740157
401	118.1102362	147.6377953	125.492126
402	118.1102362	147.6377953	118.1102362
403	118.1102362	147.6377953	110.7283465
404	118.1102362	147.6377953	103.3464567
405	118.1102362	147.6377953	95.96456693
406	110.7283465	147.6377953	147.6377953
407	110.7283465	147.6377953	140.2559055
408	110.7283465	147.6377953	132.8740157
409	110.7283465	147.6377953	125.492126
410	110.7283465	147.6377953	118.1102362
411	110.7283465	147.6377953	110.7283465
412	110.7283465	147.6377953	103.3464567
413	110.7283465	147.6377953	95.96456693
414	164.0419948	164.0419948	164.0419948
415	164.0419948	164.0419948	155.839895
416	164.0419948	164.0419948	147.6377953
417	164.0419948	164.0419948	139.4356955
418	164.0419948	164.0419948	131.2335958

Bridge No.	Span Length 1	Span Length 2	Span Length 3
419	164.0419948	164.0419948	123.0314961
420	164.0419948	164.0419948	114.8293963
421	164.0419948	164.0419948	106.6272966
422	155.839895	164.0419948	164.0419948
423	155.839895	164.0419948	155.839895
424	155.839895	164.0419948	147.6377953
425	155.839895	164.0419948	139.4356955
426	155.839895	164.0419948	131.2335958
427	155.839895	164.0419948	123.0314961
428	155.839895	164.0419948	114.8293963
429	155.839895	164.0419948	106.6272966
430	147.6377953	164.0419948	164.0419948
431	147.6377953	164.0419948	155.839895
432	147.6377953	164.0419948	147.6377953
433	147.6377953	164.0419948	139.4356955
434	147.6377953	164.0419948	131.2335958
435	147.6377953	164.0419948	123.0314961
436	147.6377953	164.0419948	114.8293963
437	147.6377953	164.0419948	106.6272966
438	139.4356955	164.0419948	164.0419948
439	139.4356955	164.0419948	155.839895
440	139.4356955	164.0419948	147.6377953
441	139.4356955	164.0419948	139.4356955
442	139.4356955	164.0419948	131.2335958
443	139.4356955	164.0419948	123.0314961
444	139.4356955	164.0419948	114.8293963
445	139.4356955	164.0419948	106.6272966
446	131.2335958	164.0419948	164.0419948

Bridge No.	Span Length 1	Span Length 2	Span Length 3
447	131.2335958	164.0419948	155.839895
448	131.2335958	164.0419948	147.6377953
449	131.2335958	164.0419948	139.4356955
450	131.2335958	164.0419948	131.2335958
451	131.2335958	164.0419948	123.0314961
452	131.2335958	164.0419948	114.8293963
453	131.2335958	164.0419948	106.6272966
454	123.0314961	164.0419948	164.0419948
455	123.0314961	164.0419948	155.839895
456	123.0314961	164.0419948	147.6377953
457	123.0314961	164.0419948	139.4356955
458	123.0314961	164.0419948	131.2335958
459	123.0314961	164.0419948	123.0314961
460	123.0314961	164.0419948	114.8293963
461	123.0314961	164.0419948	106.6272966
462	180.4461942	180.4461942	180.4461942
463	180.4461942	180.4461942	171.4238845
464	180.4461942	180.4461942	162.4015748
465	180.4461942	180.4461942	153.3792651
466	180.4461942	180.4461942	144.3569554
467	180.4461942	180.4461942	135.3346457
468	180.4461942	180.4461942	126.312336
469	180.4461942	180.4461942	117.2900262
470	171.4238845	180.4461942	180.4461942
471	171.4238845	180.4461942	171.4238845
472	171.4238845	180.4461942	162.4015748
473	171.4238845	180.4461942	153.3792651
474	171.4238845	180.4461942	144.3569554
475	171.4238845	180.4461942	135.3346457
476	171.4238845	180.4461942	126.312336
477	171.4238845	180.4461942	117.2900262
478	162.4015748	180.4461942	180.4461942
479	162.4015748	180.4461942	171.4238845
480	162.4015748	180.4461942	162.4015748
481	162.4015748	180.4461942	153.3792651
482	162.4015748	180.4461942	144.3569554
483	162.4015748	180.4461942	135.3346457
484	162.4015748	180.4461942	126.312336
485	162.4015748	180.4461942	117.2900262
486	153.3792651	180.4461942	180.4461942
487	153.3792651	180.4461942	171.4238845
488	153.3792651	180.4461942	162.4015748
489	153.3792651	180.4461942	153.3792651
490	153.3792651	180.4461942	144.3569554
491	153.3792651	180.4461942	135.3346457
492	153.3792651	180.4461942	126.312336
493	153.3792651	180.4461942	117.2900262
494	144.3569554	180.4461942	180.4461942
495	144.3569554	180.4461942	171.4238845
496	144.3569554	180.4461942	162.4015748
497	144.3569554	180.4461942	153.3792651
498	144.3569554	180.4461942	144.3569554
499	144.3569554	180.4461942	135.3346457
500	144.3569554	180.4461942	126.312336
501	144.3569554	180.4461942	117.2900262
502	135.3346457	180.4461942	180.4461942

Bridge No.	Span Length 1	Span Length 2	Span Length 3
503	135.3346457	180.4461942	171.4238845
504	135.3346457	180.4461942	162.4015748
505	135.3346457	180.4461942	153.3792651
506	135.3346457	180.4461942	144.3569554
507	135.3346457	180.4461942	135.3346457
508	135.3346457	180.4461942	126.312336
509	135.3346457	180.4461942	117.2900262
510	196.8503937	196.8503937	196.8503937
511	196.8503937	196.8503937	187.007874
512	196.8503937	196.8503937	177.1653543
513	196.8503937	196.8503937	167.3228346
514	196.8503937	196.8503937	157.480315
515	196.8503937	196.8503937	147.6377953
516	196.8503937	196.8503937	137.7952756
517	196.8503937	196.8503937	127.9527559
518	187.007874	196.8503937	196.8503937
519	187.007874	196.8503937	187.007874
520	187.007874	196.8503937	177.1653543
521	187.007874	196.8503937	167.3228346
522	187.007874	196.8503937	157.480315
523	187.007874	196.8503937	147.6377953
524	187.007874	196.8503937	137.7952756
525	187.007874	196.8503937	127.9527559
526	177.1653543	196.8503937	196.8503937
527	177.1653543	196.8503937	187.007874
528	177.1653543	196.8503937	177.1653543
529	177.1653543	196.8503937	167.3228346
530	177.1653543	196.8503937	157.480315

Bridge No.	Span Length 1	Span Length 2	Span Length 3
531	177.1653543	196.8503937	147.6377953
532	177.1653543	196.8503937	137.7952756
533	177.1653543	196.8503937	127.9527559
534	167.3228346	196.8503937	196.8503937
535	167.3228346	196.8503937	187.007874
536	167.3228346	196.8503937	177.1653543
537	167.3228346	196.8503937	167.3228346
538	167.3228346	196.8503937	157.480315
539	167.3228346	196.8503937	147.6377953
540	167.3228346	196.8503937	137.7952756
541	167.3228346	196.8503937	127.9527559
542	157.480315	196.8503937	196.8503937
543	157.480315	196.8503937	187.007874
544	157.480315	196.8503937	177.1653543
545	157.480315	196.8503937	167.3228346
546	157.480315	196.8503937	157.480315
547	157.480315	196.8503937	147.6377953
548	157.480315	196.8503937	137.7952756
549	157.480315	196.8503937	127.9527559
550	147.6377953	196.8503937	196.8503937
551	147.6377953	196.8503937	187.007874
552	147.6377953	196.8503937	177.1653543
553	147.6377953	196.8503937	167.3228346
554	147.6377953	196.8503937	157.480315
555	147.6377953	196.8503937	147.6377953
556	147.6377953	196.8503937	137.7952756
557	147.6377953	196.8503937	127.9527559
558	213.2545932	213.2545932	213.2545932

Bridge No.	Span Length 1	Span Length 2	Span Length 3
559	213.2545932	213.2545932	202.5918635
560	213.2545932	213.2545932	191.9291339
561	213.2545932	213.2545932	181.2664042
562	213.2545932	213.2545932	170.6036745
563	213.2545932	213.2545932	159.9409449
564	213.2545932	213.2545932	149.2782152
565	213.2545932	213.2545932	138.6154856
566	202.5918635	213.2545932	213.2545932
567	202.5918635	213.2545932	202.5918635
568	202.5918635	213.2545932	191.9291339
569	202.5918635	213.2545932	181.2664042
570	202.5918635	213.2545932	170.6036745
571	202.5918635	213.2545932	159.9409449
572	202.5918635	213.2545932	149.2782152
573	202.5918635	213.2545932	138.6154856
574	191.9291339	213.2545932	213.2545932
575	191.9291339	213.2545932	202.5918635
576	191.9291339	213.2545932	191.9291339
577	191.9291339	213.2545932	181.2664042
578	191.9291339	213.2545932	170.6036745
579	191.9291339	213.2545932	159.9409449
580	191.9291339	213.2545932	149.2782152
581	191.9291339	213.2545932	138.6154856
582	181.2664042	213.2545932	213.2545932
583	181.2664042	213.2545932	202.5918635
584	181.2664042	213.2545932	191.9291339
585	181.2664042	213.2545932	181.2664042
586	181.2664042	213.2545932	170.6036745

Bridge No.	Span Length 1	Span Length 2	Span Length 3
587	181.2664042	213.2545932	159.9409449
588	181.2664042	213.2545932	149.2782152
589	181.2664042	213.2545932	138.6154856
590	170.6036745	213.2545932	213.2545932
591	170.6036745	213.2545932	202.5918635
592	170.6036745	213.2545932	191.9291339
593	170.6036745	213.2545932	181.2664042
594	170.6036745	213.2545932	170.6036745
595	170.6036745	213.2545932	159.9409449
596	170.6036745	213.2545932	149.2782152
597	170.6036745	213.2545932	138.6154856
598	159.9409449	213.2545932	213.2545932
599	159.9409449	213.2545932	202.5918635
600	159.9409449	213.2545932	191.9291339
601	159.9409449	213.2545932	181.2664042
602	159.9409449	213.2545932	170.6036745
603	159.9409449	213.2545932	159.9409449
604	159.9409449	213.2545932	149.2782152
605	159.9409449	213.2545932	138.6154856
606	229.6587927	229.6587927	229.6587927
607	229.6587927	229.6587927	218.175853
608	229.6587927	229.6587927	206.6929134
609	229.6587927	229.6587927	195.2099738
610	229.6587927	229.6587927	183.7270341
611	229.6587927	229.6587927	172.2440945
612	229.6587927	229.6587927	160.7611549
613	229.6587927	229.6587927	149.2782152
614	218.175853	229.6587927	229.6587927

Bridge No.	Span Length 1	Span Length 2	Span Length 3
615	218.175853	229.6587927	218.175853
616	218.175853	229.6587927	206.6929134
617	218.175853	229.6587927	195.2099738
618	218.175853	229.6587927	183.7270341
619	218.175853	229.6587927	172.2440945
620	218.175853	229.6587927	160.7611549
621	218.175853	229.6587927	149.2782152
622	206.6929134	229.6587927	229.6587927
623	206.6929134	229.6587927	218.175853
624	206.6929134	229.6587927	206.6929134
625	206.6929134	229.6587927	195.2099738
626	206.6929134	229.6587927	183.7270341
627	206.6929134	229.6587927	172.2440945
628	206.6929134	229.6587927	160.7611549
629	206.6929134	229.6587927	149.2782152
630	195.2099738	229.6587927	229.6587927
631	195.2099738	229.6587927	218.175853
632	195.2099738	229.6587927	206.6929134
633	195.2099738	229.6587927	195.2099738
634	195.2099738	229.6587927	183.7270341
635	195.2099738	229.6587927	172.2440945
636	195.2099738	229.6587927	160.7611549
637	195.2099738	229.6587927	149.2782152
638	183.7270341	229.6587927	229.6587927
639	183.7270341	229.6587927	218.175853
640	183.7270341	229.6587927	206.6929134
641	183.7270341	229.6587927	195.2099738
642	183.7270341	229.6587927	183.7270341

Bridge No.	Span Length 1	Span Length 2	Span Length 3
643	183.7270341	229.6587927	172.2440945
644	183.7270341	229.6587927	160.7611549
645	183.7270341	229.6587927	149.2782152
646	172.2440945	229.6587927	229.6587927
647	172.2440945	229.6587927	218.175853
648	172.2440945	229.6587927	206.6929134
649	172.2440945	229.6587927	195.2099738
650	172.2440945	229.6587927	183.7270341
651	172.2440945	229.6587927	172.2440945
652	172.2440945	229.6587927	160.7611549
653	172.2440945	229.6587927	149.2782152
654	246.0629921	246.0629921	246.0629921
655	246.0629921	246.0629921	233.7598425
656	246.0629921	246.0629921	221.4566929
657	246.0629921	246.0629921	209.1535433
658	246.0629921	246.0629921	196.8503937
659	246.0629921	246.0629921	184.5472441
660	246.0629921	246.0629921	172.2440945
661	246.0629921	246.0629921	159.9409449
662	233.7598425	246.0629921	246.0629921
663	233.7598425	246.0629921	233.7598425
664	233.7598425	246.0629921	221.4566929
665	233.7598425	246.0629921	209.1535433
666	233.7598425	246.0629921	196.8503937
667	233.7598425	246.0629921	184.5472441
668	233.7598425	246.0629921	172.2440945
669	233.7598425	246.0629921	159.9409449
670	221.4566929	246.0629921	246.0629921

Bridge No.	Span Length 1	Span Length 2	Span Length 3
671	221.4566929	246.0629921	233.7598425
672	221.4566929	246.0629921	221.4566929
673	221.4566929	246.0629921	209.1535433
674	221.4566929	246.0629921	196.8503937
675	221.4566929	246.0629921	184.5472441
676	221.4566929	246.0629921	172.2440945
677	221.4566929	246.0629921	159.9409449
678	209.1535433	246.0629921	246.0629921
679	209.1535433	246.0629921	233.7598425
680	209.1535433	246.0629921	221.4566929
681	209.1535433	246.0629921	209.1535433
682	209.1535433	246.0629921	196.8503937
683	209.1535433	246.0629921	184.5472441
684	209.1535433	246.0629921	172.2440945
685	209.1535433	246.0629921	159.9409449
686	196.8503937	246.0629921	246.0629921
687	196.8503937	246.0629921	233.7598425
688	196.8503937	246.0629921	221.4566929
689	196.8503937	246.0629921	209.1535433
690	196.8503937	246.0629921	196.8503937
691	196.8503937	246.0629921	184.5472441
692	196.8503937	246.0629921	172.2440945
693	196.8503937	246.0629921	159.9409449
694	184.5472441	246.0629921	246.0629921
695	184.5472441	246.0629921	233.7598425
696	184.5472441	246.0629921	221.4566929
697	184.5472441	246.0629921	209.1535433
698	184.5472441	246.0629921	196.8503937

Bridge No.	Span Length 1	Span Length 2	Span Length 3
699	184.5472441	246.0629921	184.5472441
700	184.5472441	246.0629921	172.2440945
701	184.5472441	246.0629921	159.9409449
702	262.4671916	262.4671916	262.4671916
703	262.4671916	262.4671916	249.343832
704	262.4671916	262.4671916	236.2204724
705	262.4671916	262.4671916	223.0971129
706	262.4671916	262.4671916	209.9737533
707	262.4671916	262.4671916	196.8503937
708	262.4671916	262.4671916	183.7270341
709	262.4671916	262.4671916	170.6036745
710	249.343832	262.4671916	262.4671916
711	249.343832	262.4671916	249.343832
712	249.343832	262.4671916	236.2204724
713	249.343832	262.4671916	223.0971129
714	249.343832	262.4671916	209.9737533
715	249.343832	262.4671916	196.8503937
716	249.343832	262.4671916	183.7270341
717	249.343832	262.4671916	170.6036745
718	236.2204724	262.4671916	262.4671916
719	236.2204724	262.4671916	249.343832
720	236.2204724	262.4671916	236.2204724
721	236.2204724	262.4671916	223.0971129
722	236.2204724	262.4671916	209.9737533
723	236.2204724	262.4671916	196.8503937
724	236.2204724	262.4671916	183.7270341
725	236.2204724	262.4671916	170.6036745
726	223.0971129	262.4671916	262.4671916

Bridge No.	Span Length 1	Span Length 2	Span Length 3
727	223.0971129	262.4671916	249.343832
728	223.0971129	262.4671916	236.2204724
729	223.0971129	262.4671916	223.0971129
730	223.0971129	262.4671916	209.9737533
731	223.0971129	262.4671916	196.8503937
732	223.0971129	262.4671916	183.7270341
733	223.0971129	262.4671916	170.6036745
734	209.9737533	262.4671916	262.4671916
735	209.9737533	262.4671916	249.343832
736	209.9737533	262.4671916	236.2204724
737	209.9737533	262.4671916	223.0971129
738	209.9737533	262.4671916	209.9737533
739	209.9737533	262.4671916	196.8503937
740	209.9737533	262.4671916	183.7270341
741	209.9737533	262.4671916	170.6036745
742	196.8503937	262.4671916	262.4671916
743	196.8503937	262.4671916	249.343832
744	196.8503937	262.4671916	236.2204724
745	196.8503937	262.4671916	223.0971129
746	196.8503937	262.4671916	209.9737533
747	196.8503937	262.4671916	196.8503937
748	196.8503937	262.4671916	183.7270341
749	196.8503937	262.4671916	170.6036745

Table B3. Truck Number Reference Table – Including number of trucks being platooned, truck name, and the head spacing in feet

Truck No.	No. of Trucks	Truck Type	Spacing
1	1	HL93Tandem	0
2	2	HL93Tandem	10
3	3	HL93Tandem	10
4	2	HL93Tandem	20
5	3	HL93Tandem	20
6	2	HL93Tandem	30
7	3	HL93Tandem	30
8	2	HL93Tandem	40
9	3	HL93Tandem	40
10	2	HL93Tandem	50
11	3	HL93Tandem	50
12	2	HL93Tandem	60
13	3	HL93Tandem	60
14	1	Legal3	0
15	2	Legal3	10
16	3	Legal3	10
17	2	Legal3	20
18	3	Legal3	20
19	2	Legal3	30
20	3	Legal3	30
21	2	Legal3	40
22	3	Legal3	40
23	2	Legal3	50
24	3	Legal3	50
25	2	Legal3	60

Truck No.	No. of Trucks	Truck Type	Spacing
26	3	Legal3	60
27	1	Legal3S2	0
28	2	Legal3S2	10
29	3	Legal3S2	10
30	2	Legal3S2	20
31	3	Legal3S2	20
32	2	Legal3S2	30
33	3	Legal3S2	30
34	2	Legal3S2	40
35	3	Legal3S2	40
36	2	Legal3S2	50
37	3	Legal3S2	50
38	2	Legal3S2	60
39	3	Legal3S2	60
40	1	Legal33	0
41	2	Legal33	10
42	3	Legal33	10
43	2	Legal33	20
44	3	Legal33	20
45	2	Legal33	30
46	3	Legal33	30
47	2	Legal33	40
48	3	Legal33	40
49	2	Legal33	50
50	3	Legal33	50
51	2	Legal33	60
52	3	Legal33	60
53	1	SU4	0

Truck No.	No. of Trucks	Truck Type	Spacing
54	2	SU4	10
55	3	SU4	10
56	2	SU4	20
57	3	SU4	20
58	2	SU4	30
59	3	SU4	30
60	2	SU4	40
61	3	SU4	40
62	2	SU4	50
63	3	SU4	50
64	2	SU4	60
65	3	SU4	60
66	1	SU5	0
67	2	SU5	10
68	3	SU5	10
69	2	SU5	20
70	3	SU5	20
71	2	SU5	30
72	3	SU5	30
73	2	SU5	40
74	3	SU5	40
75	2	SU5	50
76	3	SU5	50
77	2	SU5	60
78	3	SU5	60
79	1	SU6	0
80	2	SU6	10
81	3	SU6	10

Truck No.	No. of Trucks	Truck Type	Spacing
82	2	SU6	20
83	3	SU6	20
84	2	SU6	30
85	3	SU6	30
86	2	SU6	40
87	3	SU6	40
88	2	SU6	50
89	3	SU6	50
90	2	SU6	60
91	3	SU6	60
92	1	SU7	0
93	2	SU7	10
94	3	SU7	10
95	2	SU7	20
96	3	SU7	20
97	2	SU7	30
98	3	SU7	30
99	2	SU7	40
100	3	SU7	40
101	2	SU7	50
102	3	SU7	50
103	2	SU7	60
104	3	SU7	60
105	1	EV2	0
106	2	EV2	10
107	3	EV2	10
108	2	EV2	20
109	3	EV2	20

Truck No.	No. of Trucks	Truck Type	Spacing
110	2	EV2	30
111	3	EV2	30
112	2	EV2	40
113	3	EV2	40
114	2	EV2	50
115	3	EV2	50
116	2	EV2	60
117	3	EV2	60
118	1	EV3	0
119	2	EV3	10
120	3	EV3	10
121	2	EV3	20
122	3	EV3	20
123	2	EV3	30
124	3	EV3	30
125	2	EV3	40
126	3	EV3	40
127	2	EV3	50
128	3	EV3	50
129	2	EV3	60
130	3	EV3	60
131	1	CTP2A	0
132	2	CTP2A	10
133	3	CTP2A	10
134	2	CTP2A	20
135	3	CTP2A	20
136	2	CTP2A	30
137	3	CTP2A	30

Truck No.	No. of Trucks	Truck Type	Spacing
138	2	CTP2A	40
139	3	CTP2A	40
140	2	CTP2A	50
141	3	CTP2A	50
142	2	CTP2A	60
143	3	CTP2A	60
144	1	CTP2B	0
145	2	CTP2B	10
146	3	CTP2B	10
147	2	CTP2B	20
148	3	CTP2B	20
149	2	CTP2B	30
150	3	CTP2B	30
151	2	CTP2B	40
152	3	CTP2B	40
153	2	CTP2B	50
154	3	CTP2B	50
155	2	CTP2B	60
156	3	CTP2B	60
157	1	CTP3	0
158	2	CTP3	10
159	3	CTP3	10
160	2	CTP3	20
161	3	CTP3	20
162	2	CTP3	30
163	3	CTP3	30
164	2	CTP3	40
165	3	CTP3	40

Truck No.	No. of Trucks	Truck Type	Spacing
166	2	CTP3	50
167	3	CTP3	50
168	2	CTP3	60
169	3	CTP3	60
170	1	STP3	0
171	2	STP3	10
172	3	STP3	10
173	2	STP3	20
174	3	STP3	20
175	2	STP3	30
176	3	STP3	30
177	2	STP3	40
178	3	STP3	40
179	2	STP3	50
180	3	STP3	50
181	2	STP3	60
182	3	STP3	60
183	1	STP4A	0
184	2	STP4A	10
185	3	STP4A	10
186	2	STP4A	20
187	3	STP4A	20
188	2	STP4A	30
189	3	STP4A	30
190	2	STP4A	40
191	3	STP4A	40
192	2	STP4A	50
193	3	STP4A	50

Truck No.	No. of Trucks	Truck Type	Spacing
194	2	STP4A	60
195	3	STP4A	60
196	1	STP4B	0
197	2	STP4B	10
198	3	STP4B	10
199	2	STP4B	20
200	3	STP4B	20
201	2	STP4B	30
202	3	STP4B	30
203	2	STP4B	40
204	3	STP4B	40
205	2	STP4B	50
206	3	STP4B	50
207	2	STP4B	60
208	3	STP4B	60
209	1	STP4C	0
210	2	STP4C	10
211	3	STP4C	10
212	2	STP4C	20
213	3	STP4C	20
214	2	STP4C	30
215	3	STP4C	30
216	2	STP4C	40
217	3	STP4C	40
218	2	STP4C	50
219	3	STP4C	50
220	2	STP4C	60
221	3	STP4C	60

Truck No.	No. of Trucks	Truck Type	Spacing
222	1	STP4D	0
223	2	STP4D	10
224	3	STP4D	10
225	2	STP4D	20
226	3	STP4D	20
227	2	STP4D	30
228	3	STP4D	30
229	2	STP4D	40
230	3	STP4D	40
231	2	STP4D	50
232	3	STP4D	50
233	2	STP4D	60
234	3	STP4D	60
235	1	STP4E	0
236	2	STP4E	10
237	3	STP4E	10
238	2	STP4E	20
239	3	STP4E	20
240	2	STP4E	30
241	3	STP4E	30
242	2	STP4E	40
243	3	STP4E	40
244	2	STP4E	50
245	3	STP4E	50
246	2	STP4E	60
247	3	STP4E	60
248	1	STP5BW	0
249	2	STP5BW	10

Truck No.	No. of Trucks	Truck Type	Spacing
250	3	STP5BW	10
251	2	STP5BW	20
252	3	STP5BW	20
253	2	STP5BW	30
254	3	STP5BW	30
255	2	STP5BW	40
256	3	STP5BW	40
257	2	STP5BW	50
258	3	STP5BW	50
259	2	STP5BW	60
260	3	STP5BW	60
261	1	HL93-14	0
262	2	HL93-14	10
263	3	HL93-14	10
264	2	HL93-14	20
265	3	HL93-14	20
266	2	HL93-14	30
267	3	HL93-14	30
268	2	HL93-14	40
269	3	HL93-14	40
270	2	HL93-14	50
271	3	HL93-14	50
272	2	HL93-14	60
273	3	HL93-14	60
274	1	HL93-15	0
275	2	HL93-15	10
276	3	HL93-15	10
277	2	HL93-15	20

Truck No.	No. of Trucks	Truck Type	Spacing
278	3	HL93-15	20
279	2	HL93-15	30
280	3	HL93-15	30
281	2	HL93-15	40
282	3	HL93-15	40
283	2	HL93-15	50
284	3	HL93-15	50
285	2	HL93-15	60
286	3	HL93-15	60
287	1	HL93-16	0
288	2	HL93-16	10
289	3	HL93-16	10
290	2	HL93-16	20
291	3	HL93-16	20
292	2	HL93-16	30
293	3	HL93-16	30
294	2	HL93-16	40
295	3	HL93-16	40
296	2	HL93-16	50
297	3	HL93-16	50
298	2	HL93-16	60
299	3	HL93-16	60
300	1	HL93-17	0
301	2	HL93-17	10
302	3	HL93-17	10
303	2	HL93-17	20
304	3	HL93-17	20
305	2	HL93-17	30

Truck No.	No. of Trucks	Truck Type	Spacing
306	3	HL93-17	30
307	2	HL93-17	40
308	3	HL93-17	40
309	2	HL93-17	50
310	3	HL93-17	50
311	2	HL93-17	60
312	3	HL93-17	60
313	1	HL93-18	0
314	2	HL93-18	10
315	3	HL93-18	10
316	2	HL93-18	20
317	3	HL93-18	20
318	2	HL93-18	30
319	3	HL93-18	30
320	2	HL93-18	40
321	3	HL93-18	40
322	2	HL93-18	50
323	3	HL93-18	50
324	2	HL93-18	60
325	3	HL93-18	60
326	1	HL93-19	0
327	2	HL93-19	10
328	3	HL93-19	10
329	2	HL93-19	20
330	3	HL93-19	20
331	2	HL93-19	30
332	3	HL93-19	30
333	2	HL93-19	40

Truck No.	No. of Trucks	Truck Type	Spacing
334	3	HL93-19	40
335	2	HL93-19	50
336	3	HL93-19	50
337	2	HL93-19	60
338	3	HL93-19	60
339	1	HL93-20	0
340	2	HL93-20	10
341	3	HL93-20	10
342	2	HL93-20	20
343	3	HL93-20	20
344	2	HL93-20	30
345	3	HL93-20	30
346	2	HL93-20	40
347	3	HL93-20	40
348	2	HL93-20	50
349	3	HL93-20	50
350	2	HL93-20	60
351	3	HL93-20	60
352	1	HL93-21	0
353	2	HL93-21	10
354	3	HL93-21	10
355	2	HL93-21	20
356	3	HL93-21	20
357	2	HL93-21	30
358	3	HL93-21	30
359	2	HL93-21	40
360	3	HL93-21	40
361	2	HL93-21	50

Truck No.	No. of Trucks	Truck Type	Spacing
362	3	HL93-21	50
363	2	HL93-21	60
364	3	HL93-21	60
365	1	HL93-22	0
366	2	HL93-22	10
367	3	HL93-22	10
368	2	HL93-22	20
369	3	HL93-22	20
370	2	HL93-22	30
371	3	HL93-22	30
372	2	HL93-22	40
373	3	HL93-22	40
374	2	HL93-22	50
375	3	HL93-22	50
376	2	HL93-22	60
377	3	HL93-22	60
378	1	HL93-23	0
379	2	HL93-23	10
380	3	HL93-23	10
381	2	HL93-23	20
382	3	HL93-23	20
383	2	HL93-23	30
384	3	HL93-23	30
385	2	HL93-23	40
386	3	HL93-23	40
387	2	HL93-23	50
388	3	HL93-23	50
389	2	HL93-23	60

Truck No.	No. of Trucks	Truck Type	Spacing
390	3	HL93-23	60
391	1	HL93-24	0
392	2	HL93-24	10
393	3	HL93-24	10
394	2	HL93-24	20
395	3	HL93-24	20
396	2	HL93-24	30
397	3	HL93-24	30
398	2	HL93-24	40
399	3	HL93-24	40
400	2	HL93-24	50
401	3	HL93-24	50
402	2	HL93-24	60
403	3	HL93-24	60
404	1	HL93-25	0
405	2	HL93-25	10
406	3	HL93-25	10
407	2	HL93-25	20
408	3	HL93-25	20
409	2	HL93-25	30
410	3	HL93-25	30
411	2	HL93-25	40
412	3	HL93-25	40
413	2	HL93-25	50
414	3	HL93-25	50
415	2	HL93-25	60
416	3	HL93-25	60
417	1	HL93-26	0

Truck No.	No. of Trucks	Truck Type	Spacing
418	2	HL93-26	10
419	3	HL93-26	10
420	2	HL93-26	20
421	3	HL93-26	20
422	2	HL93-26	30
423	3	HL93-26	30
424	2	HL93-26	40
425	3	HL93-26	40
426	2	HL93-26	50
427	3	HL93-26	50
428	2	HL93-26	60
429	3	HL93-26	60
430	1	HL93-27	0
431	2	HL93-27	10
432	3	HL93-27	10
433	2	HL93-27	20
434	3	HL93-27	20
435	2	HL93-27	30
436	3	HL93-27	30
437	2	HL93-27	40
438	3	HL93-27	40
439	2	HL93-27	50
440	3	HL93-27	50
441	2	HL93-27	60
442	3	HL93-27	60
443	1	HL93-28	0
444	2	HL93-28	10
445	3	HL93-28	10

Truck No.	No. of Trucks	Truck Type	Spacing
446	2	HL93-28	20
447	3	HL93-28	20
448	2	HL93-28	30
449	3	HL93-28	30
450	2	HL93-28	40
451	3	HL93-28	40
452	2	HL93-28	50
453	3	HL93-28	50
454	2	HL93-28	60
455	3	HL93-28	60
456	1	HL93-29	0
457	2	HL93-29	10
458	3	HL93-29	10
459	2	HL93-29	20
460	3	HL93-29	20
461	2	HL93-29	30
462	3	HL93-29	30
463	2	HL93-29	40
464	3	HL93-29	40
465	2	HL93-29	50
466	3	HL93-29	50
467	2	HL93-29	60
468	3	HL93-29	60
469	1	HL93-30	0
470	2	HL93-30	10
471	3	HL93-30	10
472	2	HL93-30	20
473	3	HL93-30	20

Truck No.	No. of Trucks	Truck Type	Spacing
474	2	HL93-30	30
475	3	HL93-30	30
476	2	HL93-30	40
477	3	HL93-30	40
478	2	HL93-30	50
479	3	HL93-30	50
480	2	HL93-30	60
481	3	HL93-30	60

Table B4. Column Heading Reference Table – for data tab in spreadsheet with maximum internal forces

Column Heading	Definition	Units
Bridge_Number	Corresponds to the Bridge Reference Number	-
Number_of_Spans	Number of Spans Per Bridge (1, 2, or 3 Spans)	-
Span_1_Length	Lengths of Span 1	feet
Span_2_Length	Lengths of Span 2	feet
Span_3_Length	Lengths of Span 3	feet
Truck_Number	Corresponds to the Truck Reference Number	-
Truck_Type	Oregon Truck Type - From the LRFR Manual	-
Number_of_Trucks	Number of Trucks in a Platoon	-
Head_Spacing	Spacing Between Trucks in a Platoon	feet
M_Max_Pos_EB	Maximum Positive Bending Moment for the entire bridge (all spans)	kip-feet
V_M_Max_Pos_EB	Corresponding Shear at the Max Positive Bending Moment for the entire bridge	kips
x_M_Max_Pos_EB	Location of Maximum Positive Bending Moment for the entire bridge, from left side of bridge	feet
M_Max_Neg_EB	Maximum Negative Bending Moment for the entire bridge (all spans)	kip-feet
V_M_Max_Neg_EB	Corresponding Shear at the Max Negative Bending Moment for the entire bridge	kips
x_M_Max_Neg_EB	Location of Maximum Negative Bending Moment for the entire bridge, from left side of bridge	feet
V_Max_EB	Maximum Shear for the entire bridge (all spans)	kips
M_V_Max_EB	Corresponding Moment at Max Shear for the entire bridge	kip-feet
x_V_Max_EB	Location of Shear for the entire bridge, from left side of bridge	feet
M_Max_Pos_S1	Maximum Positive Bending Moment for span 1	kip-feet

Column Heading	Definition	Units
V_M_Max_Pos_S1	Corresponding Shear at the Max Positive Bending Moment for span 1	kips
x_M_Max_Pos_S1	Location of Maximum Positive Bending Moment for span 1, from left side of bridge	feet
M_Max_Neg_S1	Maximum Negative Bending Moment for span 1	kip-feet
V_M_Max_Neg_S1	Corresponding Shear at the Max Negative Bending Moment for span 1	kips
x_M_Max_Neg_S1	Location of Maximum Negative Bending Moment for span 1, from left side of bridge	feet
V_L_S1	Shear at the left support of span 1	kips
M_V_L_S1	Corresponding Moment to the Shear at the left support of span 1	kip-feet
x_V_L_S1	Location of Shear at the left support of span 1, from left side of bridge	feet
V_R_S1	Shear at the right support of span 1	kips
M_V_R_S1	Corresponding Moment to the Shear at the right support of span 1	kip-feet
x_V_R_S1	Location of Shear at the right support of span 1, from right side of bridge	feet
M_Max_Pos_S2	Maximum Positive Bending Moment for span 2	kip-feet
V_M_Max_Pos_S2	Corresponding Shear at the Max Positive Bending Moment for span 2	kips
x_M_Max_Pos_S2	Location of Maximum Positive Bending Moment for span 2, from left side of bridge	feet
M_Max_Neg_S2	Maximum Negative Bending Moment for span 2	kip-feet
V_M_Max_Neg_S2	Corresponding Shear at the Max Negative Bending Moment for span 2	kips
x_M_Max_Neg_S2	Location of Maximum Negative Bending Moment for span 2, from left side of bridge	feet

Column Heading	Definition	Units
V_L_S2	Shear at the left support of span 2	kips
M_V_L_S2	Corresponding Moment to the Shear at the left support of span 2	kip-feet
x_V_L_S2	Location of Shear at the left support of span 2, from left side of bridge	feet
V_R_S2	Shear at the right support of span 2	kips
M_V_R_S2	Corresponding Moment to the Shear at the right support of span 2	kip-feet
x_V_R_S2	Location of Shear at the right support of span 2, from right side of bridge	feet
M_Max_Pos_S3	Maximum Positive Bending Moment for span 3	kip-feet
V_M_Max_Pos_S3	Corresponding Shear at the Max Positive Bending Moment for span 3	kips
x_M_Max_Pos_S3	Location of Maximum Positive Bending Moment for span 3, from left side of bridge	feet
M_Max_Neg_S3	Maximum Negative Bending Moment for span 3	kip-feet
V_M_Max_Neg_S3	Corresponding Shear at the Max Negative Bending Moment for span 3	kips
x_M_Max_Neg_S3	Location of Maximum Negative Bending Moment for span 3, from left side of bridge	feet
V_L_S3	Shear at the left support of span 3	kips
M_V_L_S3	Corresponding Moment to the Shear at the left support of span 3	kip-feet
x_V_L_S3	Location of Shear at the left support of span 3, from left side of bridge	feet
V_R_S3	Shear at the right support of span 3	kips
M_V_R_S3	Corresponding Moment to the Shear at the right support of span 3	kip-feet
x_V_R_S3	Location of Shear at the right support of span 3, from right side of bridge	feet

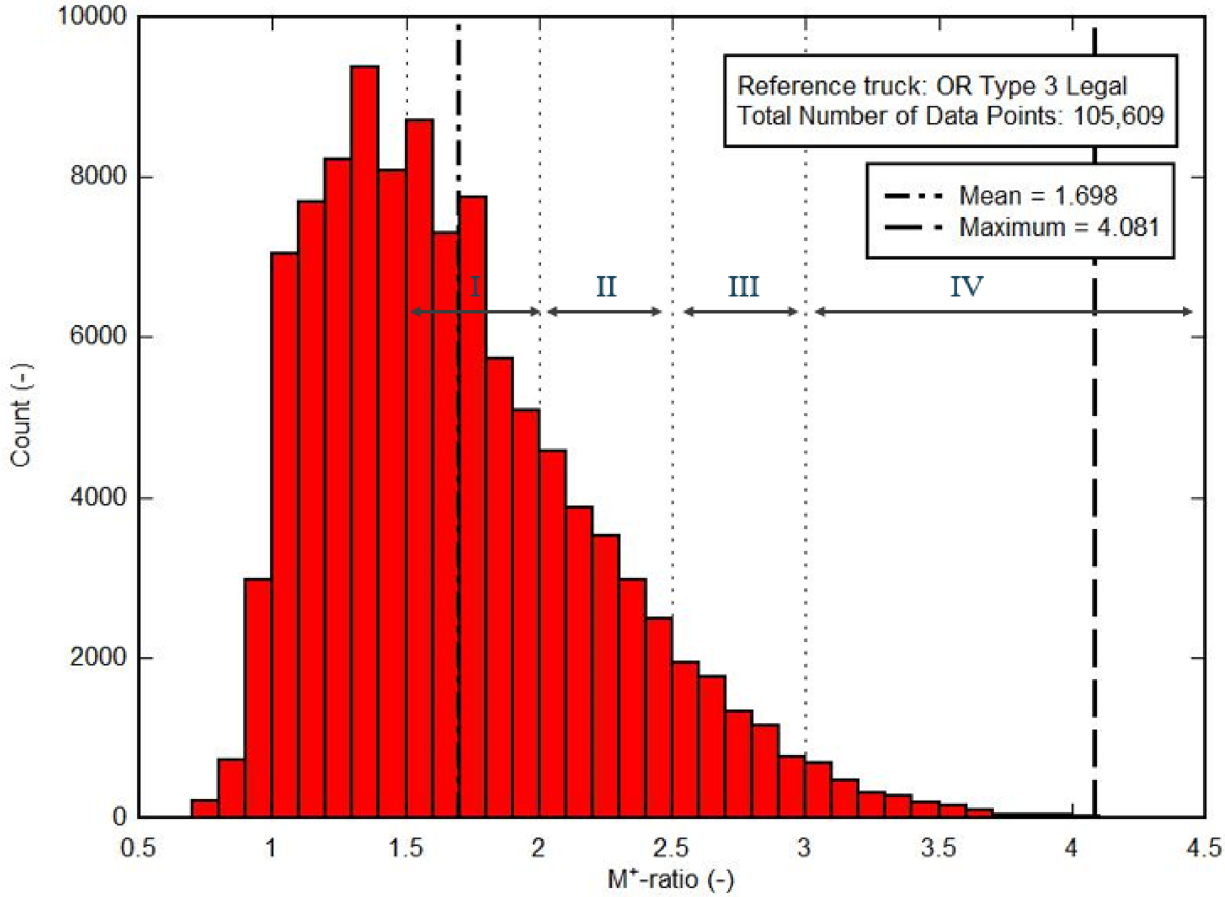


Figure B5. Histogram of maximum positive bending moment ratio (full database) normalized by OR Type 3 Legal Truck

Table B5. Count of maximum positive bending moment ratio (full database) normalized by OR Type 3 Legal Truck

Class	Count	Class	Count
0.70	208	2.40	2476
0.80	719	2.50	1942
0.90	2966	2.60	1754
1.00	7053	2.70	1338
1.10	7690	2.80	1160
1.20	8221	2.90	772
1.30	9374	3.00	685
1.40	8083	3.10	465
1.50	8711	3.20	311
1.60	7300	3.30	275
1.70	7744	3.40	186
1.80	5727	3.50	160
1.90	5085	3.60	106
2.00	4581	3.70	47
2.10	3876	3.80	44
2.20	3529	3.90	33
2.30	2976	4.00	13

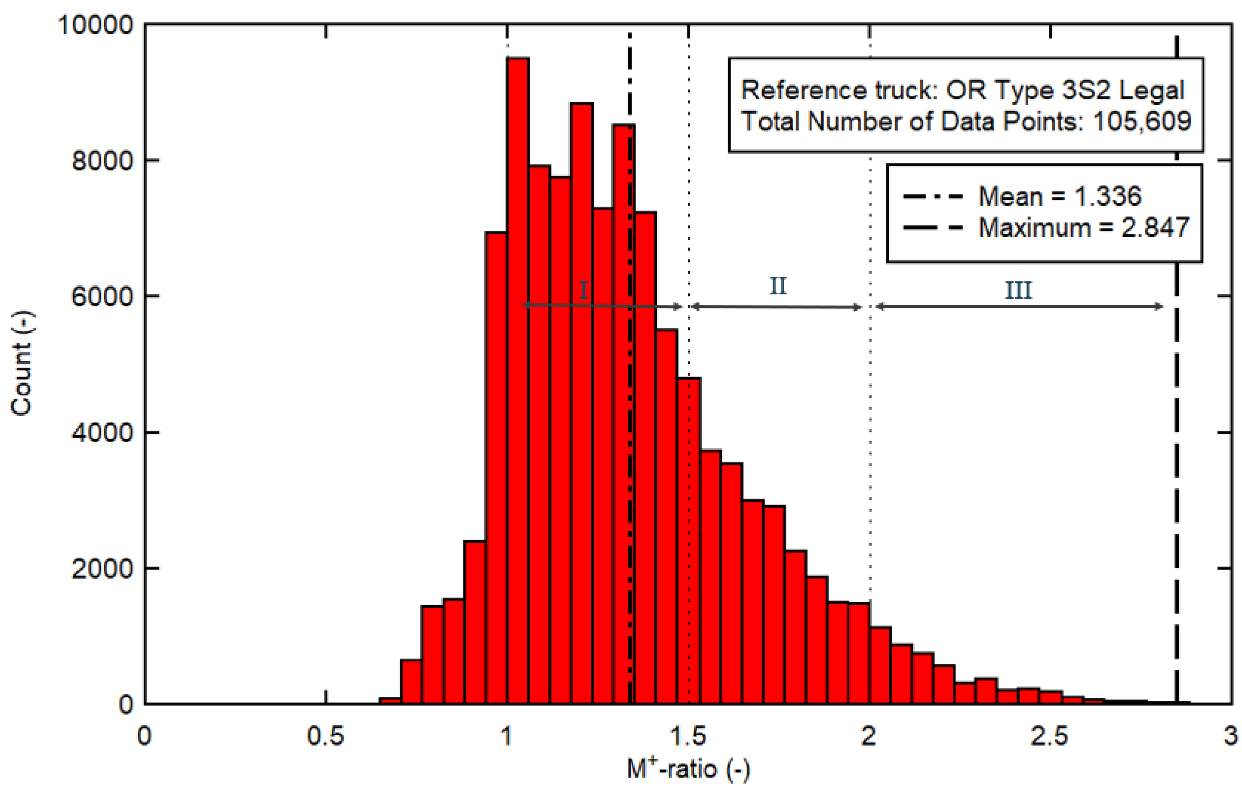


Figure B6. Histogram of maximum positive bending moment ratio (full database) normalized by OR Type 3S2 Legal Truck

Table B6. Count of maximum positive bending moment ratio (full database) normalized by OR Type 3S2 Legal Truck

Class	Count	Class	Count	Class	Count
0.65	88	1.41	5501	2.18	557
0.71	654	1.47	4787	2.24	318
0.76	1441	1.53	3730	2.29	378
0.82	1549	1.59	3551	2.35	206
0.88	2388	1.65	2990	2.41	233
0.94	6933	1.71	2911	2.47	182
1.00	9507	1.76	2256	2.53	112
1.06	7912	1.82	1868	2.59	55
1.12	7758	1.88	1490	2.65	37
1.18	8841	1.94	1484	2.71	48
1.24	7287	2.00	1131	2.76	30
1.29	8524	2.06	883	2.82	13
1.35	7224	2.12	752		

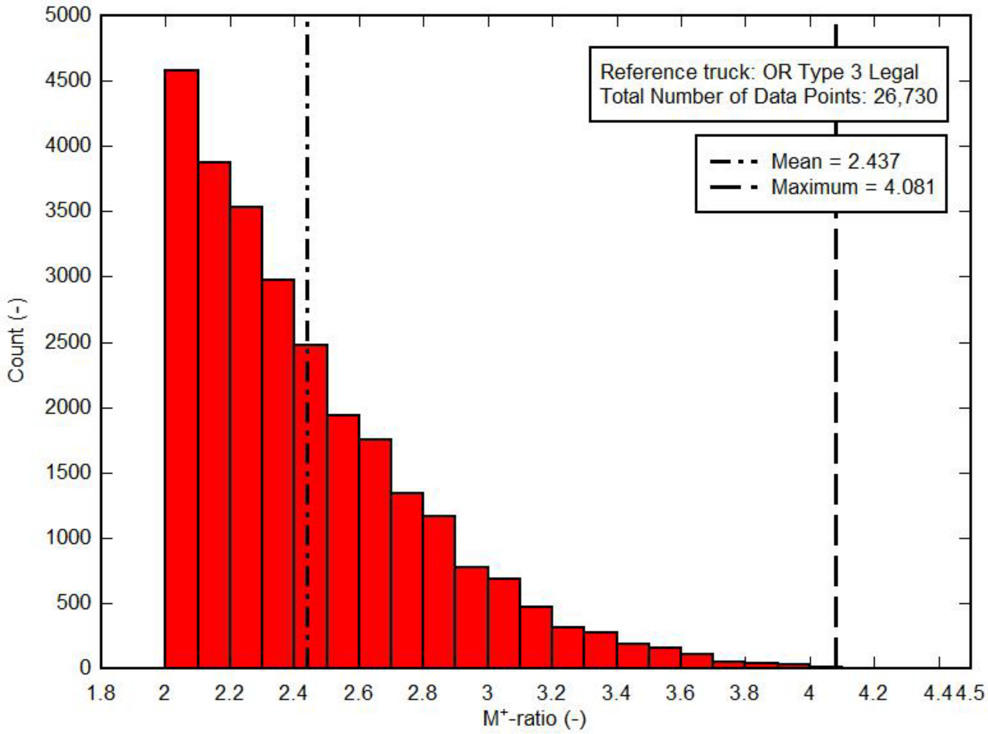


Figure B7. Histogram of maximum positive bending moment ratio (2.0+ ratio) normalized by OR Type 3 Legal Truck

Table B7. Count of maximum positive bending moment ratio (2.0+ ratio) normalized by OR Type 3 Legal Truck

Class	Count	Class	Count
2.00	4582	3.10	465
2.10	3876	3.20	311
2.20	3529	3.30	275
2.30	2976	3.40	186
2.40	2476	3.50	160
2.50	1942	3.60	106
2.60	1754	3.70	47
2.70	1338	3.80	44
2.80	1160	3.90	33
2.90	772	4.00	13
3.00	685		

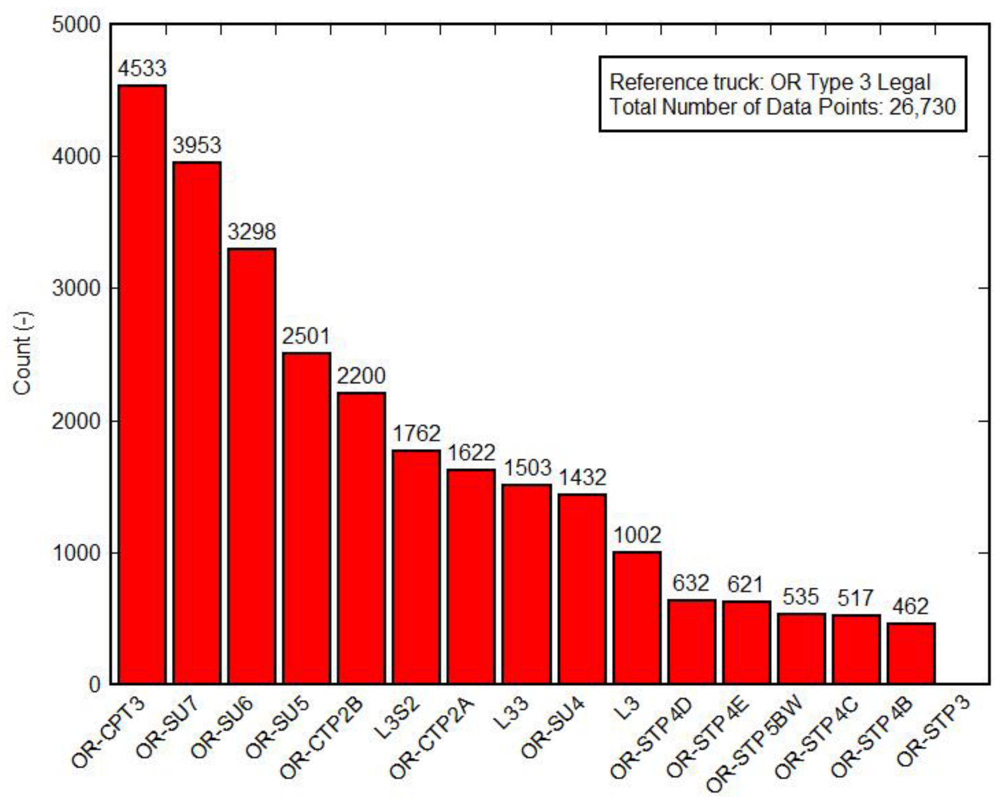


Figure B8. Histogram of maximum positive bending moment by truck type (2.0+ ratio) normalized by OR Type 3 Legal Truck

Table B8. Count of maximum positive bending moment by truck type (2.0+ ratio) normalized by OR Type 3 Legal Truck

Truck Type	Count
CTP3	4533
SU7	3953
SU6	3298
SU5	2501
CTP2B	2200
Lega13S2	1762
CTP2A	1622
Lega133	1503
SU4	1432
Lega13	1002
STP4D	632
STP4E	621
STP5BW	535
STP4C	517
STP4B	462
STP3	157

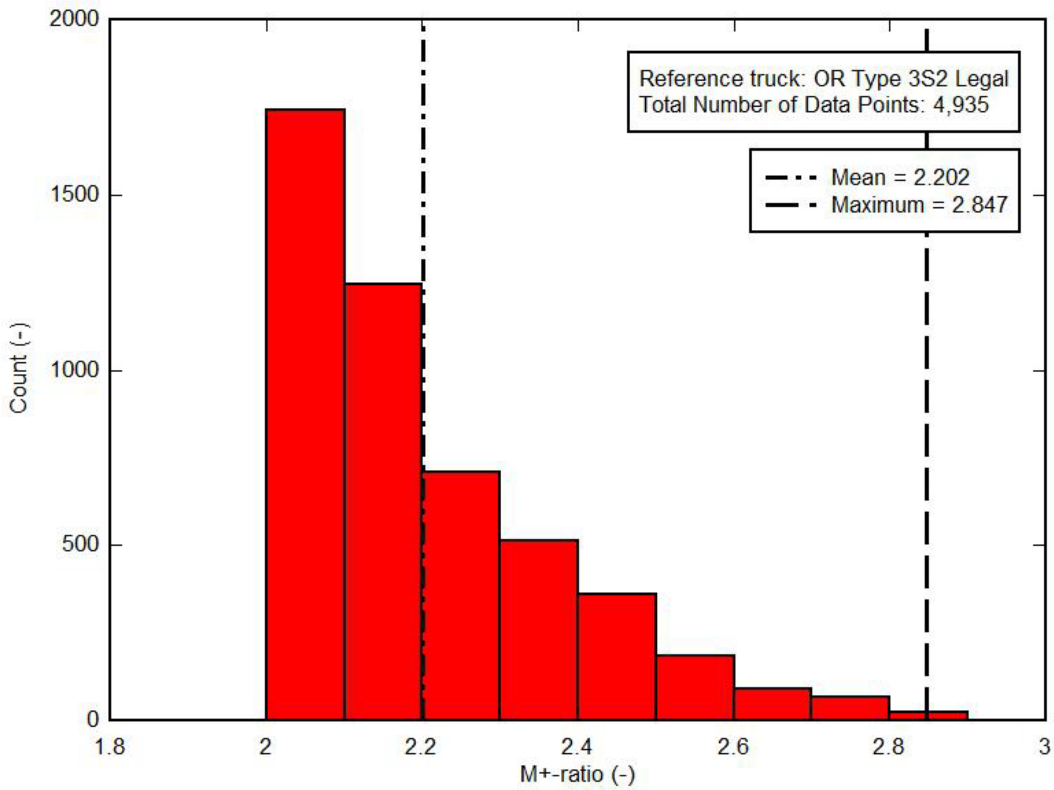


Figure B9. Histogram of maximum positive bending moment ratio (2.0+ ratio) normalized by OR Type 3S2 Legal Truck

Table B9. Count of maximum positive bending moment ratio (2.0+ ratio) normalized by OR Type 3S2 Legal Truck

Class	Count
2.00	1742
2.10	1245
2.20	708
2.30	514
2.40	359
2.50	185
2.60	91
2.70	67
2.80	24

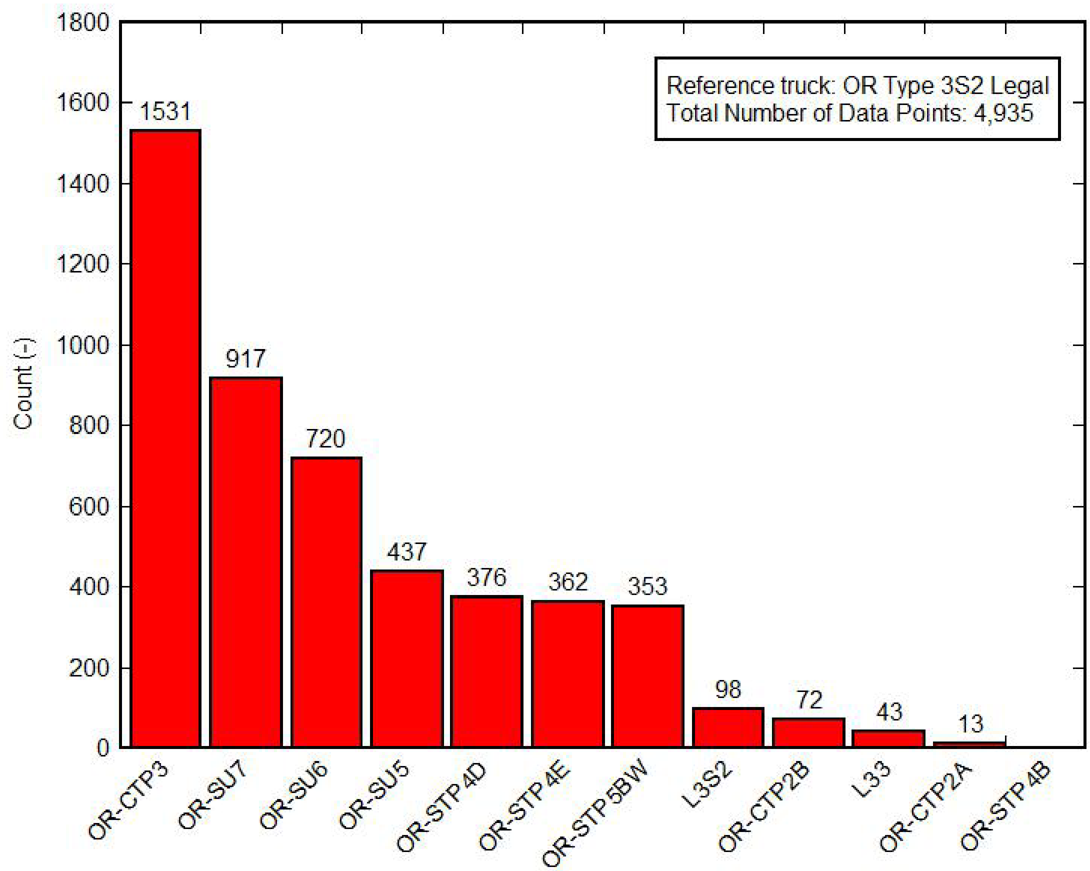


Figure B10. Histogram of maximum positive bending moment by truck type (2.0+ ratio) normalized by OR Type 3S2 Legal Truck

Table B10. Count of maximum positive bending moment by truck type (2.0+ ratio) normalized by OR Type 3S2 Legal Truck

Truck Type	Count
CTP3	1531
SU7	917
SU6	720
SU5	437
STP4D	376
STP4E	362
STP5BW	353
Lega13S2	98
CTP2B	72
Lega133	43
CTP2A	13
STP4B	13

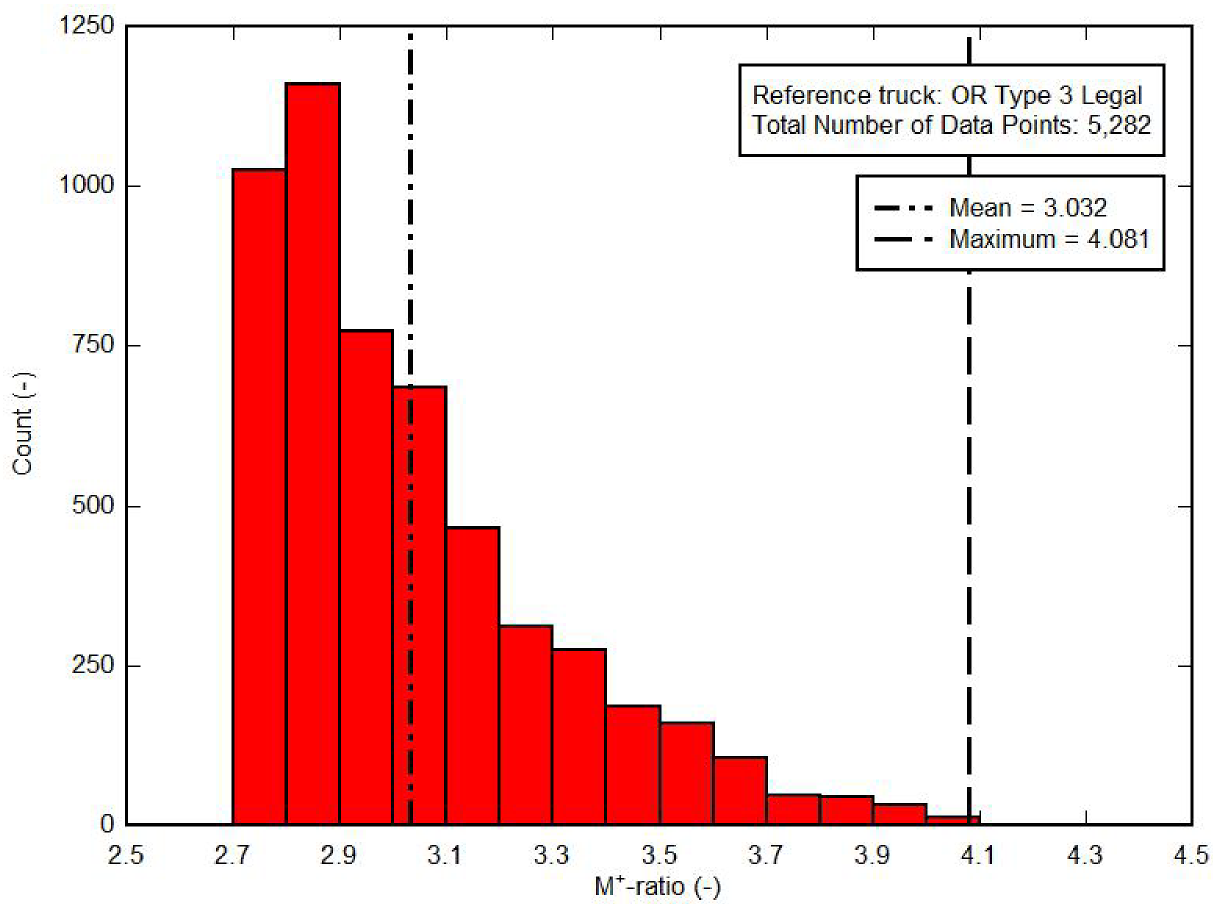


Figure B11. Histogram of maximum positive bending moment (the 95th percentile) normalized by OR Type 3 Legal Truck

Table B11. Count of maximum positive bending moment (the 95th percentile) normalized by OR Type 3 Legal Truck

Class	Count
2.70	1025
2.80	1160
2.90	772
3.00	685
3.10	465
3.20	311
3.30	275
3.40	186
3.50	160
3.60	106
3.70	47
3.80	44
3.90	33
4.00	13

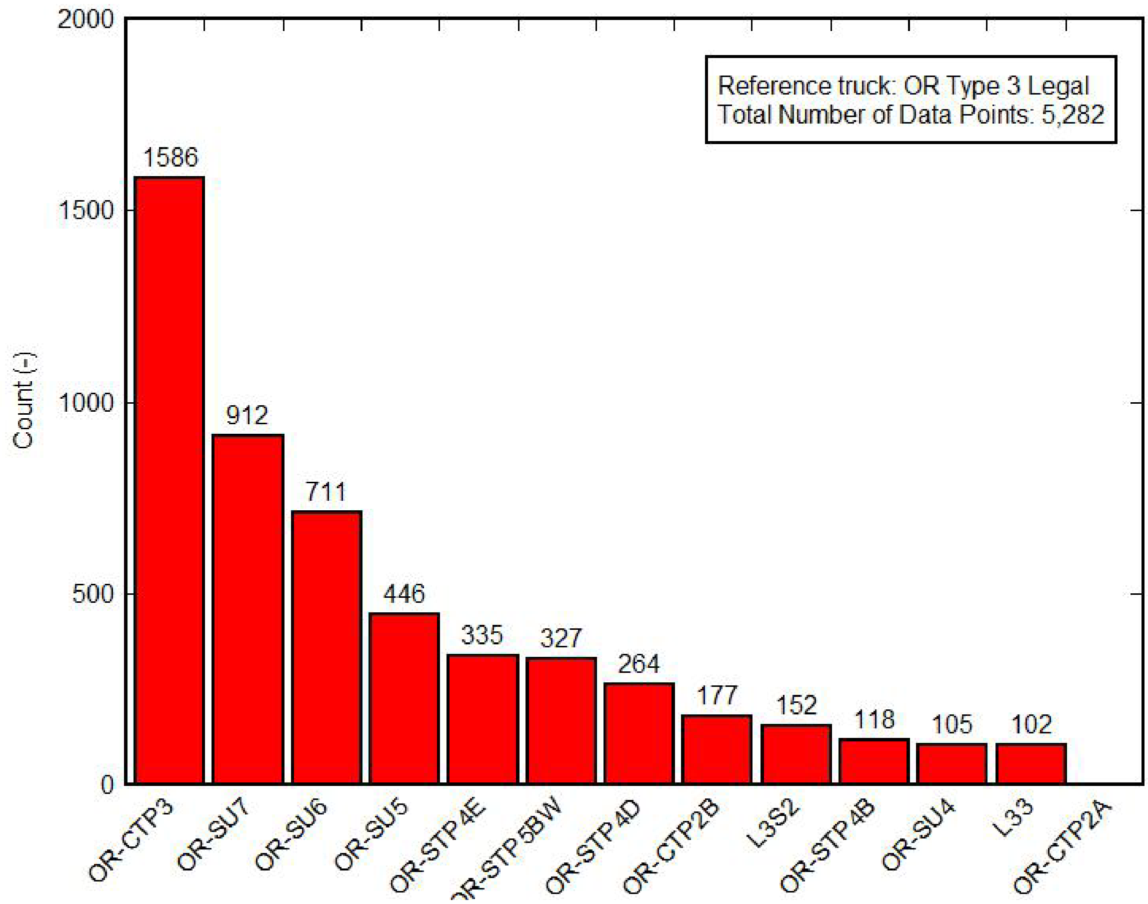


Figure B12. Histogram of maximum positive bending by truck type (the 95th percentile) normalized by OR Type 3 Legal Truck

Table B12. Count of maximum positive bending by truck type (the 95th percentile) normalized by OR Type 3 Legal Truck

Truck Type	Count
CTP3	1586
SU7	912
SU6	711
SU5	446
STP4E	335
STP5BW	327
STP4D	264
CTP2B	177
Lega13S2	152
STP4B	118
SU4	105
Legal 33	102
CTP2A	47

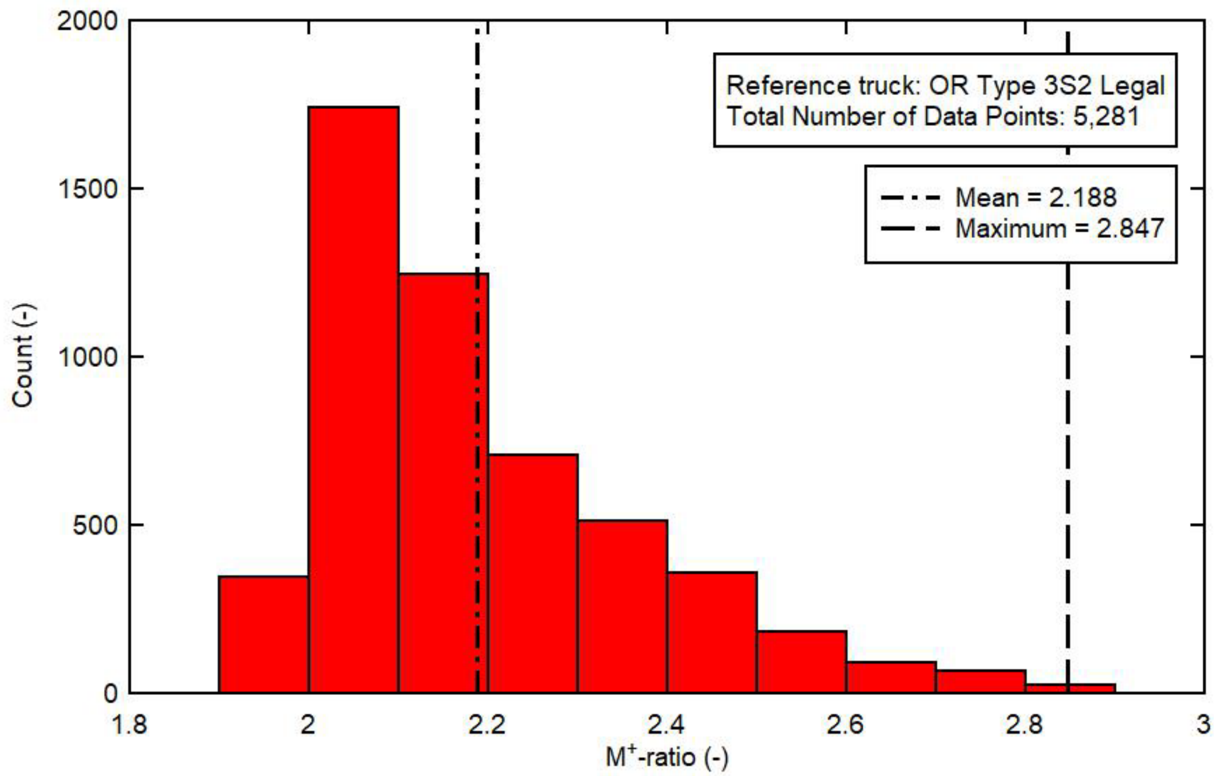


Figure B13. Histogram of maximum positive bending moment (the 95th percentile) normalized by OR Type 3S2 Legal Truck

Table B13. Count of maximum positive bending moment (the 95th percentile) normalized by OR Type 3S2 Legal Truck

Class	Count
1.90	346
2.00	1742
2.10	1245
2.20	708
2.30	514
2.40	359
2.50	185
2.60	91
2.70	67
2.80	24

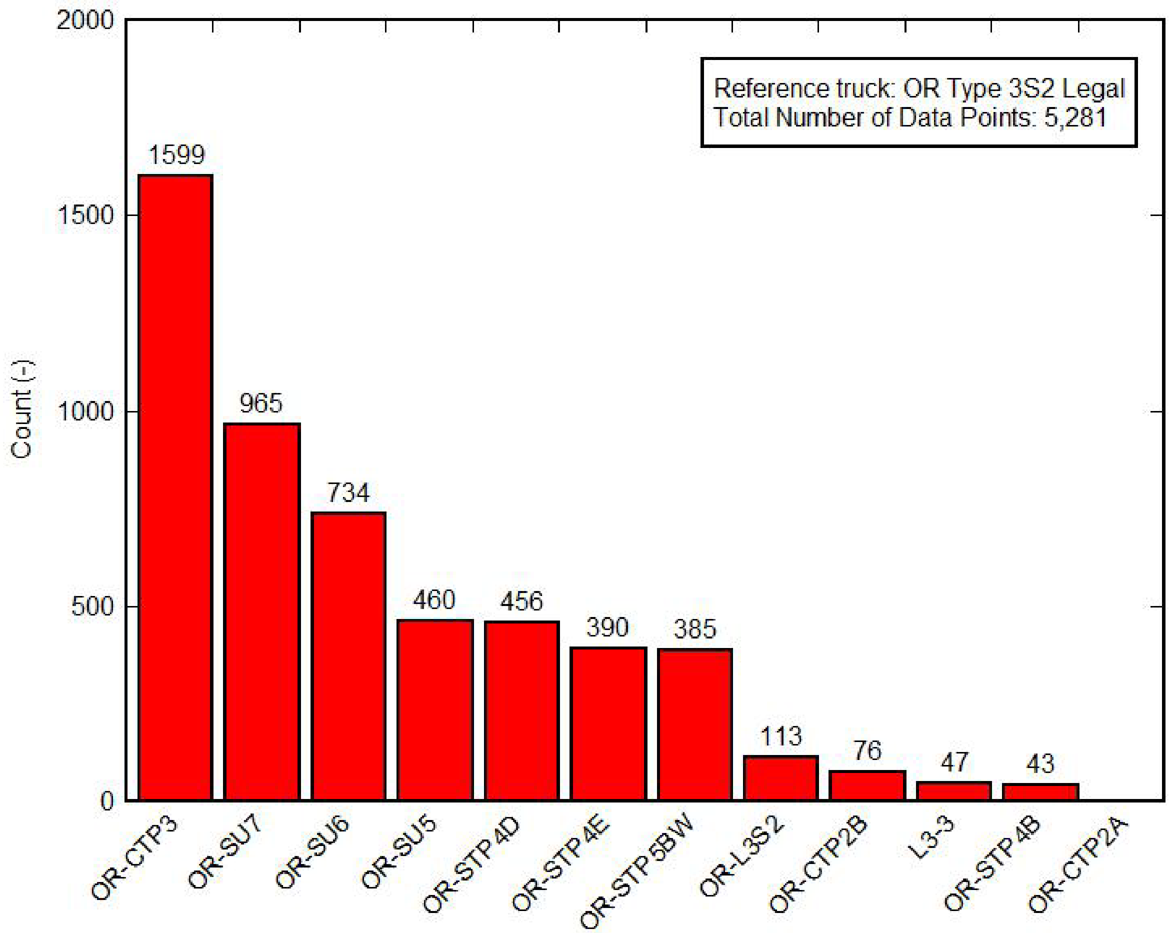


Figure B14. Histogram of maximum positive bending by truck type (the 95th percentile) normalized by OR Type 3S2 Legal Truck

Table B14. Count of maximum positive bending by truck type (the 95th percentile) normalized by OR Type 3S2 Legal Truck

Truck Type	Count
CTP3	1599
SU7	965
SU6	734
SU5	460
STP4D	456
STP4E	390
STP5BW	385
Lega13S2	113
CTP2B	76
Lega133	47
STP4B	43
CTP2A	13

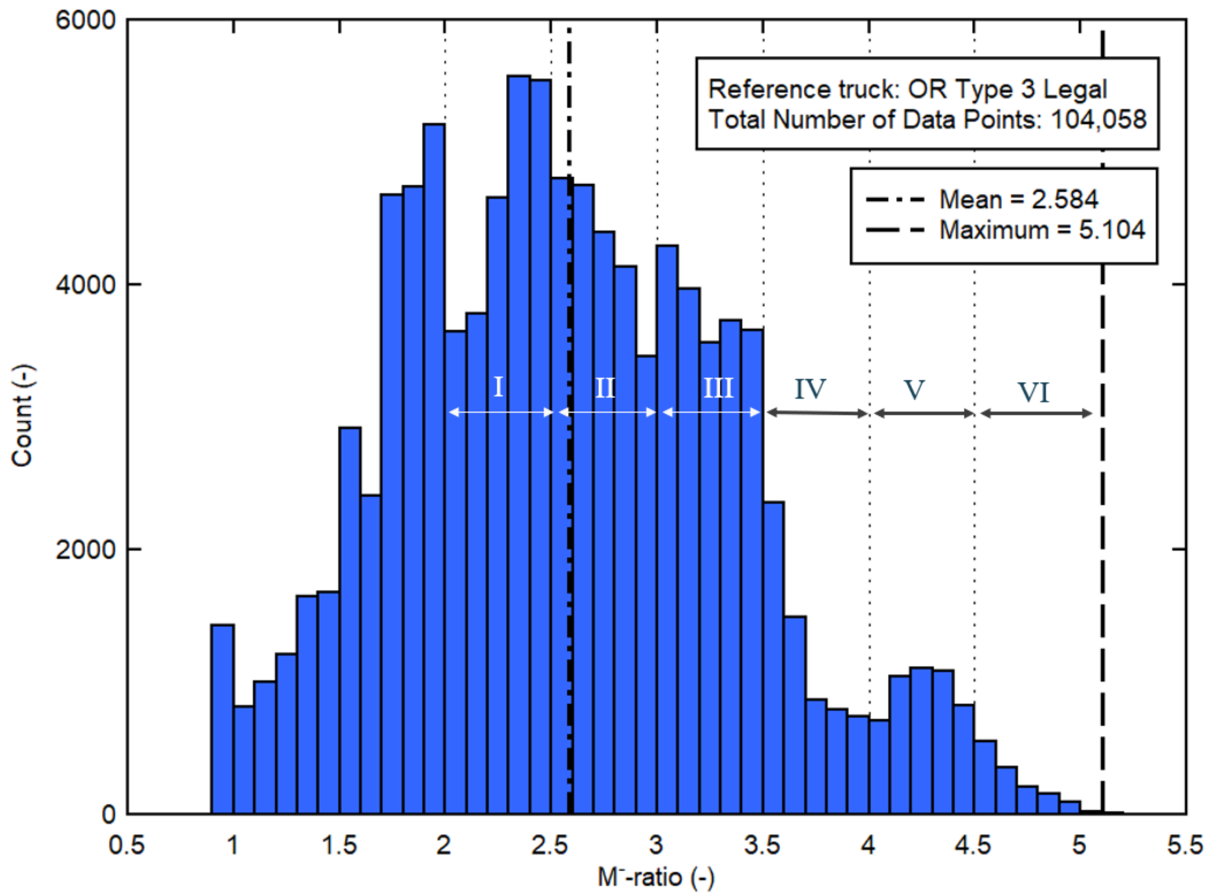


Figure B15. Histogram of maximum negative bending moment ratio (full database) normalized by OR Type 3 Legal Truck

Table B15. Count of maximum negative bending moment ratio (full database) normalized by OR Type 3 Legal Truck

Class	Count	Class	Count	Class	Count	Class	Count
0.90	1427	2.00	3649	3.10	3965	4.20	1108
1.00	810	2.10	3787	3.20	3568	4.30	1080
1.10	995	2.20	4663	3.30	3735	4.40	823
1.20	1209	2.30	5571	3.40	3653	4.50	550
1.30	1649	2.40	5533	3.50	2352	4.60	351
1.40	1681	2.50	4802	3.60	1493	4.70	204
1.50	2921	2.60	4746	3.70	860	4.80	153
1.60	2406	2.70	4392	3.80	794	4.90	93
1.70	4679	2.80	4142	3.90	740	5.00	18
1.80	4742	2.90	3458	4.00	708	5.10	13
1.90	5205	3.00	4291	4.10	1039		

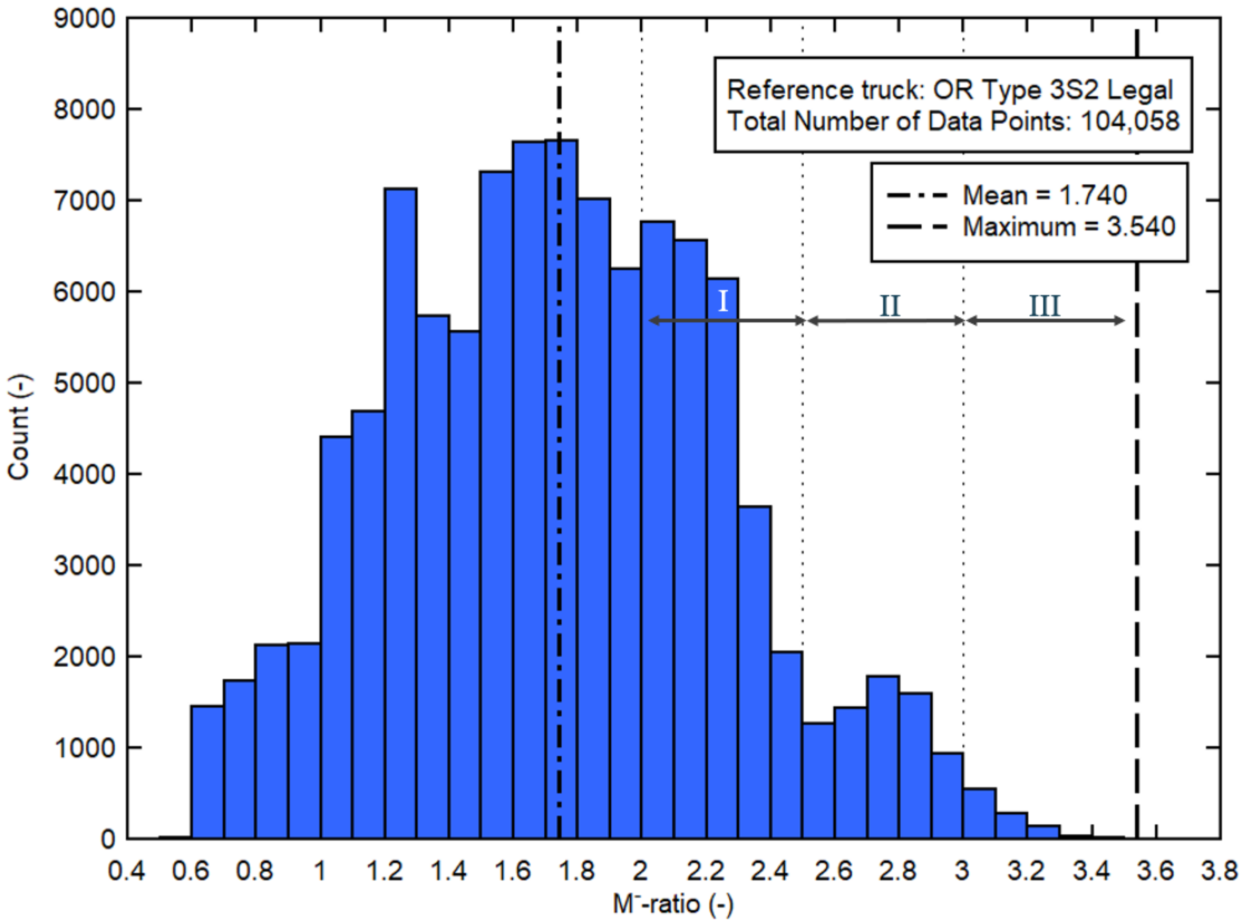


Figure B16. Histogram of maximum negative bending moment ratio (full database) normalized by OR Type 3S2 Legal Truck

Table B16. Count of maximum negative bending moment ratio (full database) normalized by OR Type 3S2 Legal Truck

Class	Count	Class	Count	Class	Count
0.50	18	1.60	7644	2.70	1788
0.60	1449	1.70	7655	2.80	1591
0.70	1732	7.80	7020	2.90	938
0.80	2125	1.90	6254	3.00	552
0.90	2148	2.00	6773	3.10	286
1.00	4404	2.10	6564	3.20	135
1.10	4682	2.20	6146	3.30	28
1.20	7121	2.30	3636	3.40	8
1.30	5733	2.40	2053	3.50	4
1.40	5567	2.50	1258		
1.50	7309	2.60	1437		

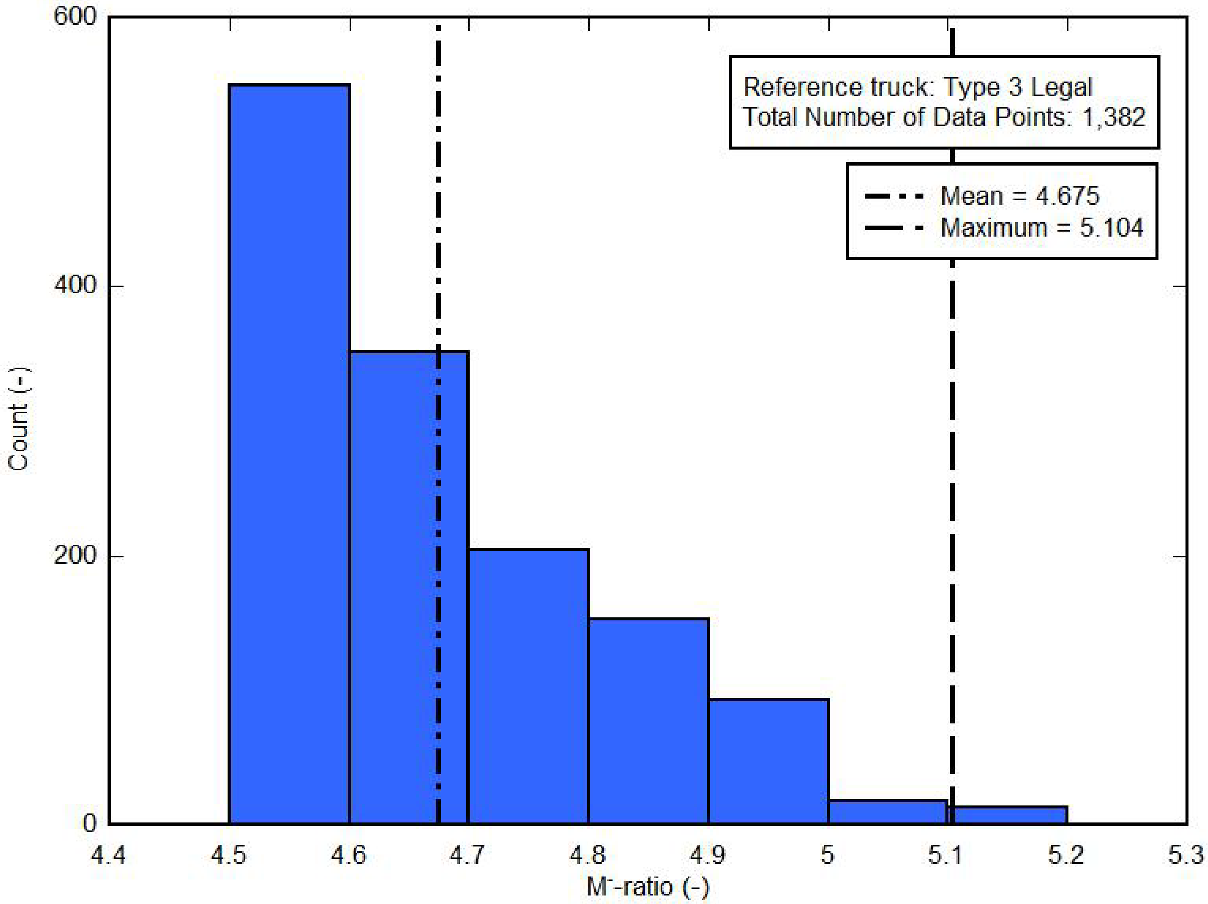


Figure B17. Histogram of maximum negative bending moment ratio (4.5+ ratio) normalized by OR Type 3 Legal Truck

Table B17. Count of maximum negative bending moment ratio (4.5+ ratio) normalized by OR Type 3 Legal Truck

Class	Count
4.50	550
4.60	351
4.70	204
4.80	153
4.90	93
5.00	18
5.10	13

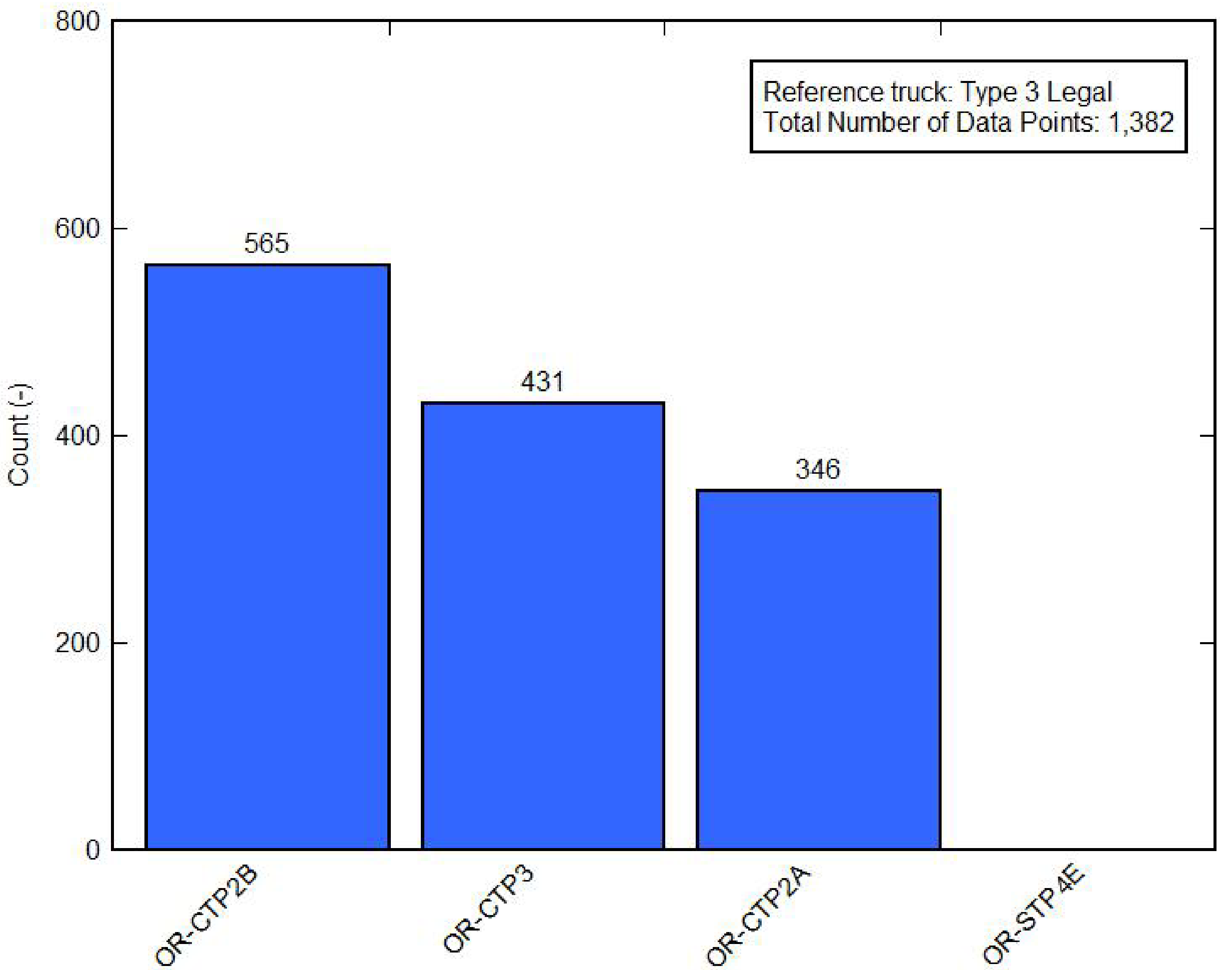


Figure B18. Histogram of maximum negative bending moment by truck type (4.5+ ratio) normalized by OR Type 3 Legal Truck

Table B18. Count of maximum negative bending moment by truck type (2.0+ ratio) normalized by OR Type 3 Legal Truck

Truck Type	Count
CTP2B	565
CTP3	431
CTP2A	346
STP4E	40

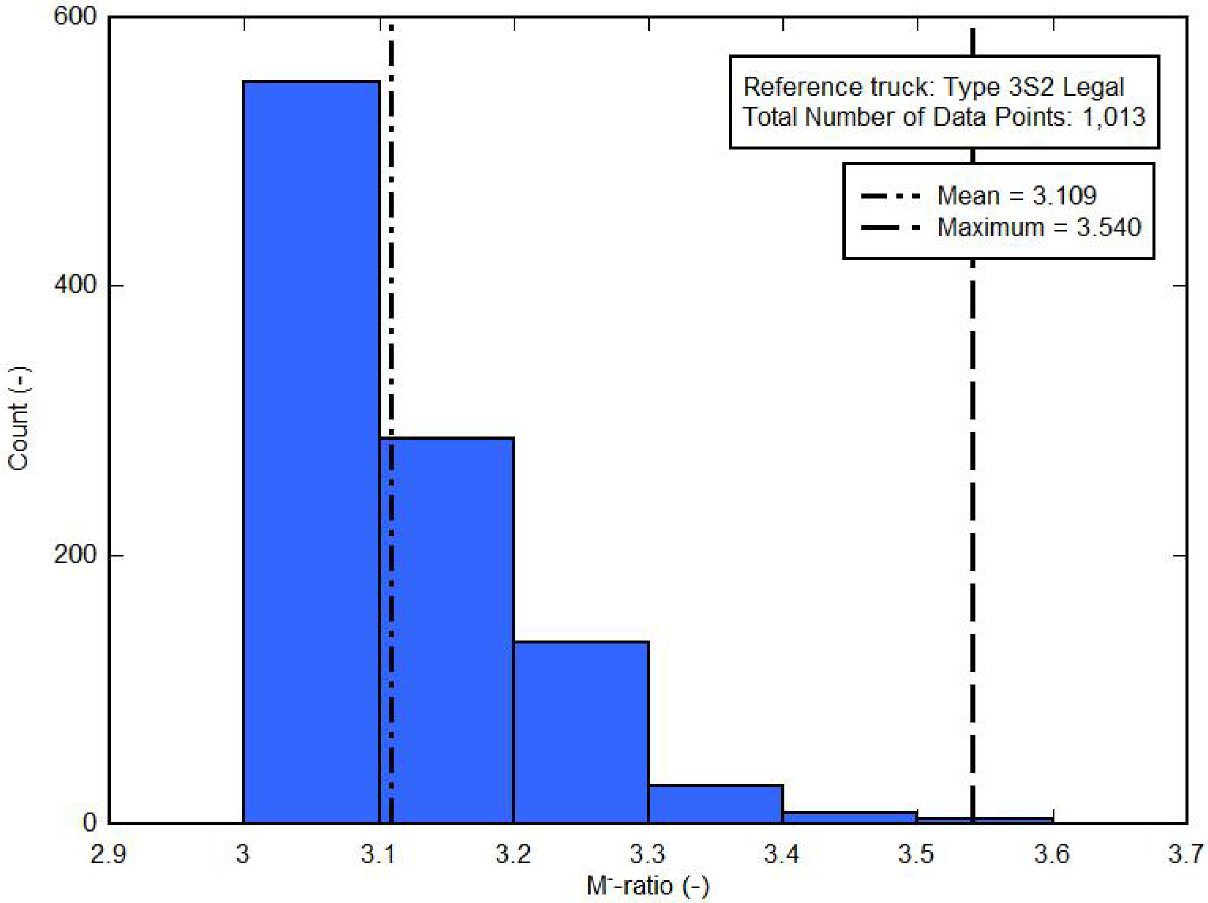


Figure B19. Histogram of maximum negative bending moment ratio (3.0+ ratio) normalized by OR Type 3S2 Legal Truck

Table B19. Count of maximum negative bending moment ratio (3.0+ ratio) normalized by OR Type 3S2 Legal Truck

Class	Count
3.00	552
3.10	286
3.20	135
3.30	28
3.40	8
3.50	4

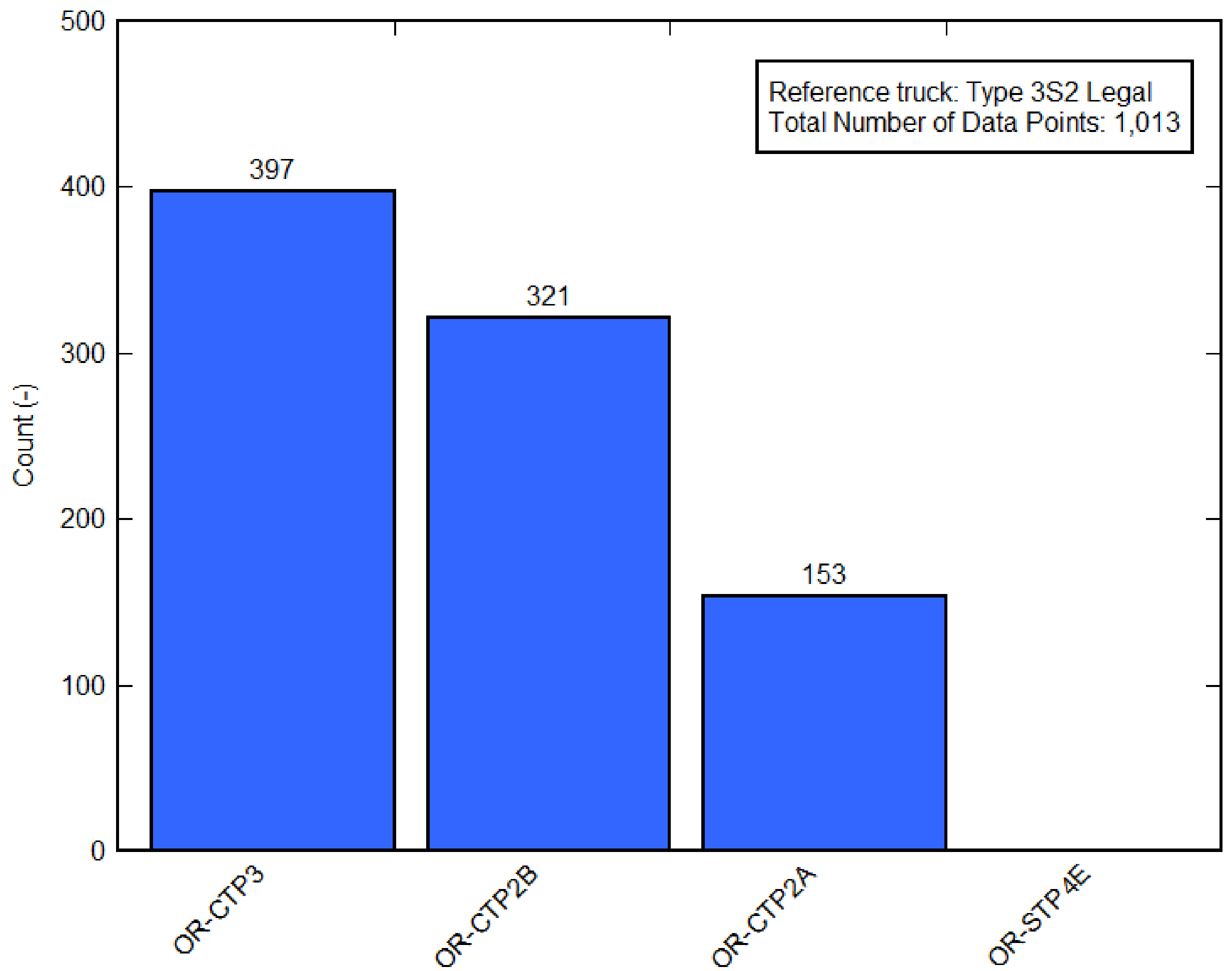


Figure B20. Histogram of maximum negative bending moment (the 95th percentile) normalized by OR Type 3 Legal Truck

Table B20. Count of maximum negative bending moment (the 95th percentile) normalized by OR Type 3 Legal Truck

Truck Type	Count
CTP3	397
CTP2B	321
CTP2A	153
STP4E	142

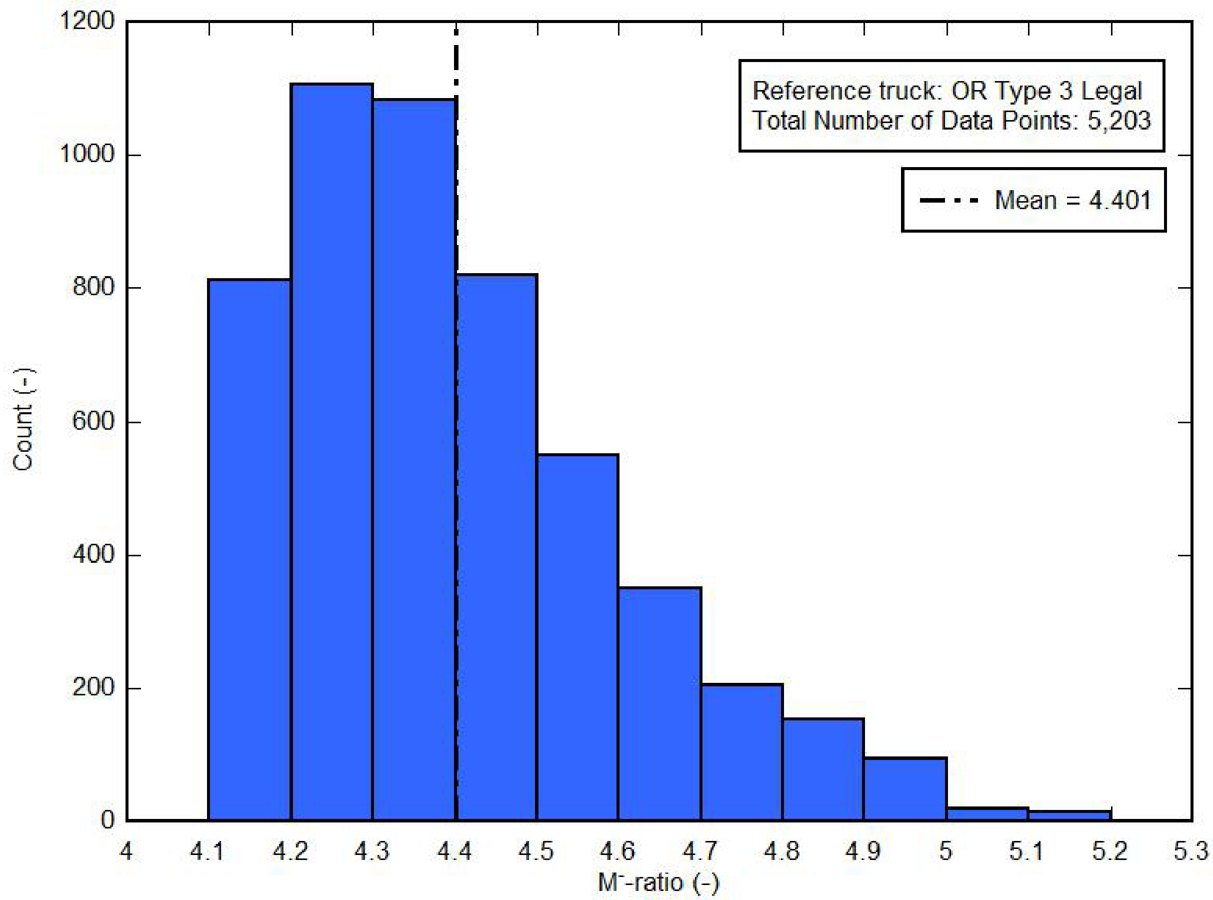


Figure B21. Histogram of maximum negative bending moment (the 95th percentile) normalized by OR Type 3 Legal Truck

Table B21. Count of maximum negative bending moment (the 95th percentile) normalized by OR Type 3 Legal Truck

Class	Count
4.10	812
4.20	1106
4.30	1083
4.40	820
4.50	550
4.60	351
4.70	204
4.80	153
4.90	93
5.00	18
5.10	13

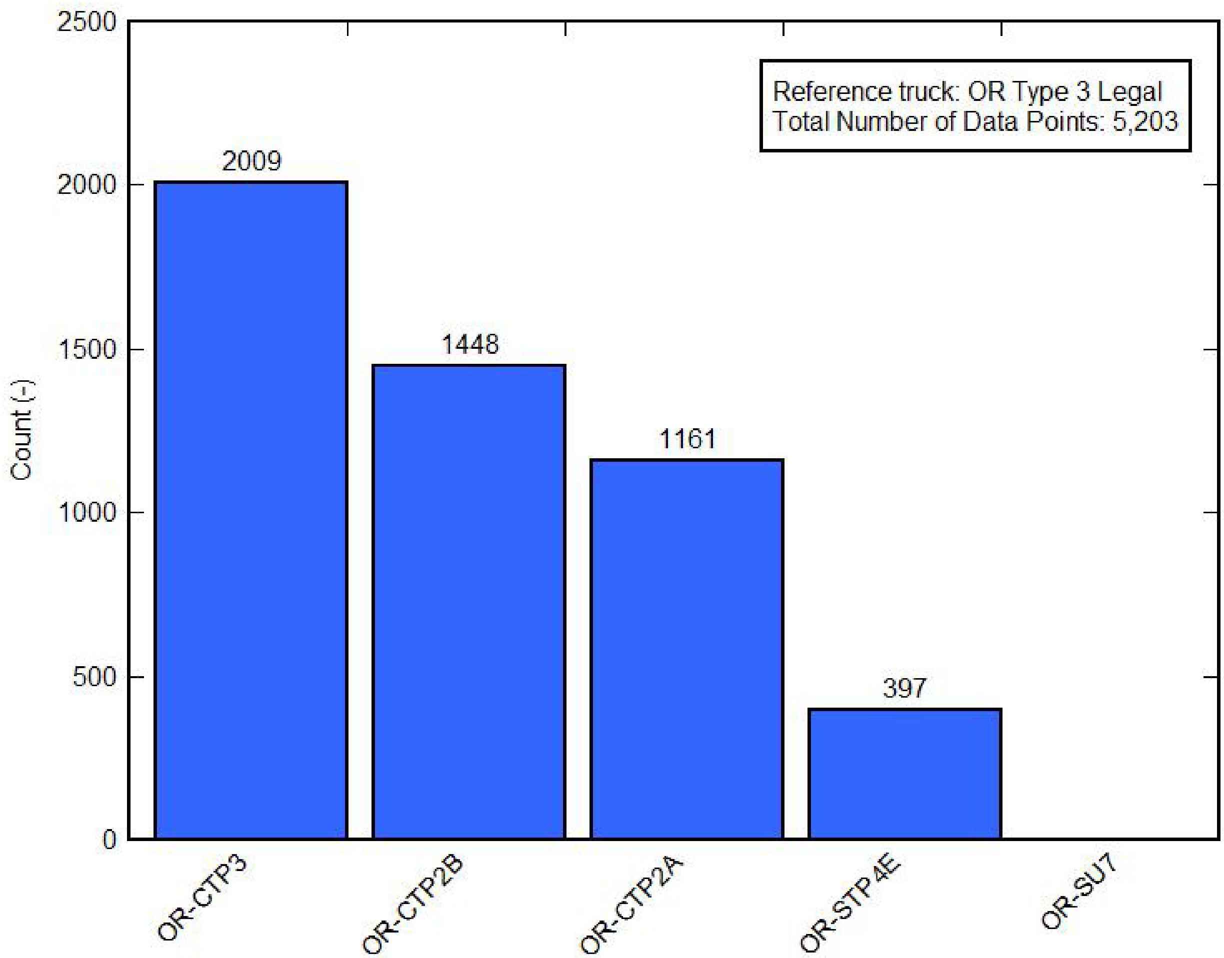


Figure B22. Histogram of maximum negative bending by truck type (the 95th percentile) normalized by OR Type 3 Legal Truck

Table B22. Count of maximum negative bending by truck type (the 95th percentile) normalized by OR Type 3 Legal Truck

Truck Type	Count
CTP3	2009
CTP2B	1448
CTP2A	1161
STP4E	397
SU7	188

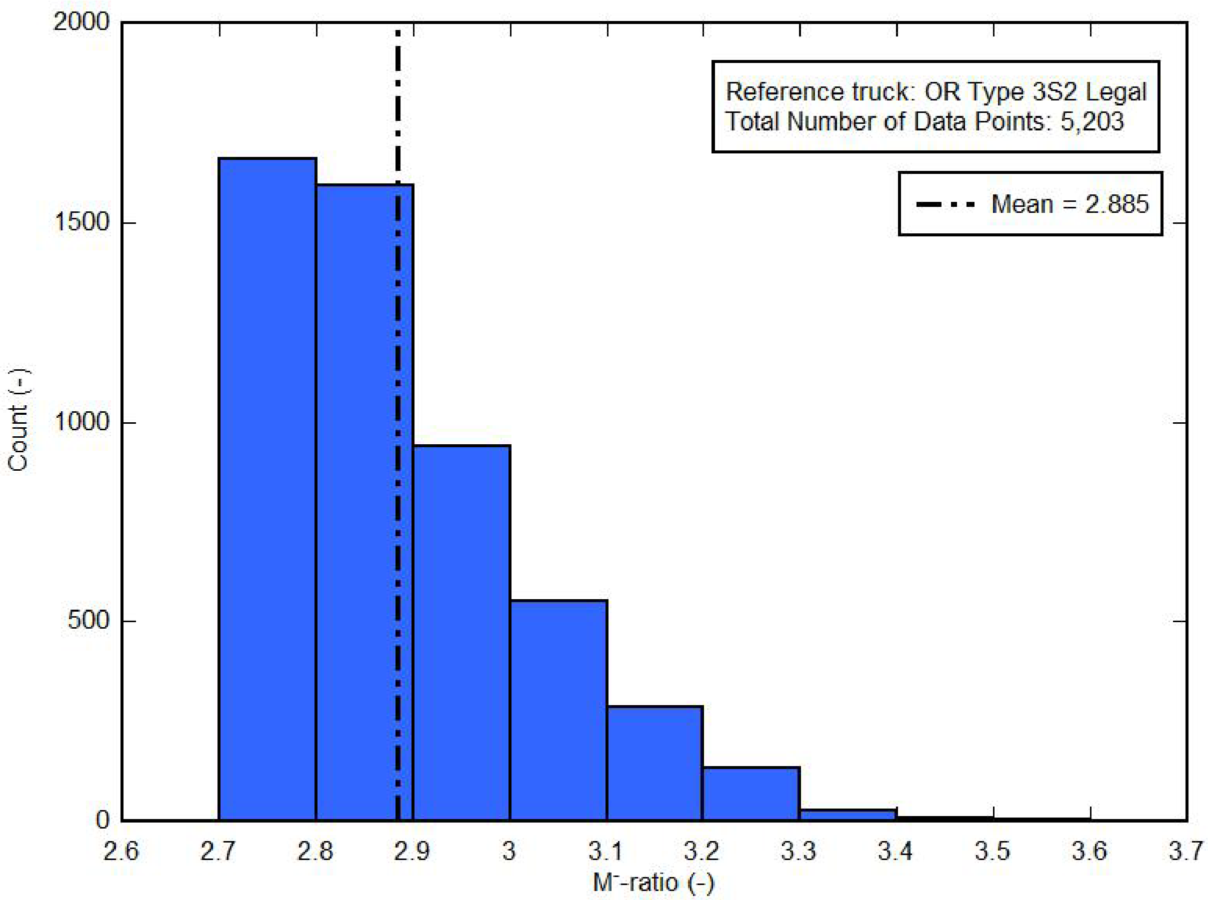


Figure B23. Histogram of maximum negative bending moment (the 95th percentile) normalized by OR Type 3S2 Legal Truck

Table B23. Count of maximum negative bending moment (the 95th percentile) normalized by OR Type 3S2 Legal Truck

Class	Count
2.70	1661
2.80	1591
2.90	938
3.00	552
3.10	286
3.20	135
3.30	28
3.40	8
3.50	4

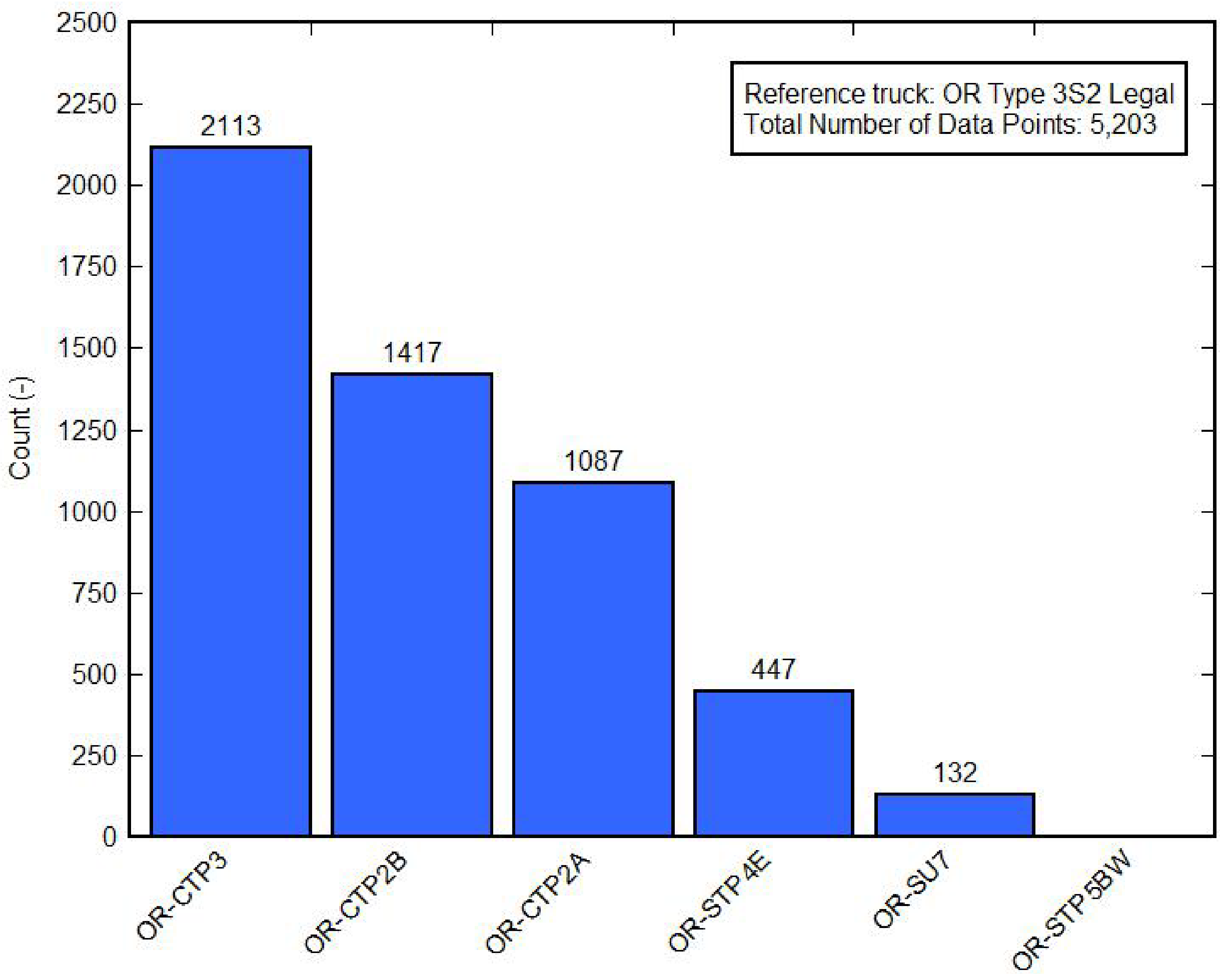


Figure B24. Histogram of maximum negative bending by truck type (the 95th percentile) normalized by OR Type 3S2 Legal Truck

Table B24. Count of maximum negative bending by truck type (the 95th percentile) normalized by OR Type 3S2 Legal Truck

Truck Type	Count
CTP3	2113
CTP2B	1417
CTP2A	1087
STP4E	447
SU7	132
STP5BW	7

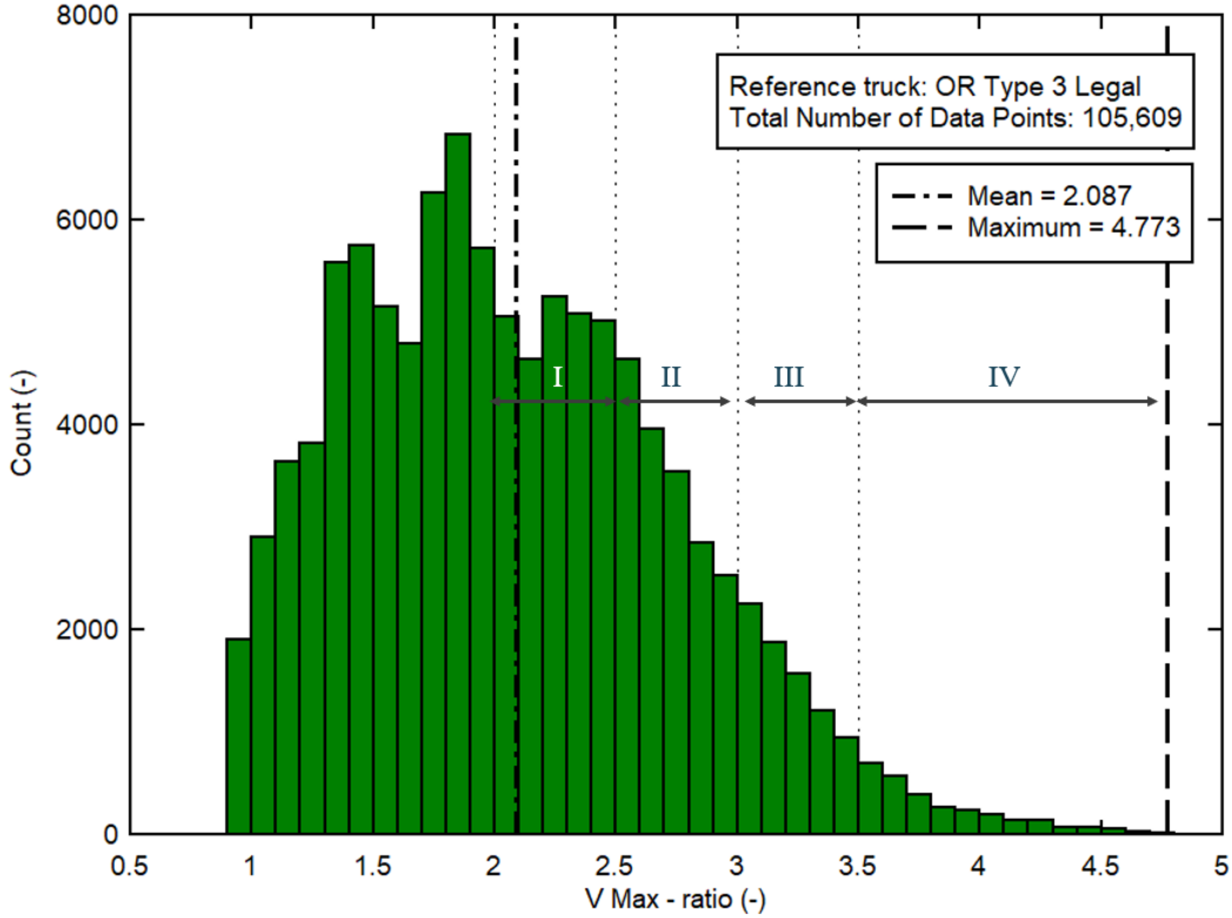


Figure B25. Histogram of maximum shear ratio (full database) normalized by OR Type 3 Legal Truck

Table B25. Count of maximum shear ratio (full database) normalized by OR Type 3 Legal Truck

Class	Count	Class	Count	Class	Count
0.90	1900	2.20	5252	3.50	696
1.00	2906	2.30	5077	3.60	566
1.10	3645	2.40	5019	3.70	389
1.20	3826	2.50	4638	3.80	266
1.30	5590	2.60	3956	3.90	242
1.40	5744	2.70	3540	4.00	195
1.50	5147	2.80	2845	4.10	136
1.60	4794	2.90	2534	4.20	144
1.70	6257	3.00	2244	4.30	63
1.80	6830	3.10	1874	4.40	68
1.90	5725	3.20	1570	4.50	53
2.00	5052	3.30	1207	4.60	30
2.10	4633	3.40	943	4.70	13

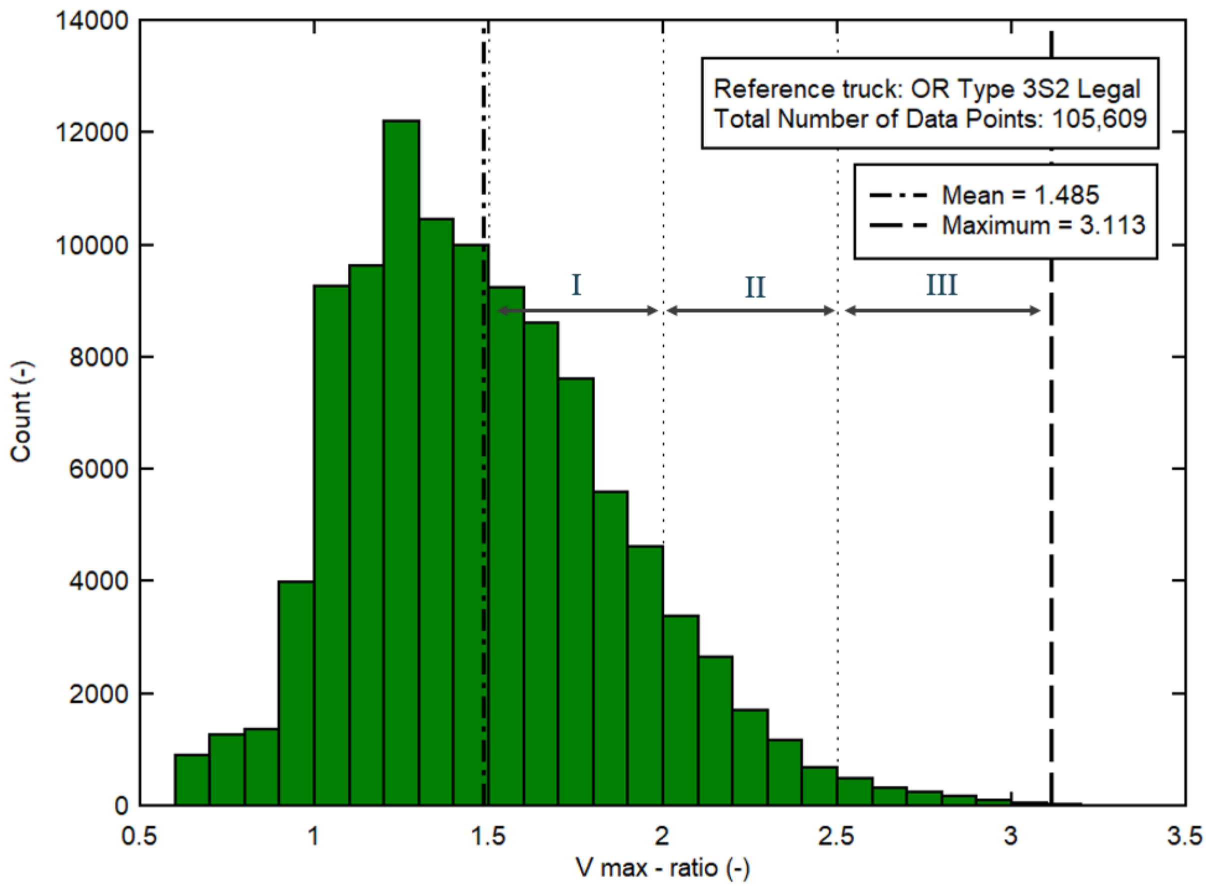


Figure B26. Histogram of maximum shear ratio (full database) normalized by OR Type 3S2 Legal Truck

Table B26. Count of maximum shear ratio (full database) normalized by OR Type 3S2 Legal Truck

Class	Count
0.60	892
0.70	1275
0.80	1360
0.90	3984
1.00	9266
1.10	9614
1.20	12202
1.30	10444
1.40	9981
1.50	9229
1.60	8611
1.70	7587
1.80	5602

Class	Count
1.90	4621
2.00	3377
2.10	2662
2.20	1699
2.30	1167
2.40	670
2.50	487
2.60	316
2.70	234
2.80	179
2.90	99
3.00	44
3.10	13

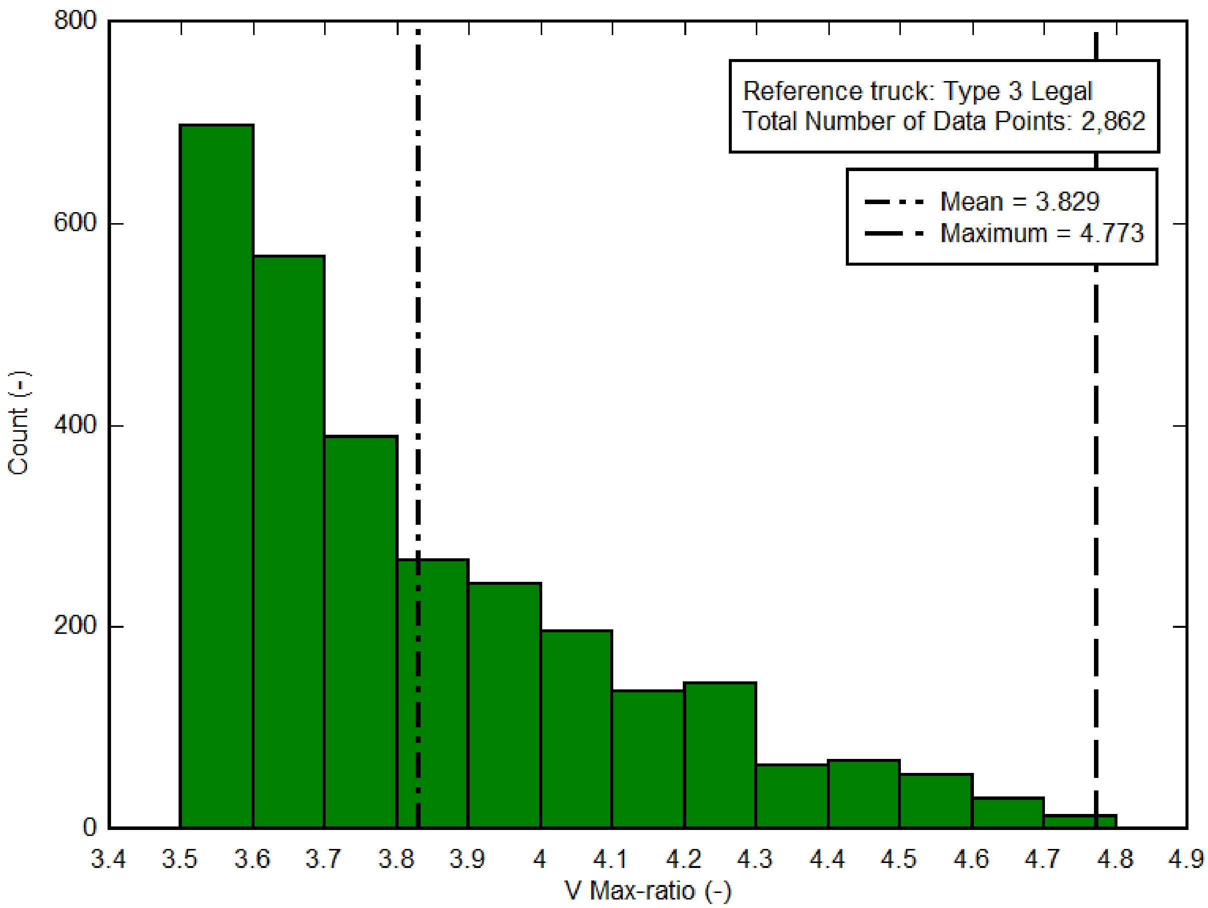


Figure B27. Histogram of maximum shear ratio (3.5+ ratio) normalized by OR Type 3 Legal Truck

Table B27. Count of maximum shear ratio (3.5+ ratio) normalized by OR Type 3 Legal Truck

Class	Count
3.50	697
3.60	566
3.70	389
3.80	266
3.90	242
4.00	195
4.10	136
4.20	144
4.30	63
4.40	68
4.50	53
4.60	30
4.70	13

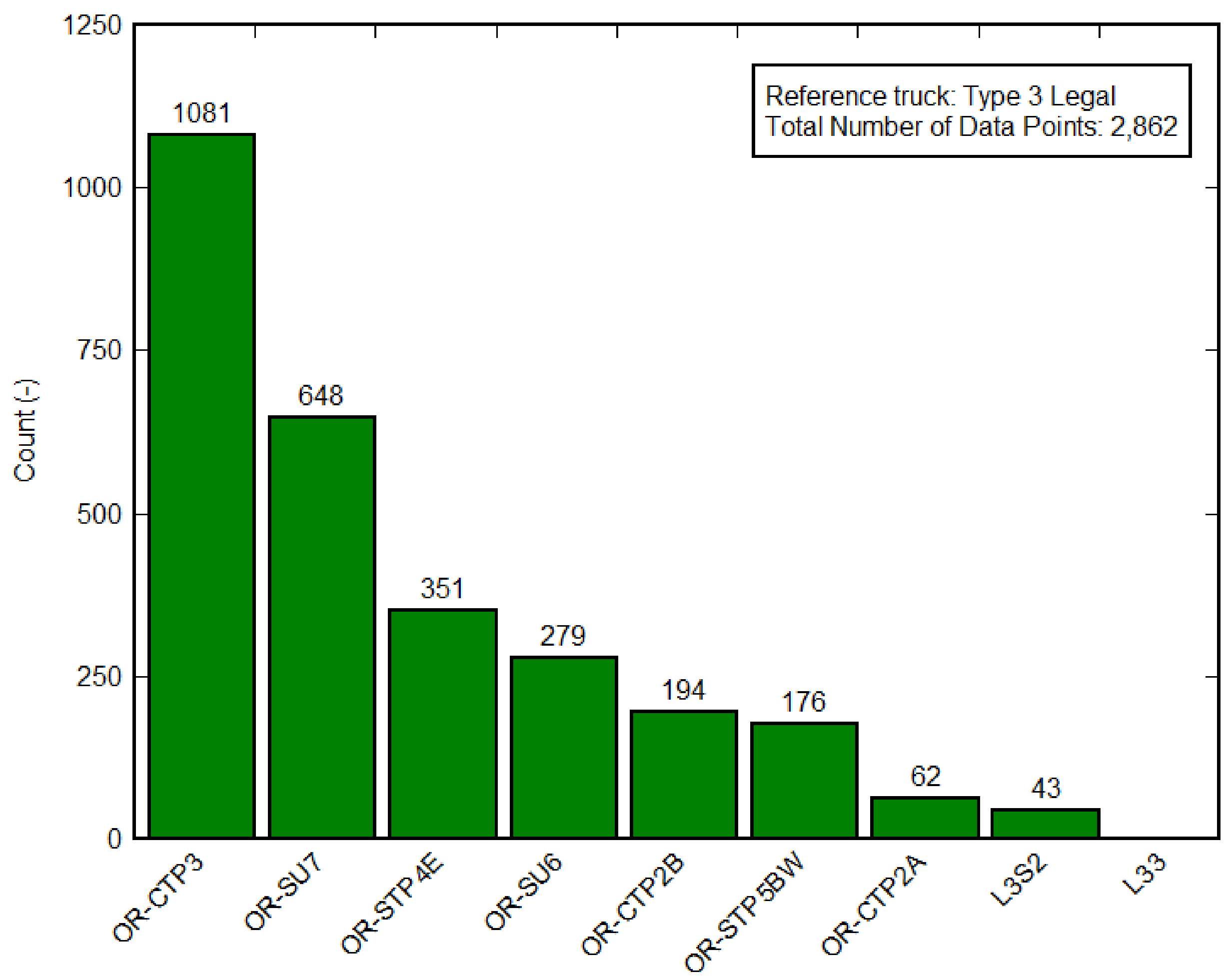


Figure B28. Histogram of maximum shear by truck type (3.5+ ratio) normalized by OR Type 3 Legal Truck

Table B28. Count of maximum shear by truck type (3.5+ ratio) normalized by OR Type 3 Legal Truck

Truck Type	Count
CTP3	1081
SU7	648
STP4E	351
SU6	279
CTP2B	194
STP5BW	176
CTP2A	62
Legal3S2	43
Legal33	28

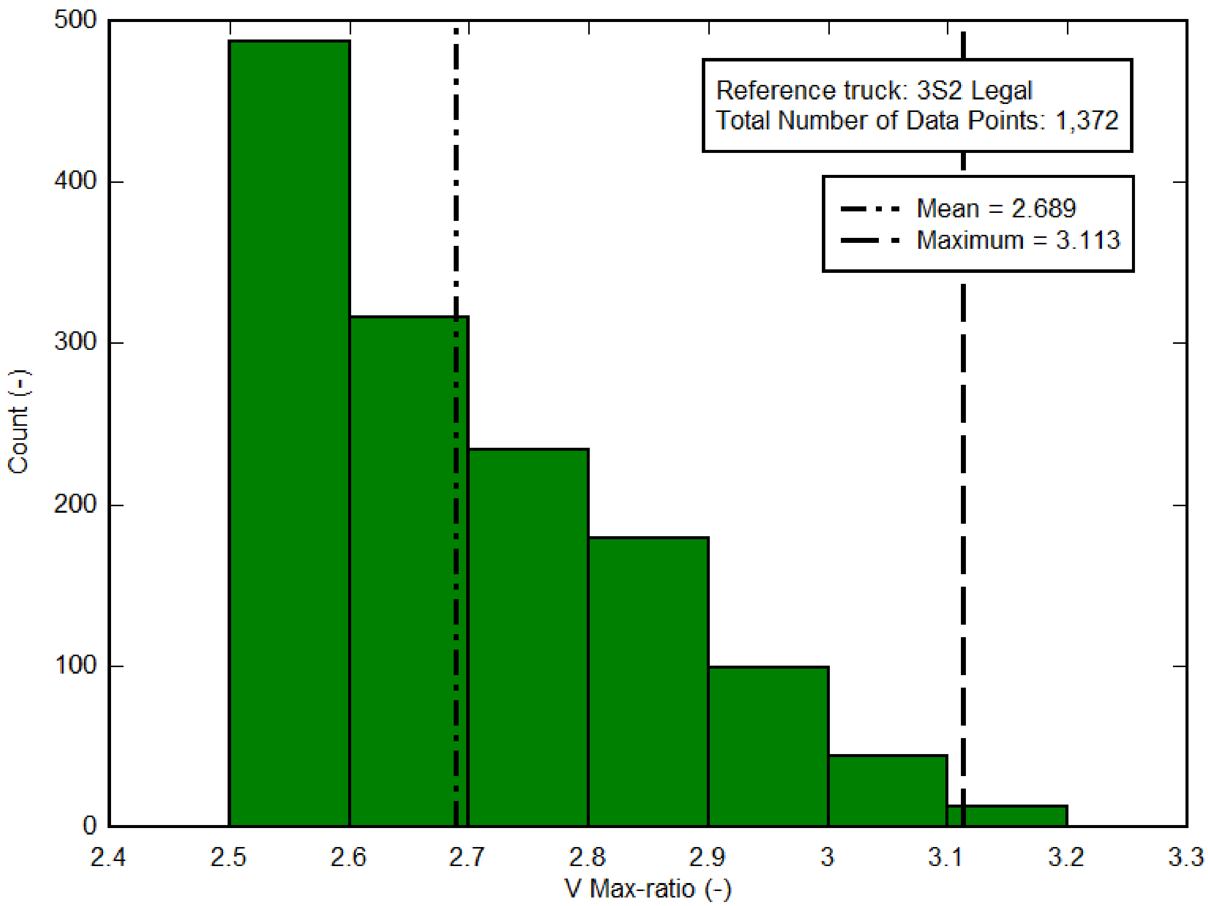


Figure B29. Histogram of maximum shear ratio (2.2+ ratio) normalized by OR Type 3S2 Legal Truck

Table B29. Count of maximum shear ratio (2.2+ ratio) normalized by OR Type 3S2 Legal Truck

Class	Count
2.50	487
2.60	316
2.70	234
2.80	179
2.90	99
3.00	44
3.10	13

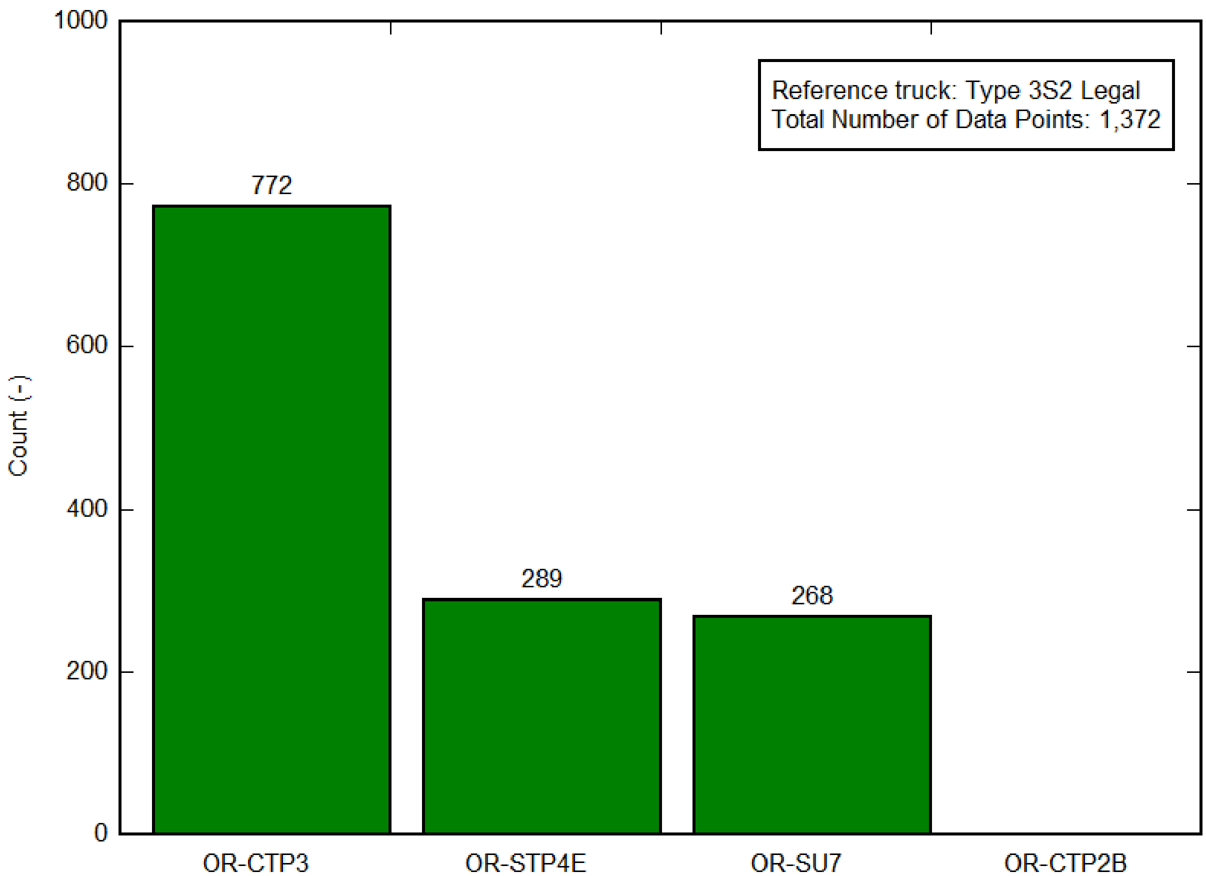


Figure B30. Histogram of maximum shear by truck type (2.5+ ratio) normalized by OR Type 3S2 Legal Truck

Table B30. Count of maximum shear by truck type (2.5+ ratio) normalized by OR Type 3S2 Legal Truck

Truck Type	Count
CTP3	772
STP4E	289
SU7	268
CTP2B	43

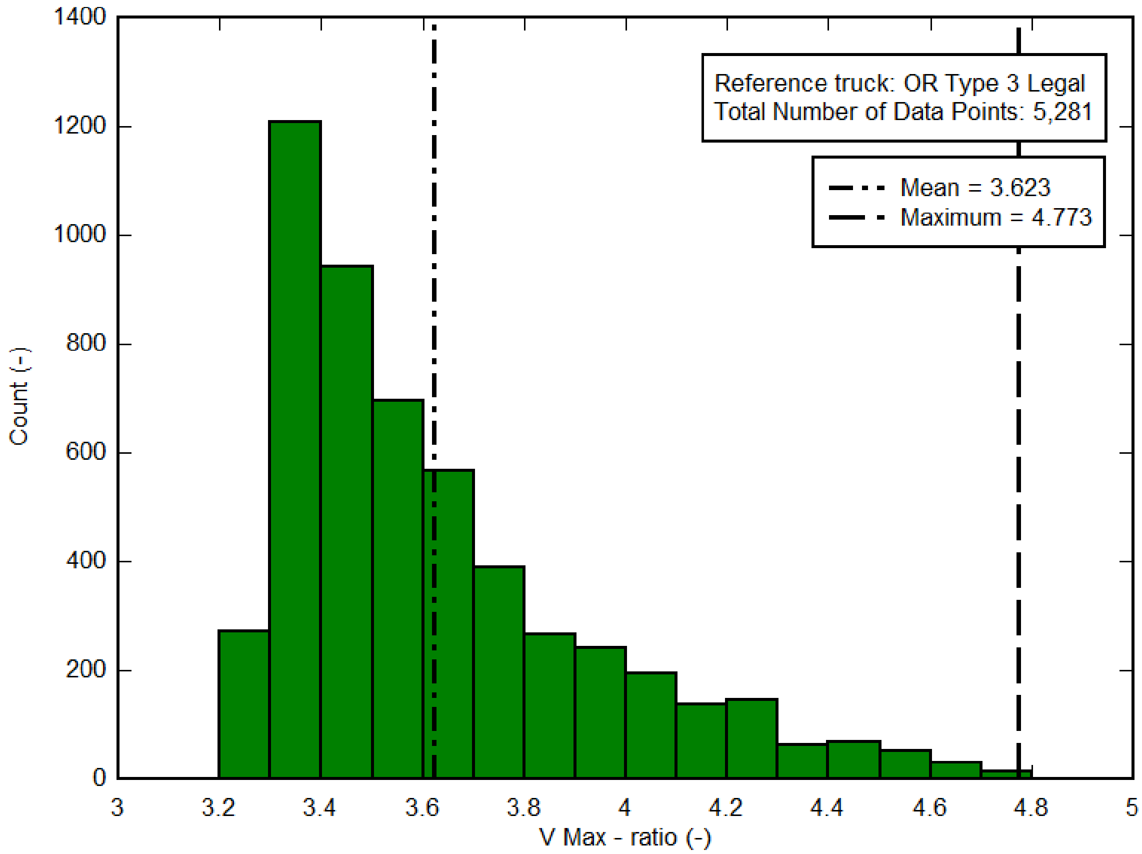


Figure B31. Histogram of maximum shear (the 95th percentile) normalized by OR Type 3 Legal Truck

Table B31. Count of maximum shear (the 95th percentile) normalized by OR Type 3 Legal Truck

Class	Count
3.20	271
3.30	1207
3.40	943
3.50	696
3.60	566
3.70	389
3.80	266
3.90	242
4.00	195
4.10	136
4.20	144
4.30	63
4.40	68
4.50	53
4.60	30
4.70	13

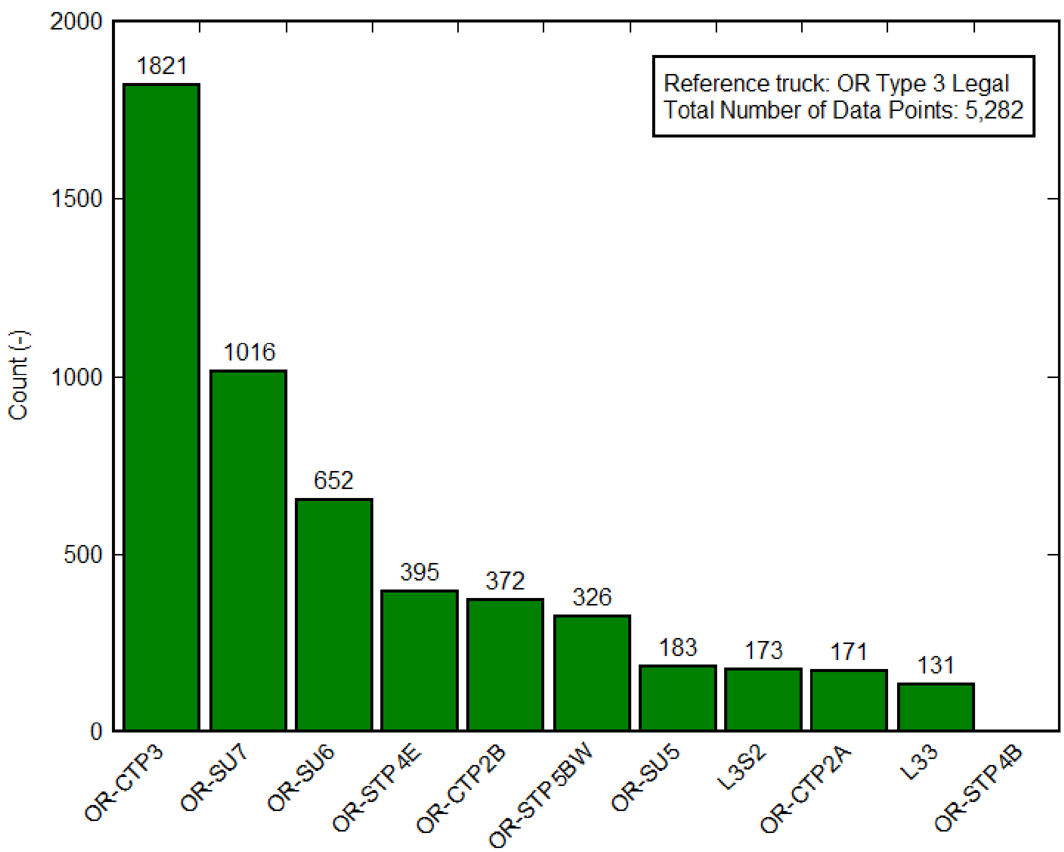


Figure B32. Histogram of maximum shear by truck type (the 95th percentile) normalized by OR Type 3 Legal Truck

Table B32. Count of maximum shear by truck type (the 95th percentile) normalized by OR Type 3 Legal Truck

Truck Type	Count
CTP3	1821
SU7	1016
SU6	652
STP4E	395
CTP2B	372
STP5BW	326
SU5	183
Lega13S2	173
CTP2A	171
Lega133	131
STP4B	42

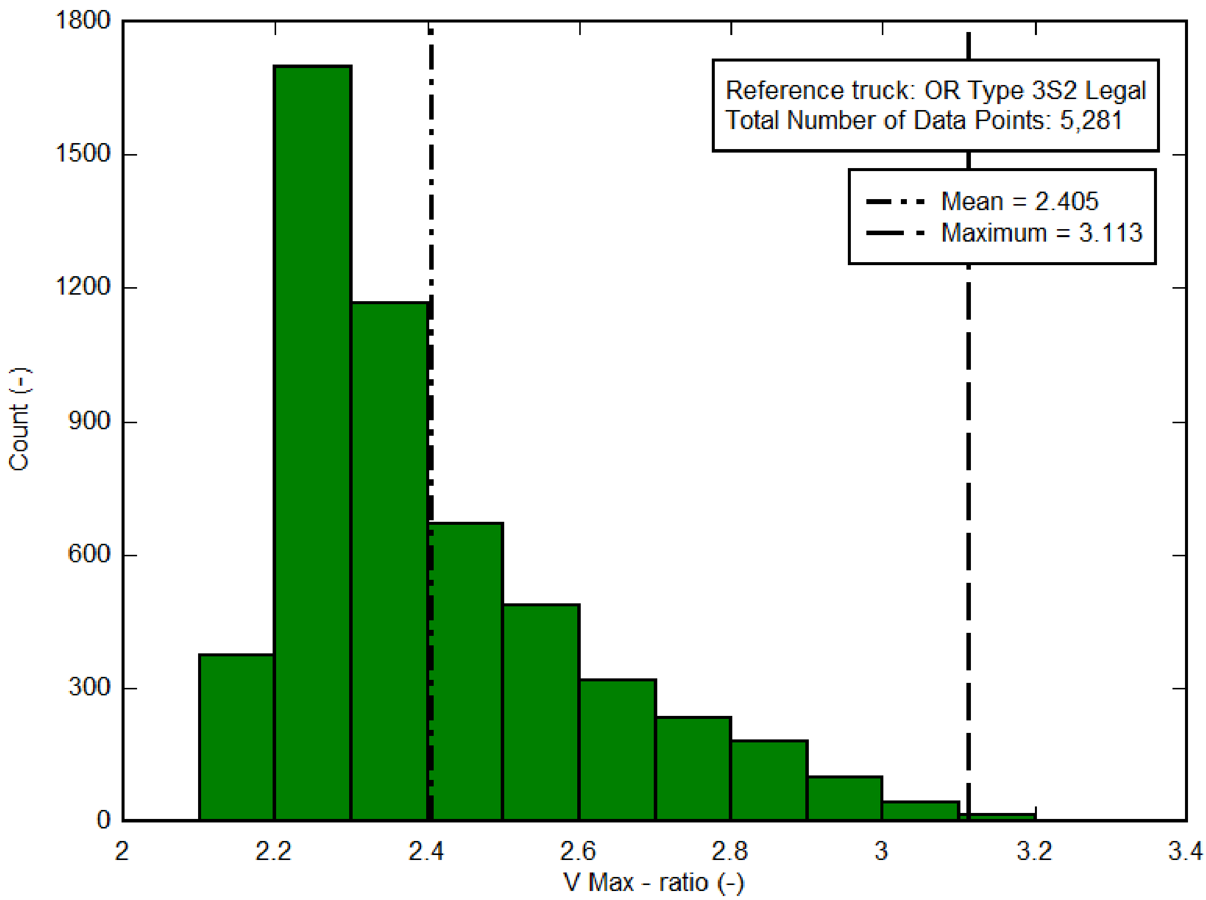


Figure B33. Histogram of maximum shear (the 95th percentile) normalized by OR Type 3S2 Legal Truck

Table B33. Count of maximum shear (the 95th percentile) normalized by OR Type 3S2 Legal Truck

Class	Count
2.10	373
2.20	1699
2.30	1167
2.40	670
2.50	487
2.60	316
2.70	234
2.80	179
2.90	99
3.00	44
3.10	13

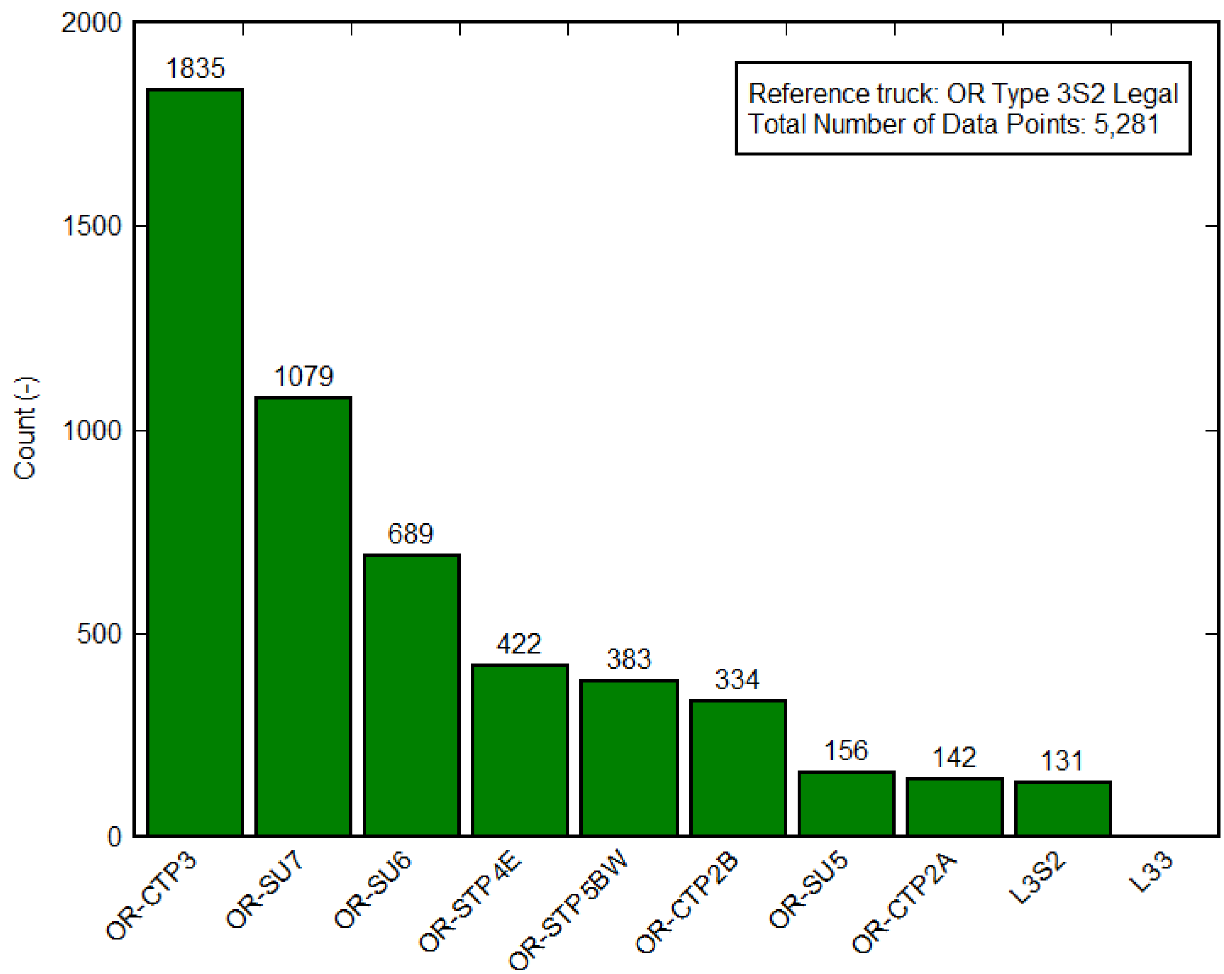


Figure B34. Histogram of maximum shear by truck type (the 95th percentile) normalized by OR Type 3S2 Legal Truck

Table B34. Count of maximum shear by truck type (the 95th percentile) normalized by OR Type 3S2 Legal Truck

Truck Type	Count
CTP3	1835
SU7	1079
SU6	689
STP4E	422
STP5BW	383
CTP2B	334
SU5	156
CTP2A	142
Lega13S2	131
Lega133	110

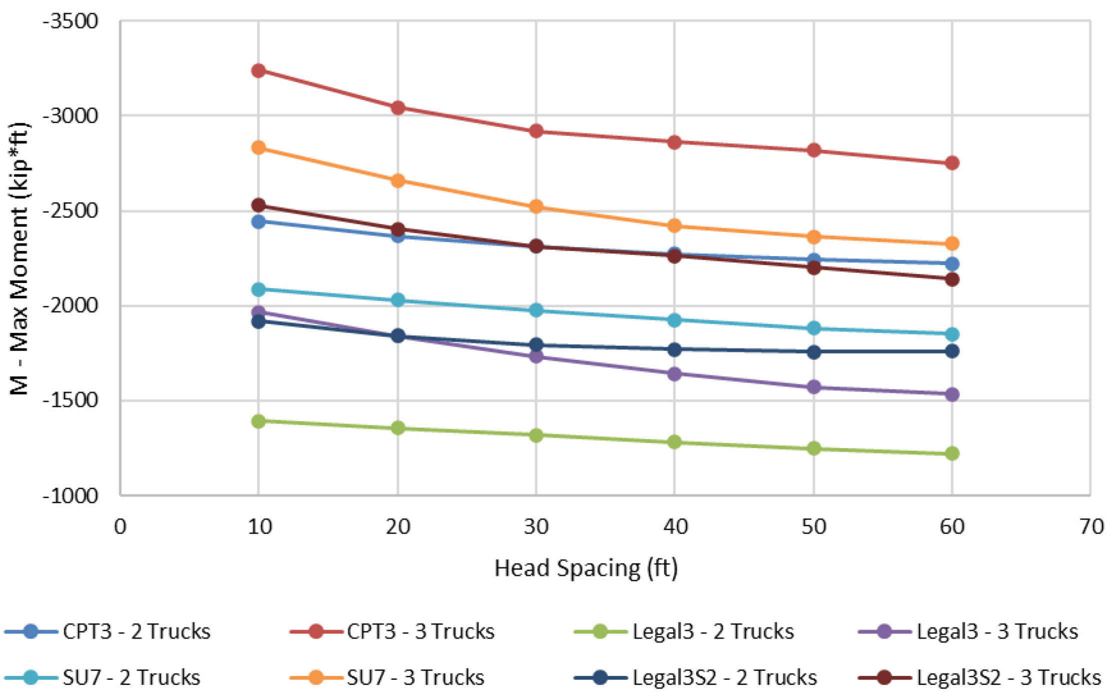


Figure B35: Effect of Head Spacing on Average Max Negative Moment of Two versus Three-Truck Platoons

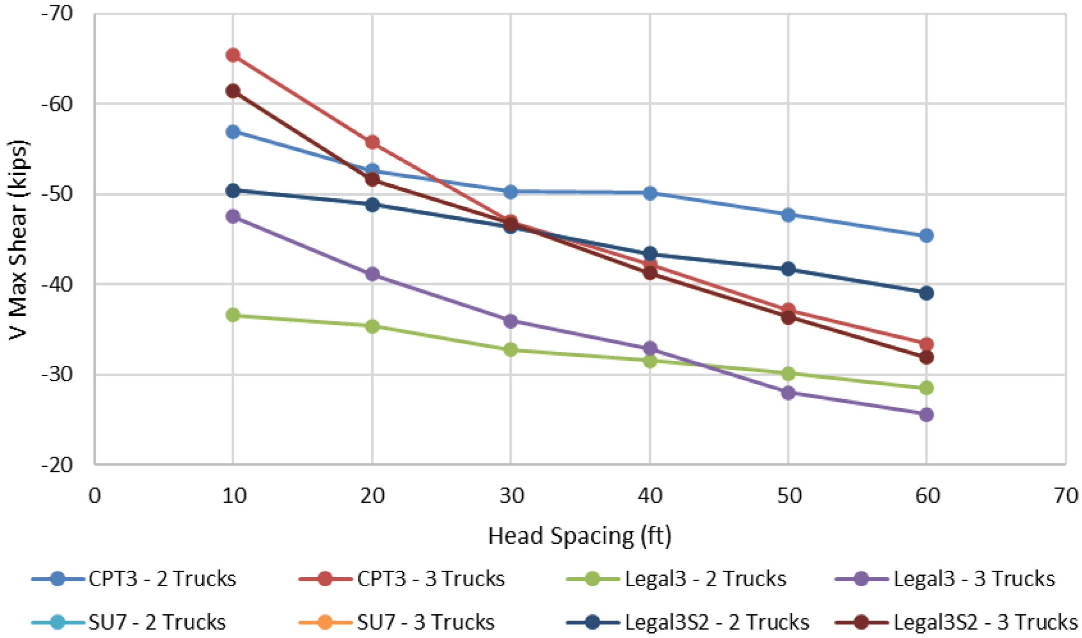


Figure B36: Effect of Head Spacing on Average Max Shear of Two versus Three-Truck Platoons

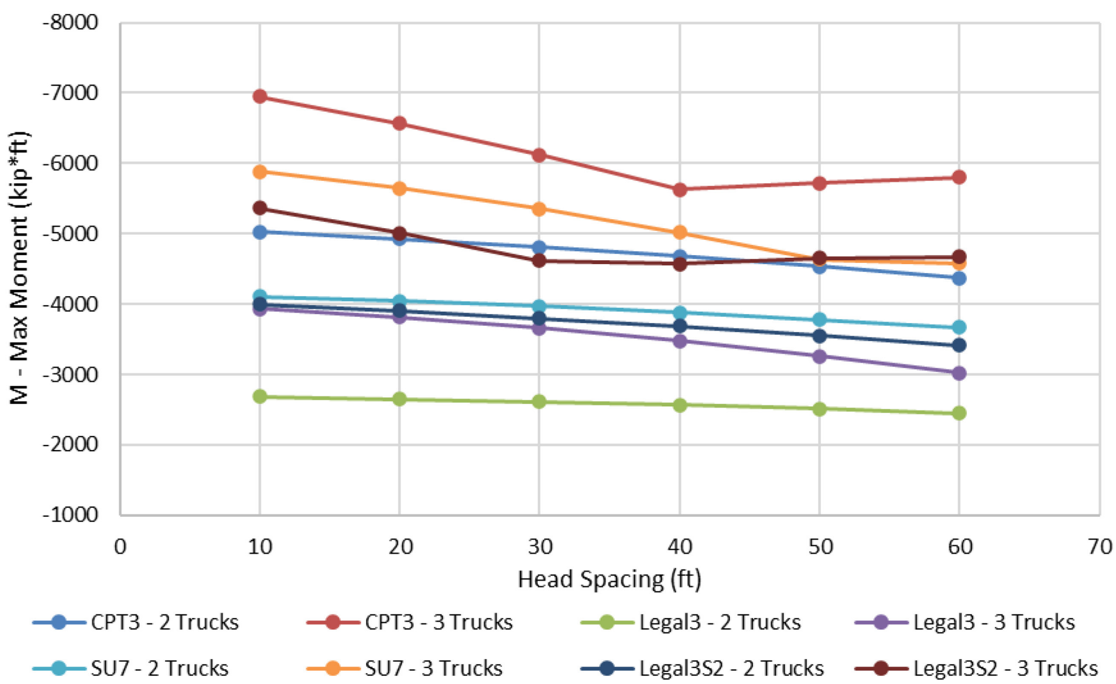


Figure B37: Effect of Head Spacing on Max Negative Moment of Two versus Three-Truck Platoons

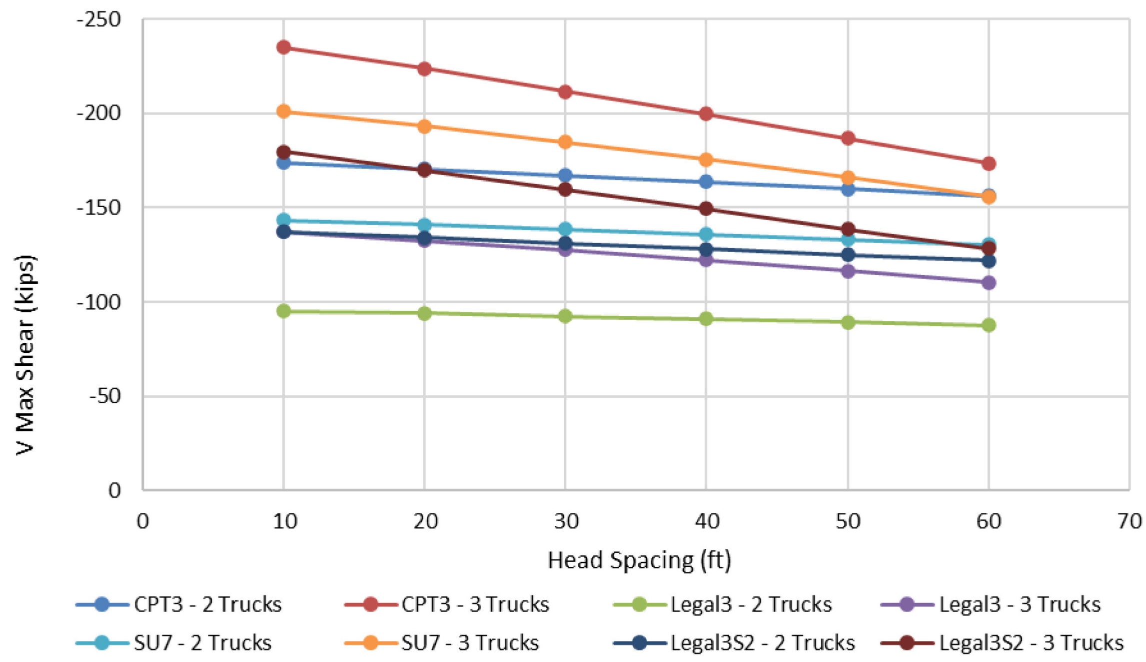


Figure B38: Effect of Head Spacing on Max Shear Moment of Two versus Three-Truck Platoons

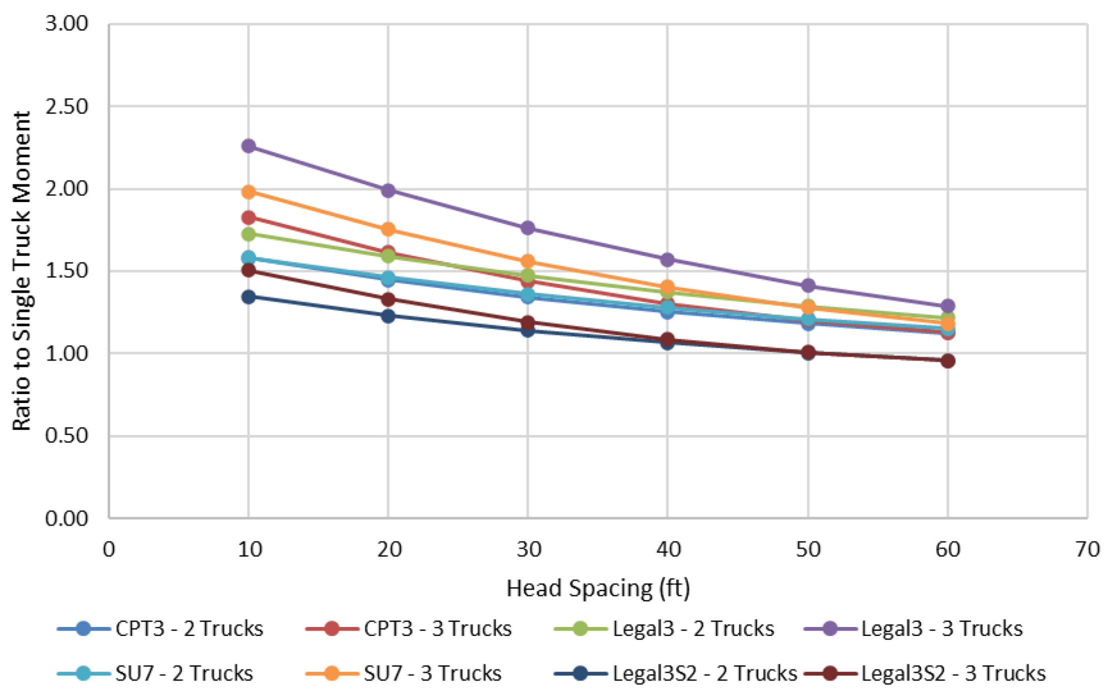


Figure B39: Effect of Head Spacing on Average Max Positive Moment of Single Truck Platoon Ratios for Two versus Three-Truck Platoons

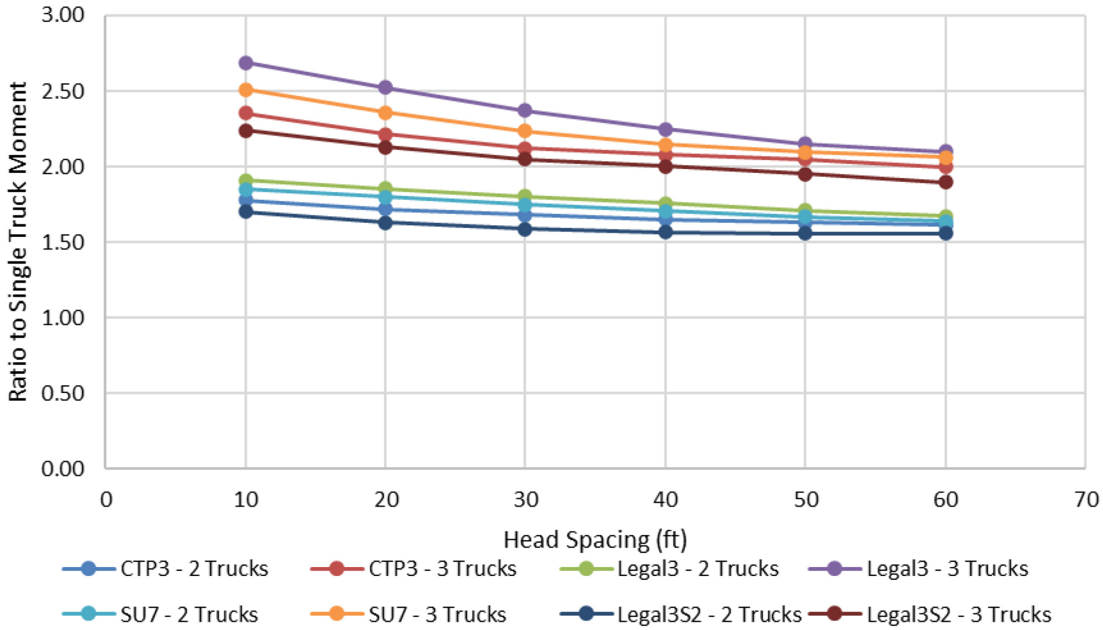


Figure B40: Effect of Head Spacing on Average Max Negative Moment of Single Truck Platoon Ratios for Two versus Three-Truck Platoons

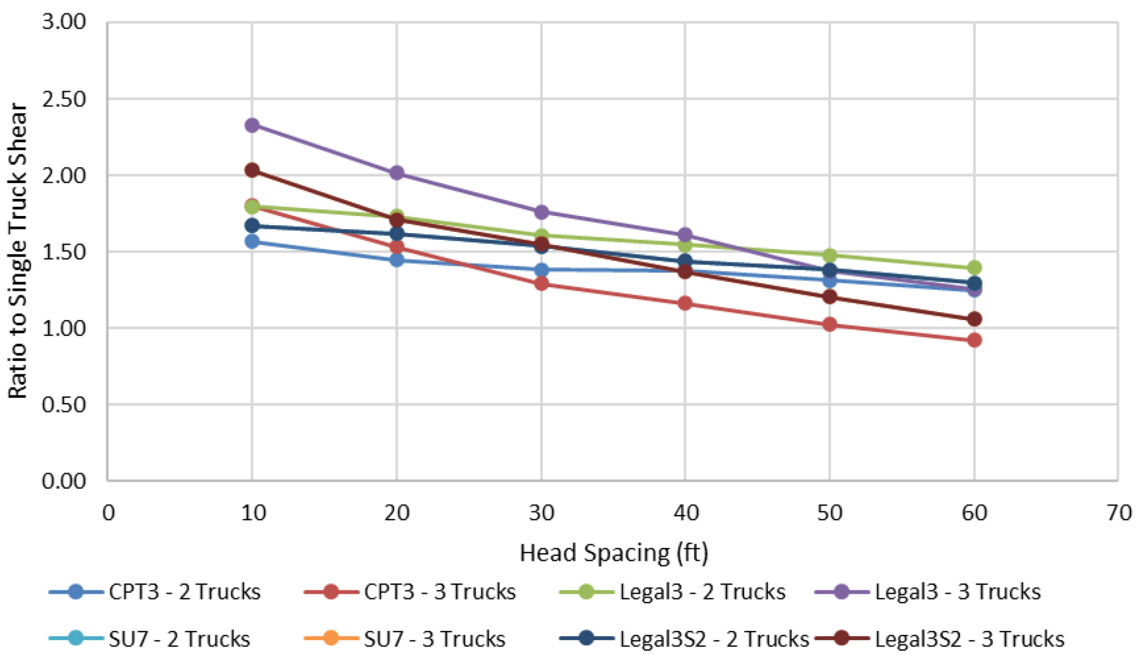


Figure B41: Effect of Head Spacing on Average Max Shear of Single Truck Platoon Ratios for Two versus Three-Truck Platoons

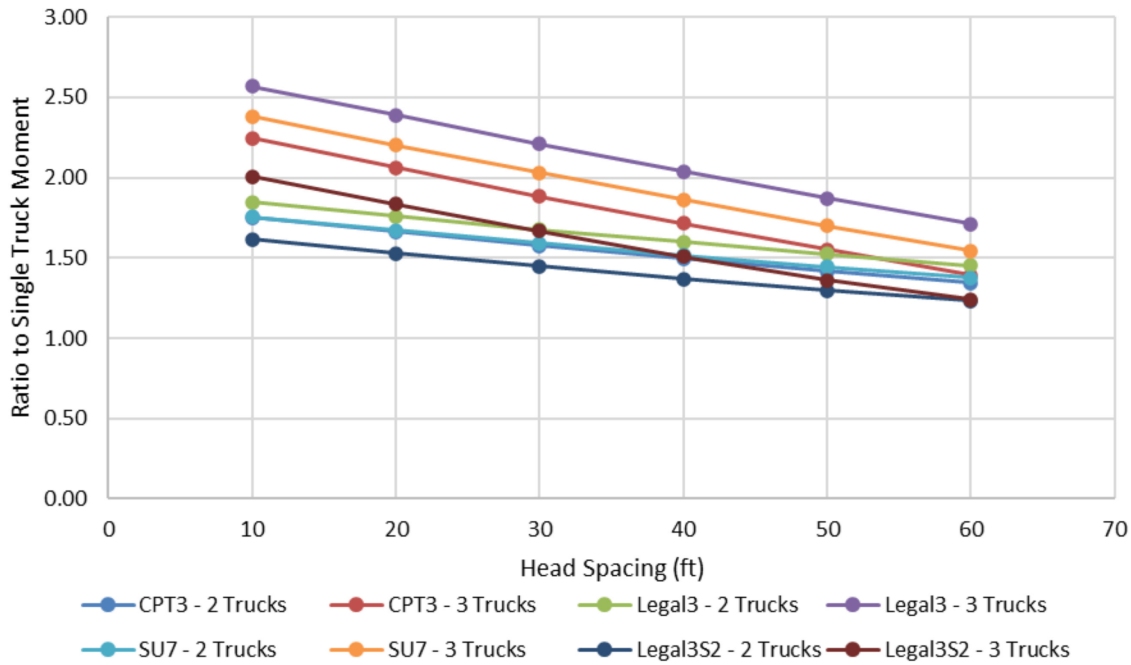


Figure B42: Effect of Head Spacing on Max Positive Moment of Single Truck Platoon Ratios for Two versus Three-Truck Platoons

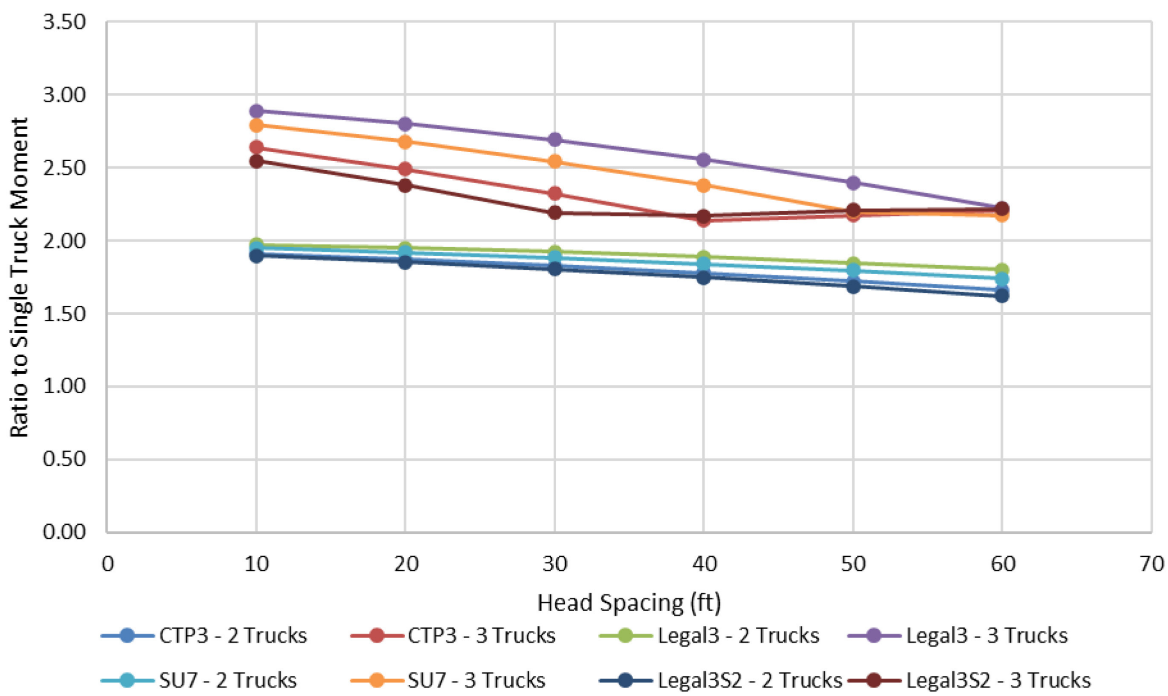


Figure B43: Effect of Head Spacing on Max Negative Moment of Single Truck Platoon Ratios for Two versus Three-Truck Platoons

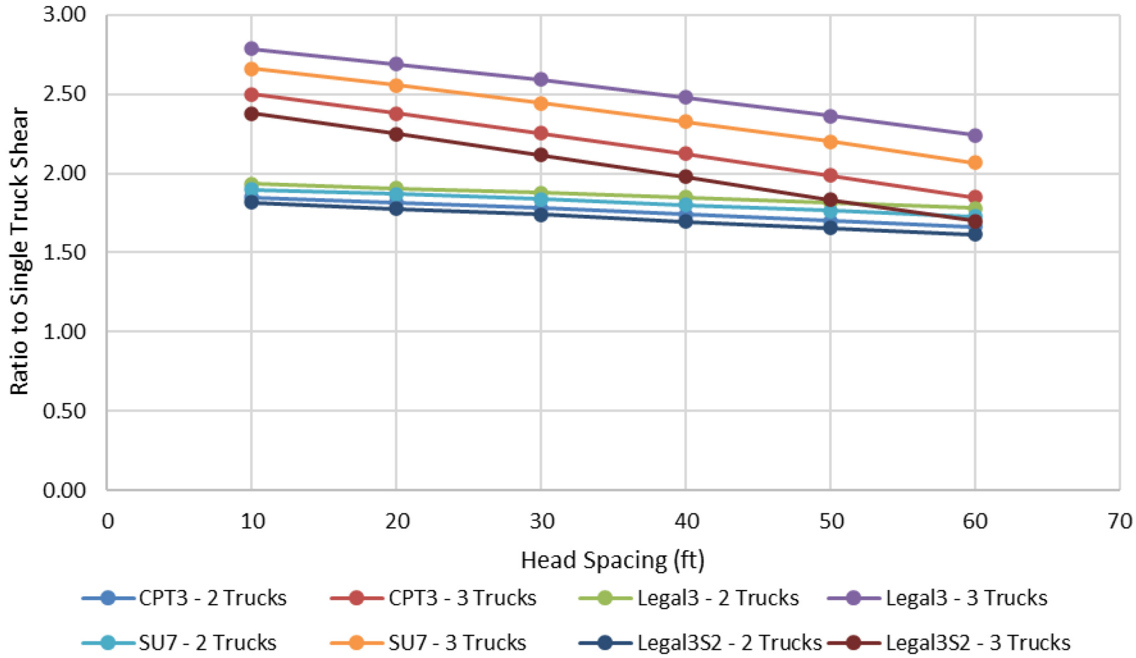


Figure B44: Effect of Head Spacing on Max Shear of Single Truck Platoon Ratios for Two versus Three-Truck Platoons

OREGON D.O.T. BRIDGE SECTION

TIER-2 LOAD RATING SUMMARY REPORT (PAGE 1)

Latest Revision 10/13/2010

BRIDGE DATA...

BRIDGE #: 20026 | NBI FEATURE: UPRR Main Line
BRIDGE NAME: Hwy 1 over UPRR Main Line
HIGHWAY NAME: Pacific Hwy | HIGHWAY #: 001
REGION: 2 | DIST: 03 | COUNTY: Marion | MILEPOST: 252.13

YEAR BUILT: 2006 | DESIGN LOADING: HL93 | OWNER: ODOT
SPAN DESCR: 1-91'10", 1-142'9" RCDG Prest Bulb-T
OTHER DESCR: 15-DgSkw

LOAD RATING ENGINEER DATA...

RATING DATE: 1/6/11 | FIRM: ODOT | LOAD RATER: JPM | CALCULATION BOOK: -

LATEST INSPECTION DATA...

INSP. DATE: 8/5/10 | ADT: 64,100 | ADTT: 10,897 | YEAR of ADT (2 digits): 08 | A.C. DEPTH, INCHES: 0.0
CONDITION RATINGS ----> DECK: 7 | SUPERSTR.: 8 | SUBSTR.: 8 | IMPACT ASSESSMENT (Elem. 325): CS1 | WEAR. SURFACE (Elem. 326): CS1

RATING DATA...

LRFR FACTORS: IMPACT 1+I: 1.10 | γ_{DC} 1.25 | γ_{DW} 1.25
LRFR RATINGS FOR N.B.I.: INVENTORY (Item 66): Tons 54.7 | OPERATING (Item 64): Tons 70.9
SECTIONS EVALUATED: 85 | COMMENTS:

NBI STATUS ITEMS:
Operational Status (Item 41): A
Bridge Posting Status (Item 70): #NAME?
Temporary Status (Item 103):

LOAD:	γ_L	<----1st rating control----> R.F.	Limit State	Force Type	Φ	CONTROLLING... MEMBER	SPAN	LOCATION	<----2nd rating control----> R.F.	Limit State	Force Type	Φ	CONTROLLING... MEMBER	SPAN	LOCATION
DESIGN & LEGAL VEHICLES															
HL93 (INVENTORY)	1.750	1.52	St1	+M	1.000	Int. Girder	1 of 2	0.5L	1.54	St1	+M	1.000	Int. Girder	1 of 2	0.45L
TYPE 3 (50K)	1.400	4.36	St1	+M	1.000	Int. Girder	1 of 2	0.5L	4.40	St1	+M	1.000	Int. Girder	1 of 2	0.45L
TYPE 3S2 (80K)	1.400	3.78	St1	+M	1.000	Int. Girder	1 of 2	0.45L	3.85	St1	+M	1.000	Int. Girder	1 of 2	0.5L
TYPE 3-3 (80K)	1.400	3.67	St1	+M	1.000	Int. Girder	1 of 2	0.5L	3.71	St1	+M	1.000	Int. Girder	1 of 2	0.45L
TYPE 3-3 & LEGAL LANE	1.400														
TYPE 3-3 TRAIN & LEGAL LANE	1.400	5.68	St1	+M	0.900	Bent 2 XB	2 of 5	0.4L	5.78	St1	+M	0.900	Bent 2 XB	4 of 5	0.59L
SU4 TRUCK (54K)	1.400	3.91	St1	+M	1.000	Int. Girder	1 of 2	0.5L	3.96	St1	+M	1.000	Int. Girder	1 of 2	0.45L
SU5 TRUCK (62K)	1.400	3.50	St1	+M	1.000	Int. Girder	1 of 2	0.5L	3.54	St1	+M	1.000	Int. Girder	1 of 2	0.45L
SU6 TRUCK (69.5K)	1.400	3.14	St1	+M	1.000	Int. Girder	1 of 2	0.5L	3.18	St1	+M	1.000	Int. Girder	1 of 2	0.45L
SU7 TRUCK (77.5K)	1.400	2.86	St1	+M	1.000	Int. Girder	1 of 2	0.5L	2.90	St1	+M	1.000	Int. Girder	1 of 2	0.45L
CTP VEHICLE, MULTI-LANE															
OR-CTP-2A (105.5K)	1.350	3.40	St2	+M	1.000	Int. Girder	2 of 2	0.5L	3.42	St2	+M	1.000	Int. Girder	2 of 2	0.45L
OR-CTP-2B (105.5K)	1.350	3.64	St2	+M	1.000	Int. Girder	2 of 2	0.45L	3.68	St2	+M	1.000	Int. Girder	2 of 2	0.5L
OR-CTP-3 (98K)	1.450	2.67	St2	+M	1.000	Int. Girder	1 of 2	0.45L	2.68	St2	+M	1.000	Int. Girder	1 of 2	0.5L
STP VEHICLE, MULTI-LANE															
OR-STP-3(120.5K)	1.250	3.14	St2	+M	1.000	Int. Girder	1 of 2	0.45L	3.14	St2	+M	1.000	Int. Girder	2 of 2	0.45L
OR-STP-4A (99K)	1.400	2.62	St2	+M	1.000	Int. Girder	1 of 2	0.45L	2.62	St2	+M	1.000	Int. Girder	1 of 2	0.5L
OR-STP-4B (185K)	1.000	3.14	St2	+M	1.000	Int. Girder	2 of 2	0.45L	3.17	St2	+M	1.000	Int. Girder	2 of 2	0.5L
OR-STP-4C (150.5K)	1.100	2.91	St2	+M	1.000	Int. Girder	2 of 2	0.45L	2.92	St2	+M	1.000	Int. Girder	2 of 2	0.5L
OR-STP-4D (162.5K)	1.050	2.51	St2	+M	1.000	Int. Girder	1 of 2	0.5L	2.54	St2	+M	1.000	Int. Girder	1 of 2	0.45L
OR-STP-4E (258K)	1.000	2.72	St2	+M	1.000	Int. Girder	1 of 2	0.5L	2.75	St2	+M	1.000	Int. Girder	1 of 2	0.45L
OR-STP-5BW (204K)	1.000	2.76	St2	+M	1.000	Int. Girder	2 of 2	0.45L	2.77	St2	+M	1.000	Int. Girder	2 of 2	0.5L
SPECIAL	1.000														
STP VEHICLE, SINGLE LANE W/ESCORT															
OR-STP-3(120.5K)	1.150	4.33	St2	+M	1.000	Ext. Girder	2 of 2	0.45L	4.34	St2	+M	1.000	Ext. Girder	2 of 2	0.5L
OR-STP-4A (99K)	1.150	4.45	St2	+M	1.000	Ext. Girder	1 of 2	0.45L	4.46	St2	+M	1.000	Ext. Girder	1 of 2	0.5L
OR-STP-4B (185K)	1.150	3.48	St2	+M	1.000	Ext. Girder	2 of 2	0.45L	3.52	St2	+M	1.000	Ext. Girder	2 of 2	0.5L
OR-STP-4C (150.5K)	1.150	3.54	St2	+M	1.000	Ext. Girder	2 of 2	0.45L	3.56	St2	+M	1.000	Ext. Girder	2 of 2	0.5L
OR-STP-4D (162.5K)	1.150	3.02	St2	+M	1.000	Ext. Girder	2 of 2	0.5L	3.07	St2	+M	1.000	Ext. Girder	2 of 2	0.45L
OR-STP-4E (258K)	1.150	3.10	St2	+M	1.000	Ext. Girder	2 of 2	0.5L	3.11	St2	+M	1.000	Ext. Girder	2 of 2	0.45L
OR-STP-5BW (204K)	1.150	3.05	St2	+M	1.000	Ext. Girder	2 of 2	0.45L	3.07	St2	+M	1.000	Ext. Girder	2 of 2	0.5L
SPECIAL	1.150														

Figure B45: ODOT Bridge Section Tier 2 Load Rating Summary Report for Bridge 20026

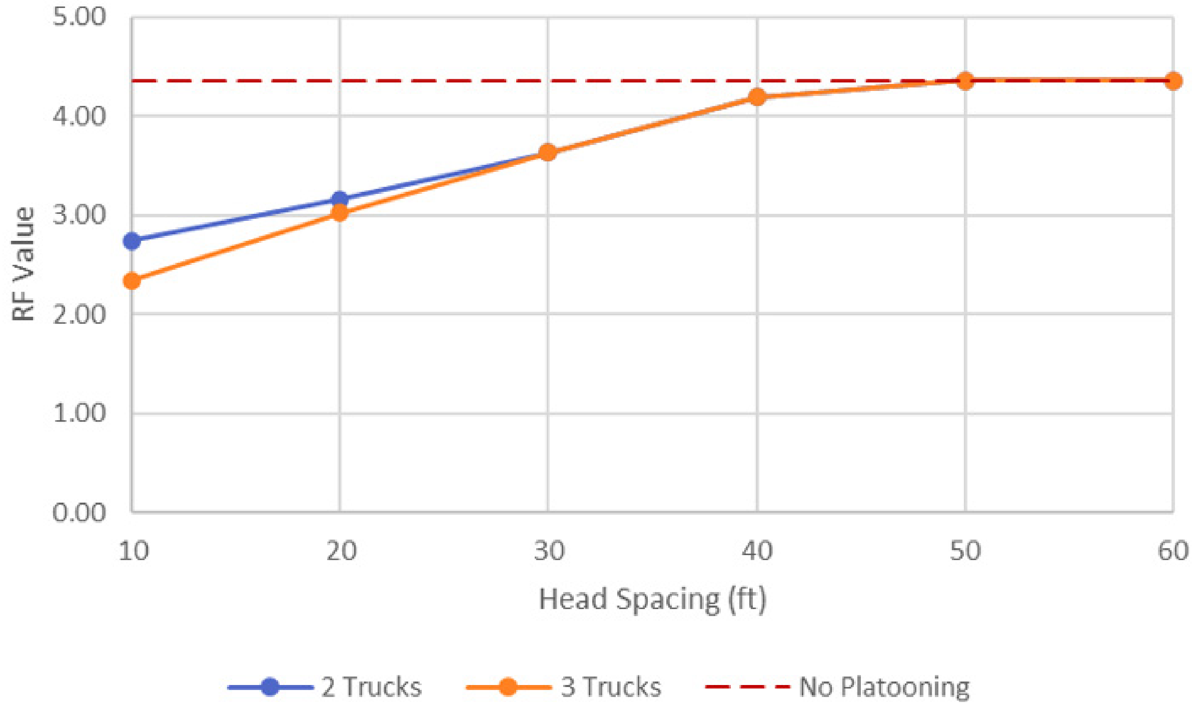


Figure B46: Rating Factor versus Head Spacing for the OR Type 3 Legal Truck

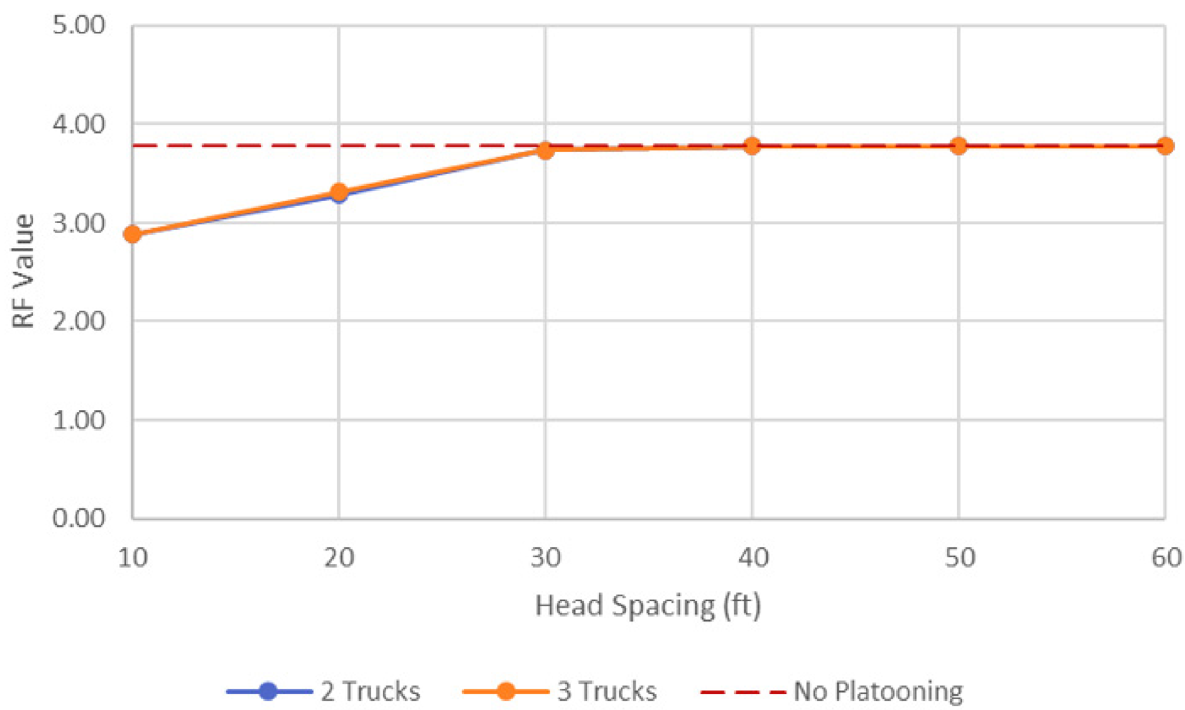


Figure B47: Rating Factor versus Head Spacing for the OR Type 3S2 Legal Truck

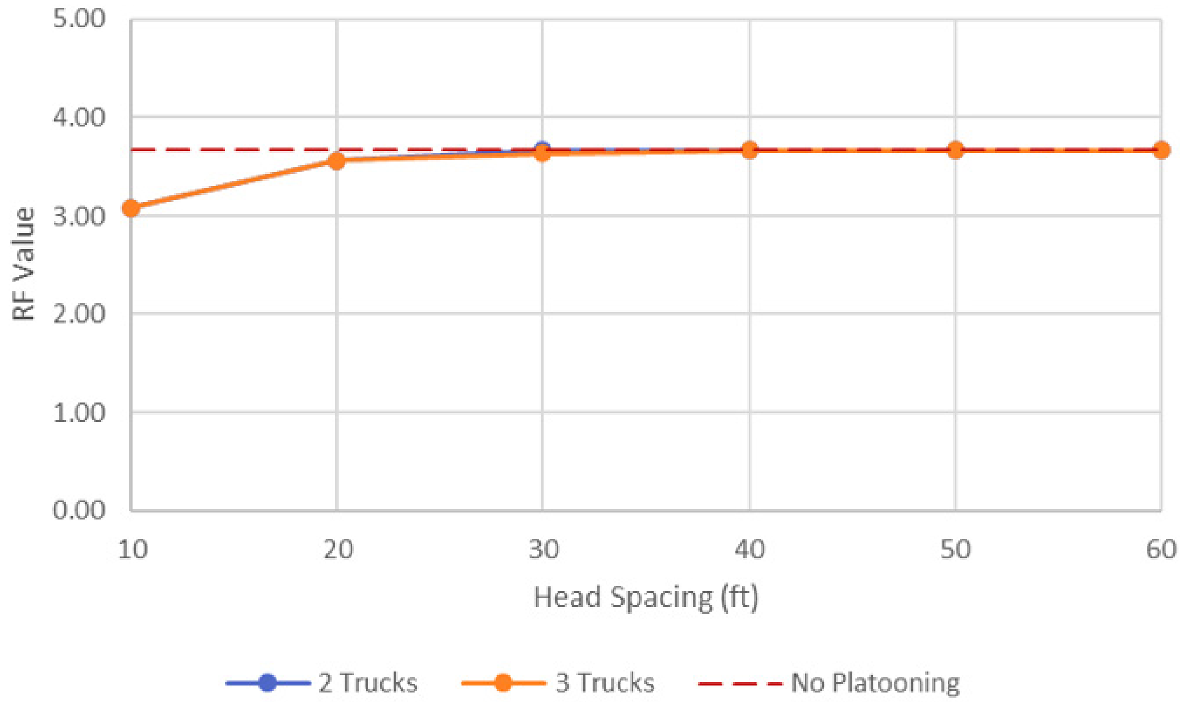


Figure B48: Rating Factor versus Head Spacing for the Type 3-3 Legal Truck

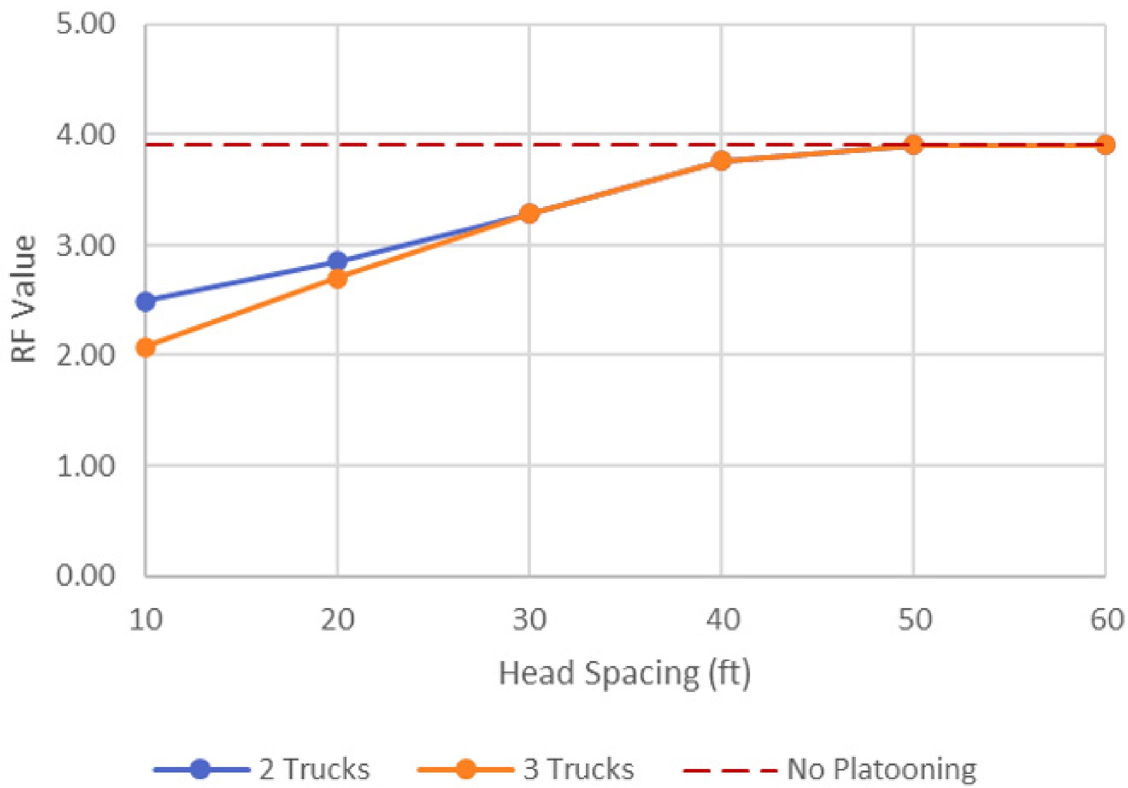


Figure B49: Rating Factor versus Head Spacing for the OR SU4 Truck

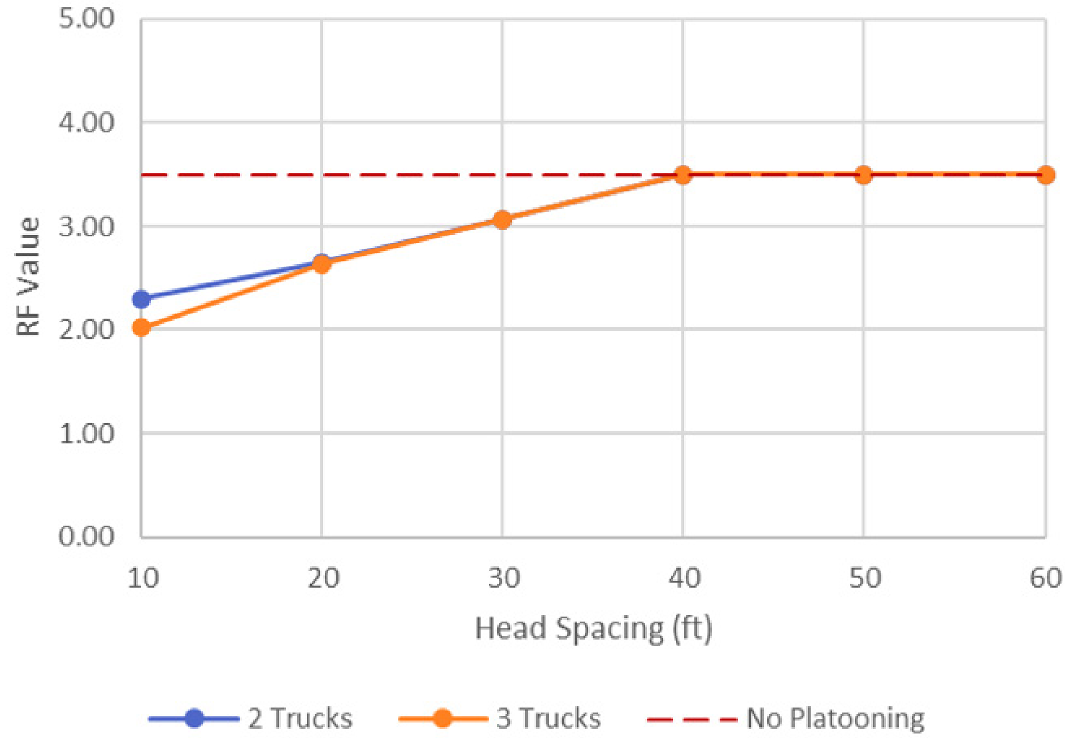


Figure B50: Rating Factor versus Head Spacing for the OR SU5 Truck

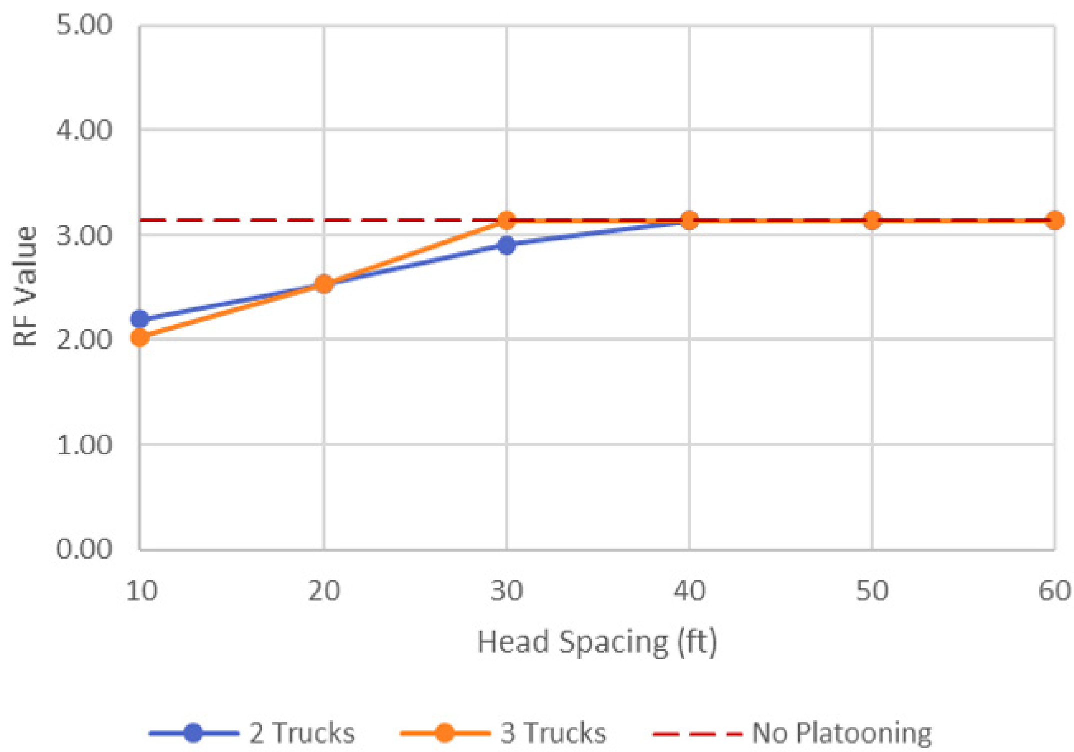


Figure B51: Rating Factor versus Head Spacing for the OR SU6 Truck

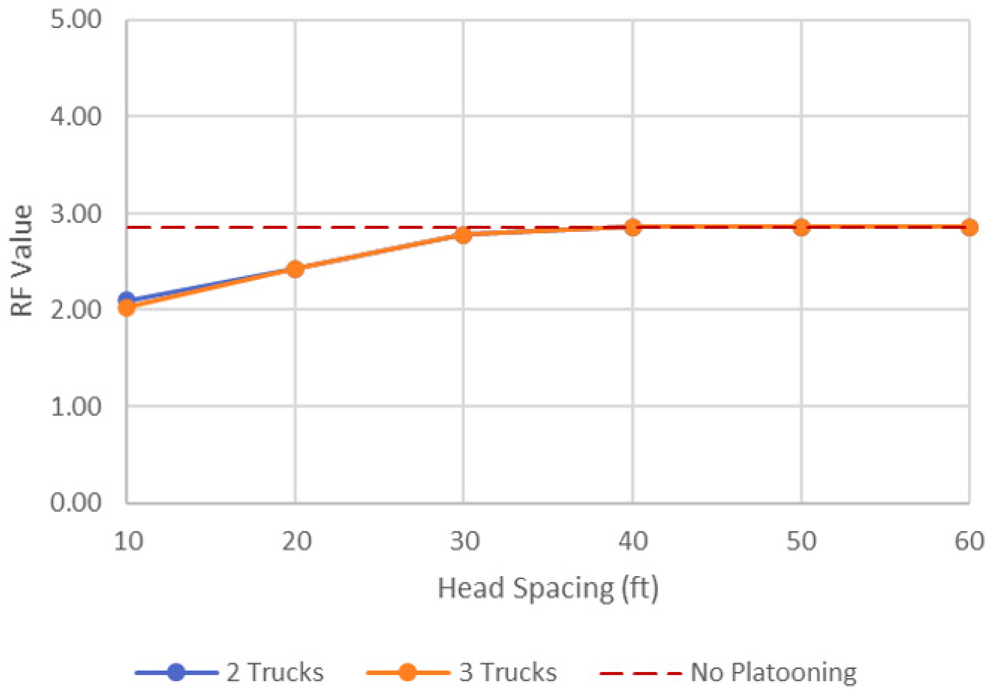


Figure B52: Rating Factor versus Head Spacing for the OR SU7 Truck

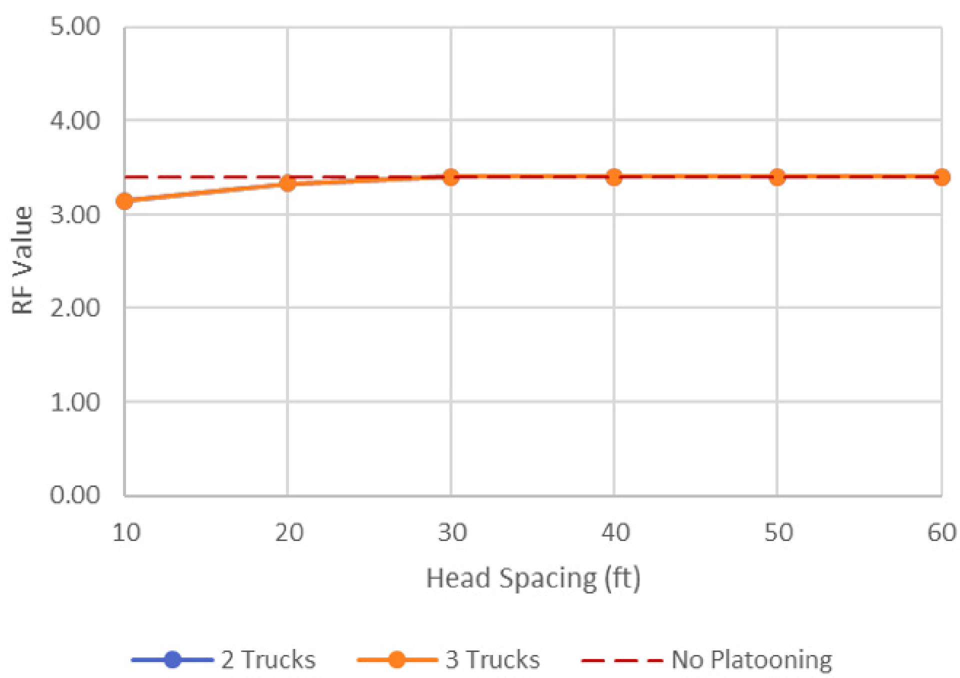


Figure B53: Rating Factor versus Head Spacing for the Type OR CTP-2A Truck

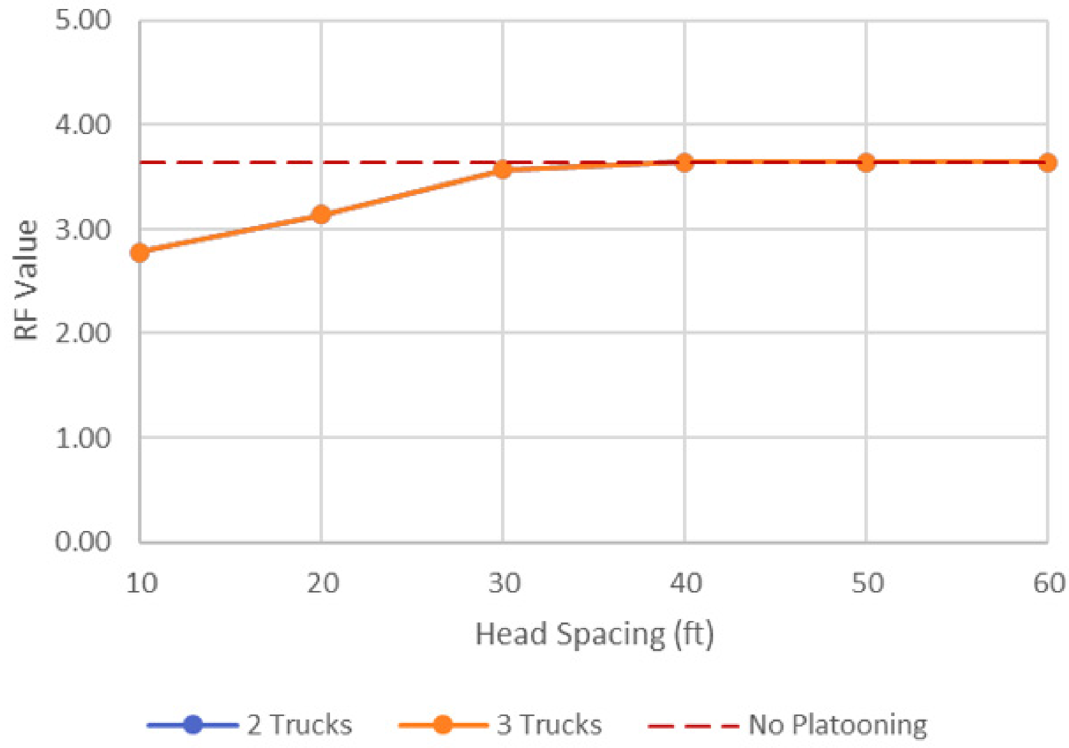


Figure B54: Rating Factor versus Head Spacing for the Type OR CTP-2B Truck

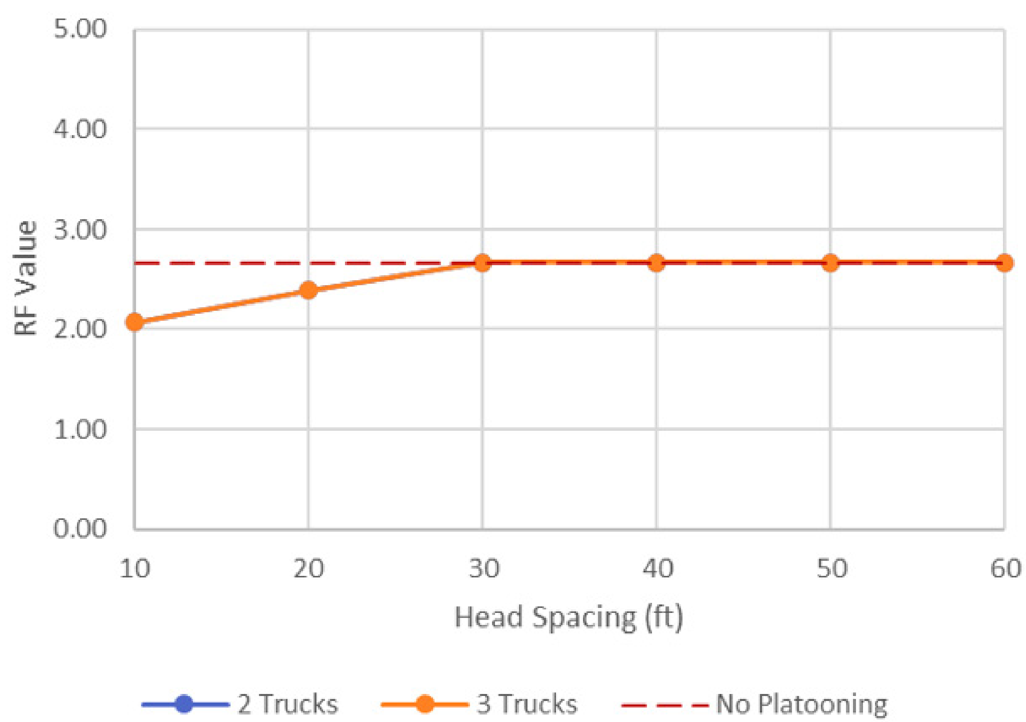


Figure B55: Rating Factor versus Head Spacing for the Type OR CTP-3 Truck