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RELIABILITY-BASED ASSESSMENT OF LOAD AND RESISTANCE FACTOR RATING FOR SPECIALIZED HAULING VEHICLES

By

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A thesis submitted to the

School of Graduate Studies

Rutgers, The State University of New Jersey

In partial fulfillment of the requirements

For the degree of

Master of Science

Graduate Program in Civil and Environmental Engineering

Written under the direction of

Dr. Hani H. Nassif, Ph.D.

And approved by

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New Brunswick, New Jersey

May 2019

ABSTRACT OF THE THESIS

RELIABILITY-BASED ASSESSMENT OF LOAD AND RESISTANCE FACTOR RATING FOR SPECIALIZED HAULING VEHICLES

by DONGJIAN GAO

Thesis Director:

Dr. Hani H. Nassif, Ph.D.

Specialized Hauling Vehicles (SHVs) are defined as short heavy trucks within the legal weight limits but induce higher load effects than routine commercial load models.

This thesis is consisted of three major parts, 1) investigation of the population, various truck characteristics of SHV traffic fleet and multiple-presence events based on available Weigh-In-Motion (WIM) data, 2) development of statistical models of SHVs for both one-lane and two-lane loading cases, and 3) assessment of live load factors for SHVs for LRFR Strength I Limit State.

The first part focuses on processing WIM data. The algorithm for data processing and the WIM database is presented first. The database consists of two sets of data: 1) data from New Jersey, and 2) data from another 21 states across the United States. Based on the data processing results, the statistics of SHV traffic in terms of percentage of entire truck traffic and average daily count at each WIM site were obtained. Also, the frequency distributions of number of axles, gross vehicle weight (GVW) as well as a summary of typical SHV configurations were acquired by assembling the SHV traffic from all sites. The multiple-

presence events were also assessed, and the statistics are presented. The second part presents the analysis of load effects of SHVs and the development of statistical models for SHVs. The statistical models consist of three factors: bias ratio, coefficient of variation and probability distribution. Due to the multiple-presence events of SHVs, the models were developed for both one-lane loading case and two-lane loading case. The probability distribution of load effects induced by SHVs on various spans was determined by hypothesis testing. Based on the probability distribution, the maximum load effects over a 5-year period of bridge evaluation were predicted for each site. The site maximum values were then assembled into one dataset and the mean and coefficient of variation were calculated as the statistical parameters for live load. The probability distribution of the site maximum values was also determined by hypothesis testing. In the third part, the statistical models for live loads were used for reliability analysis for existing steel-girder bridges. The load rating factors were obtained for the bridges and plotted against reliability indices for different combinations of SU trucks and ADTTs. The results show that the reliability level provided by the current live load factors are higher than the desired level. The live load factors as well as the live load factors were modified until reliability index equal to 2.5 when rating factor equal to 1 in each plot. New live load factors for SHVs for different ADTTs were presented based on the assessment results.

DEDICATION

To My Parents, I love you.

ACKNOWLEDGEMENTS

Thank God for giving me the strength, ability and guidance in my study, work and life.

I would like to express my deepest gratitude to my advisor, Dr. Hani Nassif, who has been guiding me and supporting me over the course of the past three years and a half. This thesis would not have been possible without his insight and knowledge in this field. Being his student will become one of my most precious experiences.

It is a great honor to have Dr. Yook-Kong Yong and Dr. Peng Lou on my committee. Their constant help and instruction prepared me well for the completion of the thesis.

I also would like to make a special acknowledgement to NJDOT for the funding of this study. I would like to thank the support and help from Mula Reddy in Bureau of Structural Evaluation and Bridge Management.

Special appreciation is made to Dr. Peng Lou, who is my great mentor and gave me insightful instructions in this study and other projects. I would also like to thank my friends and colleagues who are always by my side, inspiring me and encouraging me: He Zhang, Chan Yang, Thanachai Srithaninrat, Eason Portela and Dr. Chaekuk Na. Special appreciation is made to the department staff: Gina Cullari and Linda Szary.

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CHAPTER 1

INTRODUCTION

1.1. Background

Specialized Hauling Vehicles (SHVs) are single-unit trucks with closely-spaced multiple axles utilized as dump trucks, solid-waste trucks, concrete mixer trucks, construction vehicles, home fuel oil delivery trucks, and commodity-hauling trucks. (Sivakumar et al., 2007). Specially designed for heavy-duty purposes, SHVs have cargo-carrying bodies along with loading/unloading-assisting equipment which result in high tare (empty) weights (Wykle, 1999). Short wheelbases increase the safety and maneuverability for this type of vehicles. Furthermore, artificial features, such as auxiliary lift axles, dummy axles and spread tandems, allow SHV operators to manipulate the weight distribution to comply with weight limits. Due to the multiple axles, SHVs can be weighed up to 80 kips without exceeding the Federal truck weight limits. The limits are provided in the Code of Federal Regulations (23 CFR 658.17):

- Single axle weight shall not be greater than 20,000 lbs
- Tandem axle weights shall not be greater than 34,000 lbs
- GVW shall not be greater than 80,000 lbs
- Federal Bridge Formula (FBF), as shown in Equation 1.1, shall be satisfied:

$$W = 500\left(\frac{LN}{N-1} + 12N + 36\right) \qquad \text{Equation 1.1}$$

AASHTO Legal Load Family originally consisted of Type 3, 3S2 and 3-3 to model the short-, intermediate-, and long- truck configurations limited by FBF. However, the three legal loads may not be able to envelope the load effects induced by SHVs especially on short-span bridges (AASHTO MBE, 2018). Therefore, trucks of this type may overstress a bridge even with enough resistance for the three AASHTO legal loads. To account for SHVs in load rating, the National Cooperative Highway Research Program (NCHRP) initiated Project 12-63 *Legal Truck Loads and* AASHTO *Legal Loads for Posting* (Sivakumar et al., 2007). The project was started in July 2003 and finished in June 2006. The purpose of this research is to update the posting legal loads provided in AASHTO *Manual for Condition Evaluation of Bridges* (MCE) and AASHTO *Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges*. As a result, AASHTO Single-Unit Bridge Posting Loads (i.e. SU4, SU5, SU6 and SU7) and Notional Rating Load (NRL) were proposed for AASHTO *Manual for Bridge Evaluation* (MBE) and are designated as the legal loads for SHVs. The live load factors for SHVs in the latest AASHTO MBE were proposed in NCHRP Project 12-78 (Mlynarski, Wassef & Nowak, 2011).

1.2. Motivation

In November 2013, a memorandum was issued by Federal Highway Administration (FHWA) to require state DOTs to load rate bridges for AASHTO legal loads for SHVs (i.e., SU4, SU5, SU6, SU7 and NRL). In 2016, New Jersey Department of Transportation (NJDOT) Bureau of Research initiated Bridge Resource Program aiming at improving the direction and decision making involved in the activities of NJDOT's Division of Bridge Engineering and Infrastructure Management for the State. One of the tasks under this program is to traverse the SHV traffic fleet operating in New Jersey. Statistics, characteristics and load effects were studied for this task. The result shows that the AASHTO legal loads for SHVs may not be able to envelope the SHV traffic fleet. The current live load factors for SHVs were not derived from a reliability-based analysis. Instead, the factors for routine commercial traffic were simply adopted as the factors for SHVs (Mlynarski, Wassef & Nowak, 2011). Therefore, the adequacy of the live load factors for SHVs regarding reliability level is in question and needs to be evaluated.

1.3. Research Significance

In 2007, single-unit trucks take 68% of the trucking traffic, and 46% of single-unit trucks with three axles or more are SHVs (Sivakumar et al., 2007). Due to the short wheelbase configurations, SHVs have a higher potential to risk the safety of bridges than other trucking configurations. Estimation was made that SHVs can cause load effects greater than those caused by HS20-44 and the routine commercial trucks (Type 3, 3S2, and 3-3) by 22% and 50%, respectively (AASHTO MBE, 2018). Therefore, it is crucial for the safety of infrastructure that validated live loads and live load factors for load rating for

SHVs are provided. The current AASHTO MBE adopted different live load factors for different ADTTs. The thesis will be consistent to this convention by performing the analysis for different ADTTs. Additionally, SHVs will be divided into different groups based on the number of axles and compared with their respective AASHTO SU trucks. It is expected from this thesis that the live load factors for SHVs will be updated for all combinations of SU trucks and ADTTs.

1.4. Objectives

The primary objective of this research is to assess the live load factors for SHVs if the reliability index for rating factor equal to 1 achieve the target reliability index of 2.5 for LRFR Strength I limit state. The objectives of this thesis can be summarized as follows:

1. Search literature for the procedures for calibration of live load factors, load rating and posting practices in different states, methodology of reliability analysis and statistical parameters for dead loads and resistance;
2. Process WIM data across New Jersey to obtain the statistics, characteristics and multiple-presence events for SHVs.;
3. Develop statistical models for SHVs by extrapolation as the live load inputs for the subsequent reliability analysis;
4. Perform reliability analysis and calculate load rating factors for existing bridges using the obtained statistical models;
5. Investigate the relationship between reliability indices and rating factors of the existing bridges to assess the current LRFR practices for SHVs regarding reliability.

1.5. Organization of the Thesis

The thesis consists of six chapters. This chapter is an introduction for the thesis, depicting the problem statement as well as the objectives.

Chapter two contains a comprehensive literature review of relevant research works about the development and calibration of load factors, the necessary techniques for reliability analysis and the current load rating practices of state DOTs.

Chapter three presents the methodology and output of WIM data processing.

Chapter four presents the development of the statistical models for SHVs, including hypothesis testing and load extrapolation.

Chapter five presents the procedures for the assessment of live load factors based on the goodness-of-fit between reliability indices and rating factors.

Chapter six contains the summary and conclusion of this thesis.

CHAPTER 2

LITERATURE REVIEW

2.1. FHWA's Position on Bridge Load Rating and Posting for SHVs

In November 2013, the Federal Highway Administration (FHWA) issued a memorandum, titled '*Load Rating of Specialized Hauling Vehicles*', as the guidelines for state DOTs to load rate bridges for SHVs (FHWA, 2013). The requirements are outlined as follows:

- AASHTO SHVs loads (i.e., SU4, SU5, SU6 and SU7 or NRL) are required to be applied in load rating in all situations where two conditions are not met:

  'Condition A: The State verifies that State laws preclude SHV use; or

  Condition B: The state has its own rating vehicle models for legal loads and verifies that the state legal load models envelope the applicable AASHTO SHV loading models specified in Appendix D6A and Figure 6B.9.2-2 of the 1st Edition of the MBE (Figure 6B.7.2-2 of the 2nd Edition of the MBE), and the State legal load models have been included in rating/posting analyses of all bridges. The SHV types, e.g. six- or seven-axle SHVs, precluded by State laws need not be considered'.

- It divides all inventory bridges less than 200 ft into two groups and specifies a deadline for each of the groups

'Group 1: Bridges with the shortest span not greater than 200 feet should be re-rated after their next NBIS inspection, but no later than December 31, 2017, that were last rated by: a. either Allowable Stress Rating (ASR) or Load Factor Rating (LFR) method and have an operating rating for the AASHTO Routine Commercial Vehicle either Type 3, Type 3S2, b. or Type 3-3 less than 33 tons (English), 47 tons (English), or 52 tons (English) respectively; or

b. Load and Resistance Factor Rating (LRFR) method and have a legal load rating factor for the AASHTO Routine Commercial Vehicle, either Type 3, Type 3S2 or Type 3-3, less than 1.3.

Group 2: Rate those bridges not in Group 1 no later than December 31, 2022'.

Following the memorandum, FHWA answered questions regarding specific issues that individual states may address (FHWA, 2014). According to FHWA, states could apply their own load rating models as long as they envelope AASHTO SHVs. The posting decision will be based on the results:

- If bridges do not need to be posted for state-specific loads, AASHTO SHV load rating is not required.
- If bridges need to be posted for state-specific loads, load rating should be performed for AASHTO SHV as well. Posting will be determined by comparing the two load rating results.

Since some of the states prohibit the operation of SHVs, load rating for SHVs is not required in the districts where they are not allowed to operate. However, FHWA highlights that interstate highways are not restricted by state laws. As long as SHVs satisfy

the federal weight limits, they are allowed to operate on bridges of interstate highways even in the states prohibiting SHVs. Therefore, states must load rate bridges on interstate highways for AASHTO SHVs regardless of the states' legislation.

2.2. Load Rating and AASHTO SHV Live Load Models

ASSHTO Manual for Bridge Evaluation provides the guidelines for transportation agencies to acquire the physical conditions, maintenance requirements, and the capacity to carry load of highway bridges nationwide (AASHTO MBE, 2018). The previous standards were *AASHTO Manual for Condition Evaluation of Bridges* and *AASHTO Guide Manual for Condition and Load and Load Resistance Factor Rating (LRFR) of Highway Bridges*. Section 6 of AASHTO MBE provides the equations, factors, live load models and detailed explanation and instruction about the procedures and policies for load rating and posting. The philosophies of load rating include Load and Resistance Factor Rating (LRFR), Allowable Stress Rating (ASR) and Load Factor Rating (LFR). The procedures of load rating include: Design load rating, Legal load rating and Permit load rating. The design load rating is further divided into Inventory level and Operating level. Inventory level has the same reliability as adopted by *AASHTO LRFD Bridge Design Specifications* while Operating level has a lower reliability level originating in past load-rating experiences. Legal load rating is performed only when the rating factor (RF) is less than 1 at the Operating level of Design load rating. And bridges are supposed to be load rated for permit loads only when they have adequate resistance for legal loads. Load rating for SHVs is categorized as one part of Legal load rating. The equation of RF is shown in Equation 2.1.

$$\mathrm{RF} = \frac{\mathrm{C} - \gamma_{\mathrm{DC}}(\mathrm{DC}) - \gamma_{\mathrm{DW}}(\mathrm{DW}) \pm \gamma_{\mathrm{P}}(\mathrm{P})}{\gamma_{\mathrm{LL}}(\mathrm{LL} + \mathrm{IM})} \qquad \text{Equation 2.1}$$

Where

RF = rating factor

C = capacity

DC = dead load effect due to structural components and attachments

DW = dead load effect due to wearing surface and utilities

P = permanent loads other than dead loads

LL = live load effect

IM = dynamic load allowance

γ_{DC} = LRFD load factor for structural components and attachments

γ_{DW} = LRFD load factor for wearing surface and utilities

γ_{P} = LRFD load factor for Permanent loads other than dead loads = 1.0

γ_{LL} = evaluation live load factor

The load factors for different limit states and load rating levels are shown in Figure 2.1.

Table 6A.4.2.2-1—Limit States and Load Factors for Load Rating

Bridge Type	Limit State*	Dead Load γ_{DC}	Dead Load γ_{DW}	Design Load Inventory γ_{LL}	Design Load Operating γ_{LL}	Legal Load γ_{LL}	Permit Load γ_{LL}
Steel	Strength I	1.25	1.50	1.75	1.35	Tables 6A.4.4.2.3a-1 and 6A.4.4.2.3b-1	—
	Strength II	1.25	1.50	—	—	—	Table 6A.4.5.4.2a-1
	Service II	1.00	1.00	1.30	1.00	1.30	1.00
	Fatigue	0.00	0.00	0.75	—	—	—
Reinforced Concrete	Strength I	1.25	1.50	1.75	1.35	Tables 6A.4.4.2.3a-1 and 6A.4.4.2.3b-1	—
	Strength II	1.25	1.50	—	—	—	Table 6A.4.5.4.2a-1
	Service I	1.00	1.00	—	—	—	1.00
Prestressed Concrete	Strength I	1.25	1.50	1.75	1.35	Tables 6A.4.4.2.3a-1 and 6A.4.4.2.3b-1	—
	Strength II	1.25	1.50	—	—	—	Table 6A.4.5.4.2a-1
	Service III	1.00	1.00	0.80	—	1.00	—
	Service I	1.00	1.00	—	—	—	1.00
Wood	Strength I	1.25	1.50	1.75	1.35	Tables 6A.4.4.2.3a-1 and 6A.4.4.2.3b-1	—
	Strength II	1.25	1.50	—	—	—	Table 6A.4.5.4.2a-1

* Defined in the *AASHTO LRFD Bridge Design Specifications*

Notes:

- Shaded cells of the table indicate optional checks.
- Service I is used to check the 0.9 F_y stress limit in reinforcing steel.
- Load factor for *DW* at the strength limit state may be taken as 1.25 where thickness has been field measured.
- Fatigue limit state is checked using the LRFD fatigue truck (see Article 6A.6.4.1).

Figure 2.1. Limit States and Load Factors for Load Rating (AASHTO MBE, 2018)

The specific live load factors for SHVs are shown in Figure 2.2.

Table 6A.4.4.2.3b-1—Generalized Live Load Factors, γ_L for Specialized Hauling Vehicles

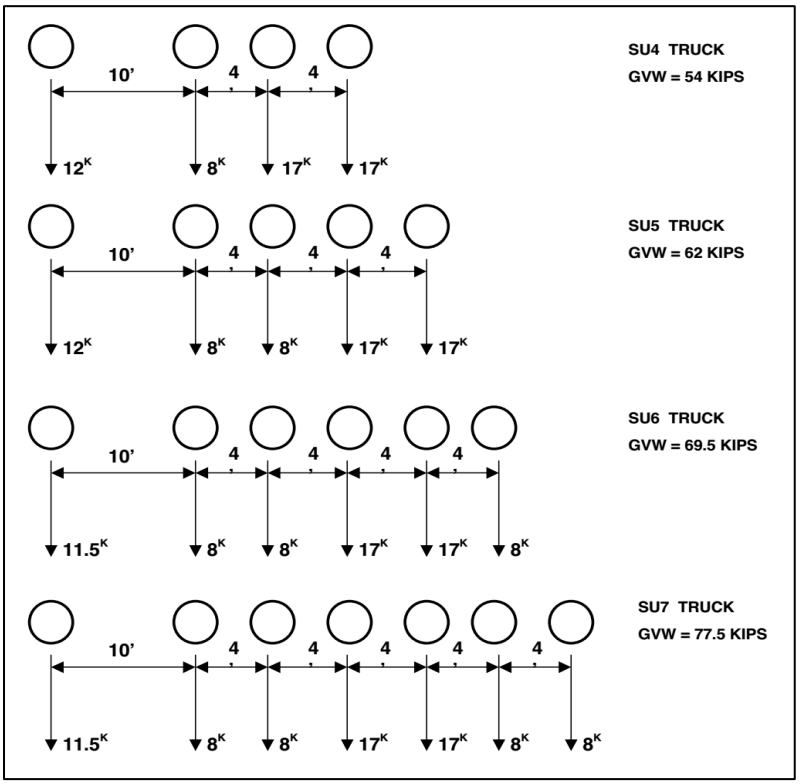
Traffic Volume (One Direction)	Load Factor
Unknown	1.45
$ADTT \geq 5{,}000$	1.45
$ADTT = 1{,}000$	1.30

Linear interpolation is permitted for *ADTT* values between 1,000 and 5,000.

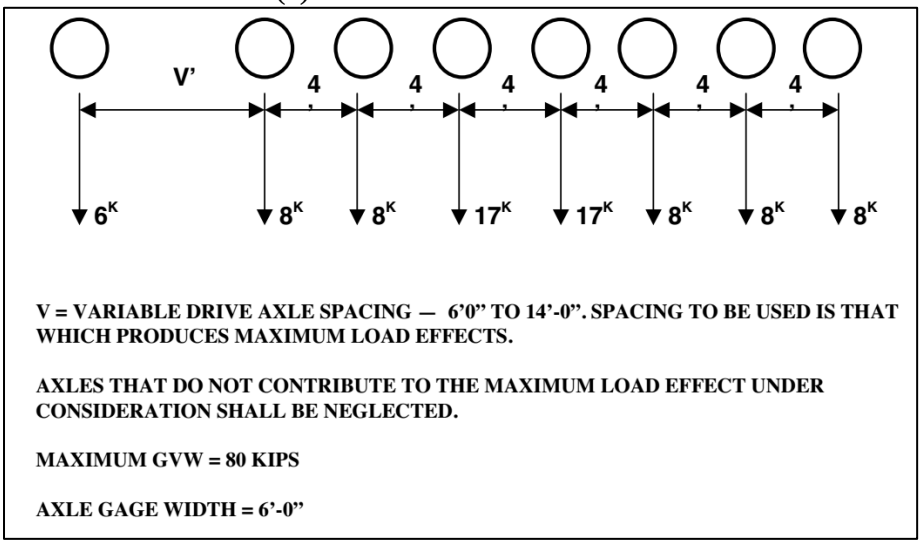
Figure 2.2. Generalized Live Load Factors, γ_L for Specialized Hauling Vehicles

(AASHTO MBE, 2018)

AASHTO SU4, SU5, SU6, SU7 and Notional Rating Load (NRL) are sequentially shown in Figure 2.3:



(a) AASHTO SU Trucks



(b) AASHTO NRL

Figure 2.3. AASHTO Single-Unit Bridge Posting Loads and Notional Rating Load (NRL) (AASHTO MBE, 2018)

2.3. NCHRP Studies for Load Rating and SHVs

The National Cooperative Highway Research Program (NCHRP) was founded by Transportation Research Board (TRB) in 1962 and sponsored by American Association of State Highway and Transportation Officials (AASHTO) and FHWA. It undertakes research aimed at solving issues related to *highway planning, design, construction, operation, and maintenance* (FHWA website) nationwide.

NCHRP has conducted several studies to develop/calibrate the live load factors for load rating in AASHTO MBE. Also, it has developed live load models of SHVs along with corresponding live load factors which were adopted by AASHTO MBE.

To have a better understanding of the calibration approaches as well as the up-to-date research effort for SHVs, the author has investigated three NHCRP projects: NCHRP Project 12-46 *Calibration of Load Factors for LRFR Bridge Evaluation* (Moses, 2001), Project 12-63 *Legal Truck Loads and AASHTO Legal Loads for Posting* (Sivakumar et al., 2007) and NCHRP Project 12-78 *A Comparison of AASHTO Bridge Load Rating Methods* (Mlynarski, Wassef & Nowak, 2011).

2.3.1. Calibration of Load Factors for LRFR Bridge Evaluation (Moses, 2001)

This research provides the methodology to determine the load factors for load rating existing bridges with proper margins of safety. The database used in this research is from the Ontario truck survey in 1975.

The first step is to determine the equivalent weight parameters of 3S2 trucks as the benchmark for the calibration. Therefore, the live load statistical parameters obtained for

designing should also herein be transformed to serve for load rating. Three major changes have been made in this research, comparing to the calibration of the design code:

1) The nominal live load is changed from HL-93 to AASHTO legal vehicles.

2) The exposure period is changed from 75 years to 5 years.

3) The reliability index is changed from 3.5 to 2.5.

Ratios between the maximum moment from survey data and the HL-93 moment is tabulated in Table 2.1:

Table 2.1 Mean maximum moments for simple spans divided by corresponding new LRFD moments, M(LRFD) (Nowak, 1999)

Span (ft)	M(LRFD) (k-ft)	1 day	2 weeks	1 month	2 months	6 months	1 year	5 years	50 years	75 years
10	88	0.88	1.02	1.07	1.12	1.18	1.25	1.33	1.50	1.50
20	232	0.90	0.98	1.02	1.06	1.10	1.14	1.21	1.30	1.30
30	397	0.95	1.04	1.08	1.12	1.15	1.19	1.26	1.35	1.35
40	578	1.02	1.11	1.14	1.17	1.21	1.23	1.28	1.35	1.35
50	826	1.00	1.08	1.12	1.15	1.18	1.22	1.25	1.33	1.33
60	1093	1.02	1.09	1.12	1.15	1.18	1.21	1.24	1.32	1.32
70	1376	1.02	1.08	1.12	1.15	1.18	1.21	1.25	1.31	1.31
80	1675	1.02	1.08	1.11	1.14	1.17	1.21	1.25	1.32	1.32
90	1990	1.02	1.08	1.11	1.14	1.16	1.20	1.24	1.31	1.31
100	2322	1.02	1.08	1.10	1.13	1.16	1.20	1.24	1.31	1.31
110	2670	1.02	1.07	1.10	1.12	1.15	1.19	1.24	1.31	1.31
120	3033	1.01	1.07	1.09	1.12	1.15	1.18	1.22	1.29	1.29
130	3413	1.00	1.06	1.09	1.11	1.13	1.16	1.20	1.27	1.27
140	3809	0.98	1.03	1.06	1.08	1.10	1.13	1.17	1.24	1.24
150	4220	0.98	1.03	1.06	1.07	1.09	1.12	1.16	1.23	1.23
160	4648	0.98	1.03	1.07	1.09	1.10	1.13	1.17	1.24	1.24
170	5092	0.99	1.03	1.07	1.09	1.11	1.13	1.18	1.24	1.24
180	5552	0.98	1.03	1.06	1.08	1.11	1.13	1.17	1.24	1.24
190	6028	0.97	1.02	1.06	1.08	1.10	1.13	1.17	1.24	1.24
200	6520	0.96	1.02	1.05	1.08	1.09	1.12	1.16	1.23	1.23

It can be seen from the table that the average moment at 60 ft span is 0.72 of HS-20 moment. The moment at 60 ft span of HS-20 is 403 kip-ft, which implies that the average truck moment is $403 \times 0.72 = 290.16$ kip-ft. Similarly, the one-day maximum truck

moment is 403 × 1.37 = 552.11 kip-ft. The weight of AASHTO 3S2 is 72 kips. Since the researchers assume that the majority of the trucks are belong to 3S2 type, the average weight of the trucks is supposed to be proportional to its corresponding moment with the AASHTO 3S2 moment (309 kip-ft) as the base. Therefore, the mean truck weight is calculated by Equation 2.2:

$$\bar{W} = \frac{290.16}{309} \times 72 = 67.61\ kips \qquad \text{Equation 2.2}$$

The standard deviation is calculated by Equation 2.3:

$$\sigma_W = \frac{\frac{552.11}{309} \times 72 - 67.61}{3.09} = 19.7\ kips \qquad \text{Equation 2.3}$$

3.09 is the normal variate at 1/1000 level. 552.11 kip-ft is from the projected one-day maximum moment. The researchers have done this calculation for different spans. The values are very close. The mean and standard deviation of equivalent 3S2 was determined to be 68 kips and 18 kips, respectively.

The second step is to determine the maximum projected truck weights using Equation 2.4:

$$\mu + t \times \sigma \qquad \text{Equation 2.4}$$

Where

μ = 68kips, the mean population weight of 3S2.

σ = 18 kips, standard deviation of population weight.

t = normal deviate for extrapolation level.

The third step is to determine the maximum 2-lane truck weights using Equation 2.5:

$$2\mu + t \times \sqrt{2}\sigma \qquad \text{Equation 2.5}$$

Where

μ = 68kips, the mean population weight of 3S2.

σ = 18 kips, standard deviation of population weight.

t = normal deviate for an extrapolation level.

In the two-lane case, it is assumed the bridge is loaded with 2 independent trucks with the same mean (260 kips) and standard deviation (18 kips). According to the probability theorem, for two independent normal variables, the mean is the summation of the two means, and the standard deviation is the square root of the summation of the two squred standard deviations. Two-lane case depends on the occurancy of multiple prescense. For ADTT of 5000, the probability of side-by-side is 1/15; for ADTT of 1000, it is 1%; for ADTT of 100, it is 0.1%. Therefore, the total number of loading occurrences for the two-lane case is calculated by its one-lane counterpart multiplied with the corresponding multiple prescense probability. For example, for ADTT = 5000 and n = 5 years, the multiple prescense N = 5000 ×20% ×5 × 365 × 1/15 = 121667. Note that only the upper 20% of the whole truck weight population will be used for the extrapolation. The 2-year projection results are shown in Table 2.2:

Table 2.2 - 2-Year Projections of Maximum GVW [12]

ADTT	2 Year Projections of Maximum GVW Using Ontario Data						
	Two Lanes				One Lane		
	$P_{s/s}$	N	t	W_T	N	t	W_1
5000	1/15	48667	4.09	240.1	730000	4.7	152.6
1000	0.01	1460	3.2	217.5	146000	4.35	146.3
100	0.001	14.6	1.49	173.9	14600	3.81	136.6

The fourth step is to determine the live load factors. Equation 2.6 is how the live load factor for legal load with 5000 ADTT is obtained:

$$1.75HL93 = 1.75 \times 0.91 \times 0.76 \times 0.94 \times 1.73 \times 0.92 \times 3S2$$
$$= 1.81 \times 3S2$$
Equation 2.6

The expressions on the two sides of the equation are supposed to provide the same live load level. Several adjustments have to be made to reach the proposed values. The explanations of each adjustment factors are as follows:

- 0.91: 0.91 = 1.6/1.75. This is because Nowak admitted 1.6 is acceptable for average spans.
- 0.76: 0.76 = 1.35/1.75. To hit the target beta of 2.5 using HL93 as the live load, the ranged live load factors are between 1.28 and 1.35. To be conservative, 1.35 is adopted.
- 0.94: To convert the exposure period from 75 years to 5 years. The ratios of 75-year to 5-year mean maximum simple span moment are around 0.94, according to Nowak's research.
- 1.73: The average ratio of HL-93 bending moment to AASHTO legal vehicles is 1.73.
- 0.92: 0.92 = 1.8/1.95. The live load factor is further reduced to comply with a lower target beta 2.3. (Moses and Verma, 1987)

The fifth step is to calibrate the factors for other values of ADTT using Equation 2.7 (multiple-lane bridge) and Equation 2.8 (one-lane bridge):

$$\gamma_{L,ADTT} = Maimum\ Load \times \frac{1.8}{240\ kips}$$ Equation 2.7

$$\gamma_{one-lane} = one\ lane\ projection\ GVW \times \frac{1.8}{120}$$ Equation 2.8

Note that the method to obtain the bias factors aforementioned is based on Ontario's data. With the development of WIM technology, the live load factors can be calibrated with updated traffic data. They are computed using Equation 2.9 and Equation 2.10:

$$\gamma_{two-lane} = 1.8 \times \frac{2W^* + t_{(ADTT)}1.41\sigma^*}{240} > 1.30 \qquad \text{Equation 2.9}$$

$$\gamma_{one-lane} = 1.8 \times \frac{W^* + t_{(ADTT)}\sigma^*}{120} > 1.80 \qquad \text{Equation 2.10}$$

Where

W^* = the average weight of the 20% upper tail of sample trucks from WIM data.

σ^* = the standard deviation of the 20% upper tail of sample trucks from WIM data

$t_{(ADTT)}$ = the normal deviate for an extrapolation level

1.3, and 1.8 serve as the lower bounds for two-lane load case, and one-lane load case respectively.

2.3.2. Legal Truck Loads and AASHTO Legal Loads for Posting (Sivakumar et al., 2007)

Based on the configurations identified in WIM data, this study chooses a commonly used 4-ft axle spacing for axles forming a group. The front axle spacing varies from 6 ft to 14 ft. After determining the representative configurations of short wheelbase trucks with multiple axles, individual axle loads are maximized by reaching the Formula B limits. A suite of 12 candidates, shown in Figure 2.4 and Figure 2.5, is then propose and denoted as Formula B trucks (FBF trucks). The researchers of this study also carried out trials to determine a truck model which can envelope all the FBF trucks, which is denoted as Bridge Formula Truck (BFT). BFT is shown in Figure 2.6.

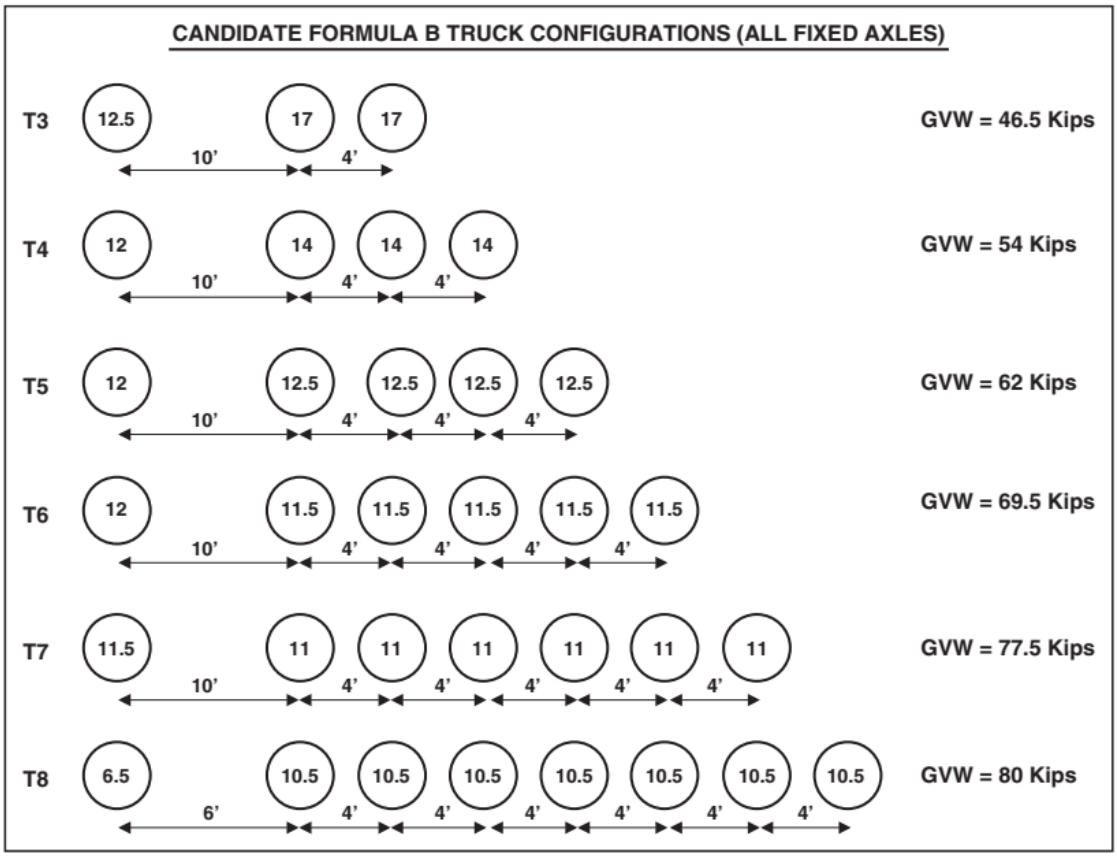


Figure 2.4. Candidate Formula B truck configurations with all fixed (equal) rear axles (Sivakumar et al., 2007)

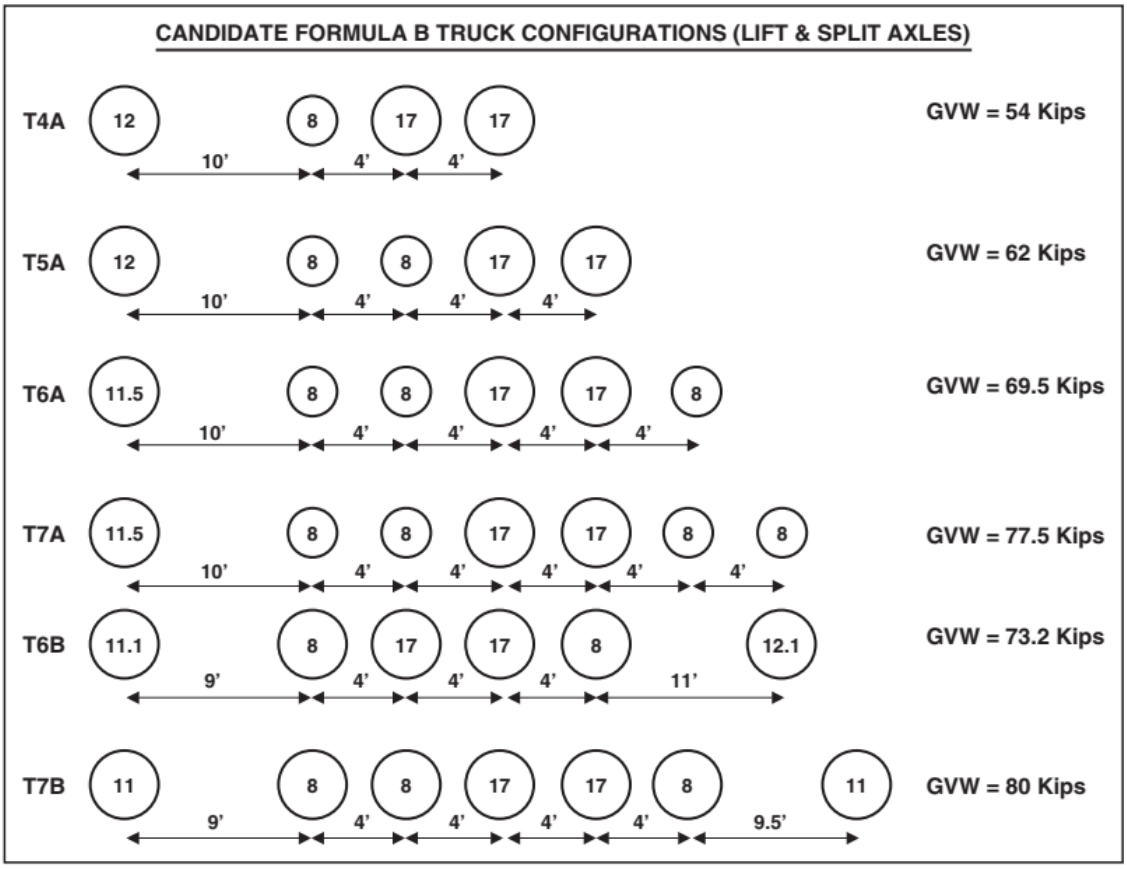


Figure 2.5. Candidate Formula B truck configurations with lift axles and split rear axle (Sivakumar et al., 2007)

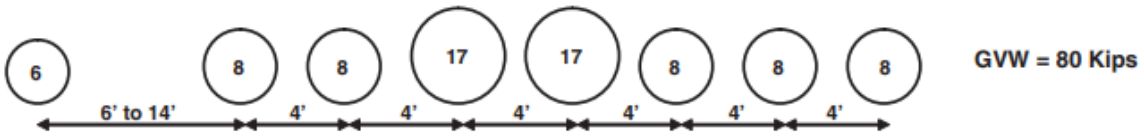


Figure 2.6. Bridge formula truck (Sivakumar et al., 2007)

The algorithm to identify SHVs in Weigh-In-Motion (WIM) data is provided in this study as follows:

- Check if a given vehicle exceeds 35 ft. If it does not, move it for next check;

- Check if the vehicle satisfies FBF and federal weight limits. If it does, move it for next check;
- Check if the vehicle induces a larger load effect than the three legal loads, i.e., Type 3, Type 3S2 (NJ Type 3S2) and Type 3-3. The load effect would be moment at the mid-span and shear at the support for simple spans of 10, 20, 40, 60, 80, 100, 120, 140, 160, 180, and 200 ft.

Short heavy trucks ranging from 3 to 8 axles are then obtained from the procedure above. Note that the length limit is set as 35 ft. If the trucks are longer than 35', their GVW limit will exceed the 80 kips limit.

After determining the live load models for SHVs, the study has also performed live load calibration for SHVs. Note that 4 loading scenarios are considered herein to determine the maximum load: Single-lane loads, Multiple presence of routine trucks, Two SHVs side-by-side, One SHV and one routine truck side-by-side. Instead of evaluating the safety index for SHVs, the study calibrated the live load factors for SHVs by the following steps for each of the four scenarios:

1. Compute the expected maximum live load L_{max}

    1) Determine N, the number of loading event during the exposure period.

    2) Determine t, the normal distribution Z score of cumulative probability (1-1/N).

    3) Determine the mean and standard deviation for a certain loading scenario.

4) Determine L_{max}, as shown in Equation 2.11

$$L_{max} = Mean + t \times Standard\ deviation \qquad \text{Equation 2.11}$$

2. Compute the live load factor, as shown in Equation 2.12:

$$\gamma_L = [\gamma_{L,ref}]\frac{L_{max}}{L_{max,ref}} \qquad \text{Equation 2.12}$$

where:

$L_{max,\ ref}$ = Reference value of L_{max}, namely Ontario data and 5000 ADTT

$\gamma_{L,ref}$ = 1.8 (corresponding live load factor for $\gamma_{L,\ ref}$

3. Adjust γ_L by being divided by α, as shown in

$$\gamma_L = \gamma_{SHV} = [\gamma_{L,ref}]\frac{L_{max}}{\alpha L_{max,ref}} \qquad \text{Equation 2.13}$$

where:

α = AASHTO SHV Live Load Model / AASHTO Routine Commercial Traffic, varying between 1.0 and 2.0.

The governing case for one-lane and two-lane depends on the respective maximum expected load and girder distribution factor in each case. Live load factors for SHVs were calibrated for sites with various ADTT values and SHV volumes. The SHV volumes for the sites are based on conservative assumptions of the percentage of SHV traffic over ADTT.

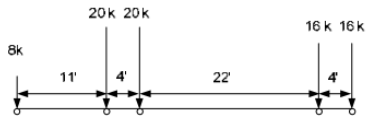
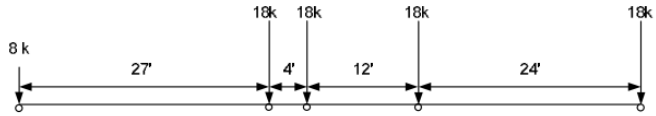
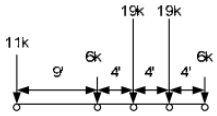
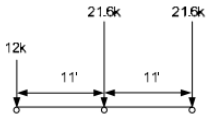
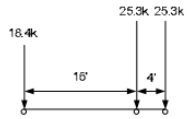
2.3.3. A Comparison of AASHTO Bridge Load Rating Methods (Mlynarski, Wassef & Nowak, 2011)

This research compares the load rating results obtained by Load and Resistance Factor Rating (LRFR) and Load Factor Rating (LFR). It also calibrated the live load factors for the Manual for Bridge Evaluation (MBE) by adjusting the factors until the target reliability index is reached.

There are 3036 girders in total for the analysis. The bridges are sorted into 8 categories. Table 2.3 shows the categories of the girders used in the analysis. Figure 2.7, Figure 2.8 and Figure 2.9show the live load models (nominal loads) used in the analysis.

Table 2.3 Girder type and number (Mlynarski, Wassef & Nowak, 2011)

Girder Type	*Number of Girders*
Simple Span Steel	1037
Simple Span Prestressed Concrete I	467
Simple Span Prestressed Concrete Box	377
Simple Span Reinforced Concrete T-Beam	295
Simple Span Reinforced Concrete Slab	99
Continuous Span Steel	418
Continuous Span Reinforced Concrete Slabs	105
Continuous Span Prestressed I	238

Vehicle	GVW (kips)	Length (ft)	Schematic
DE-07	80	41	
FL-04	80	67	
NC-21	61	21	
NM-04	55.2	22	
TX-04	69	20	

GVW=gross vehicle weight

Figure 2.7. Routine permit vehicles used in analysis (Mlynarski, Wassef & Nowak, 2011)

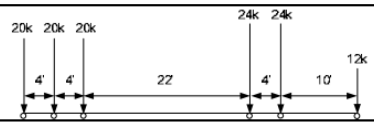
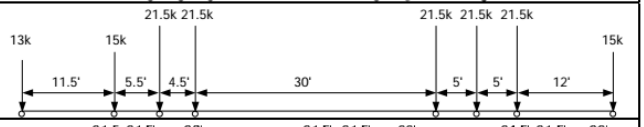
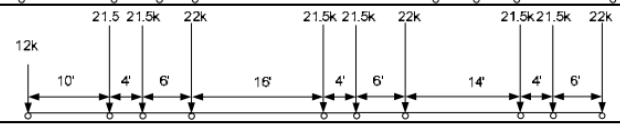
Vehicle	GVW (kips)	Length (ft)	Schematic
IL-01	120	44	
OR-06	150.5	73.5	
WA-02	207	70	

Figure 2.8. Special or limited crossing permit vehicles (Mlynarski, Wassef & Nowak, 2011)

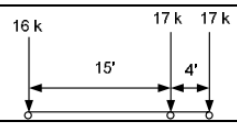
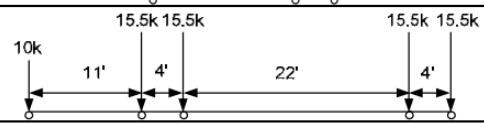
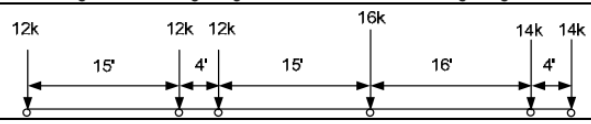
Vehicle	GVW (kips)	Length (ft)	Schematic
Type 3	50	19	
Type 3-3	80	54	
Type 3S2	72	41	

Figure 2.9. AASHTO legal vehicles (Mlynarski, Wassef & Nowak, 2011)

Equation 2.14 is the equation for the reliability index:

$$\beta = \frac{(1-2V_R)\left(1+LN\left(\frac{1}{1-2V_R}\right)\right)-\frac{\mu_Q}{\lambda_R R_n}}{\sqrt{(V_R-2V_R^2)^2+\frac{\sigma_q^2}{(\lambda_R R_N)^2}}} \qquad \text{Equation 2.14}$$

Where:

V_R = coefficient of variation of resistance

μ_Q = mean total applied load

$\lambda_R R_n$ = mean unfactored resistance (actual) or mean factored applied load (required)

σ_q = standard deviation of total applied load

Equation 2.15 and Equation 2.16 compute the mean and standard deviation of total load applied:

$$\mu_Q = \mu_{LL+IM} + \mu_{DC1} + \mu_{slab} + \mu_{DW} \qquad \text{Equation 2.15}$$

$$\sigma_Q = \sqrt{\sigma_{LL+IM}^2 + \sigma_{DC1}^2 + \sigma_{slab}^2 + \sigma_{DW}^2} \qquad \text{Equation 2.16}$$

The research indicates the load rating results for different live load models by plotting histograms of various rating ranges. For comparison purposes, the results for different values of ADTT (less than 100, 1000, and greater than 5000) and from LFR are shown in each bin. The plots are also categorized by different types of bridges and load effects. Figure 2.10 is an example of the plots.

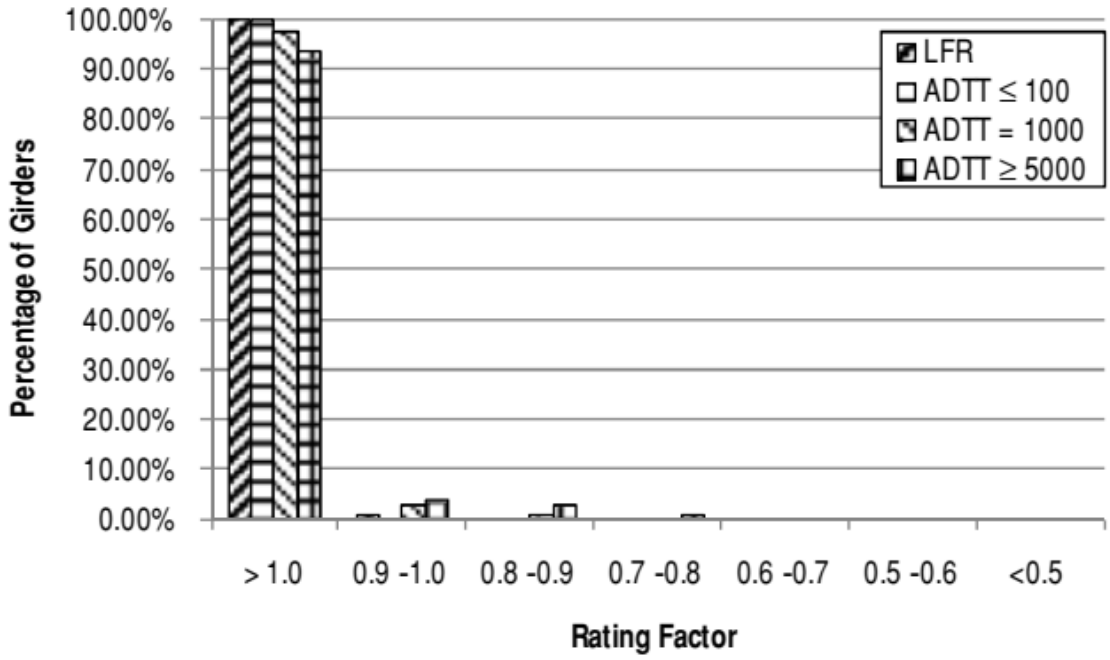


Figure 2.10. Load ratings for different ADTT (Mlynarski, Wassef & Nowak, 2011)

The research has performed reliability analysis to determine the appropriate live load factors for AASHTO legal loads. Reliability indices of different types of superstructure are plotted against live load factors for different live load models. Both moment and shear are considered. The live load factor is determined by the highest value among the different types of superstructure, which corresponds to the target reliability index (2.5). Figure 2.11 is an example of the plots.

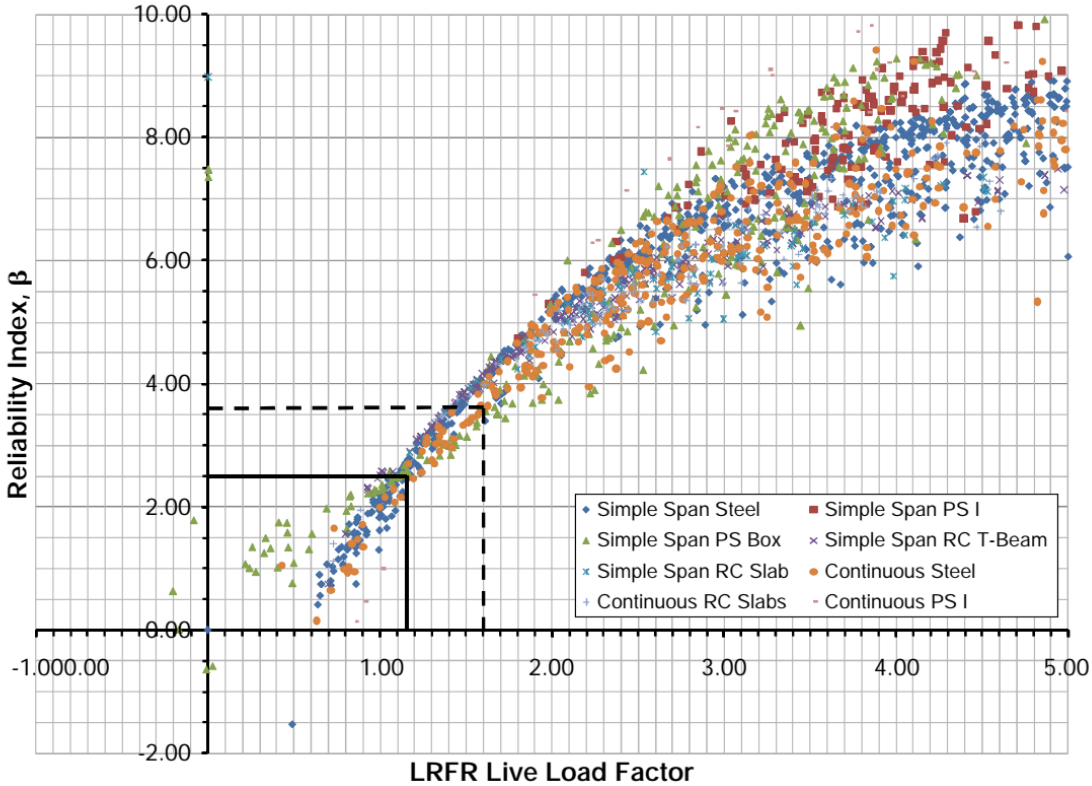


Figure 2.11. Reliability index versus live load factor (Mlynarski, Wassef & Nowak, 2011)

In the case shown above, a live load factor of 1.15 could be obtained to match a 2.5 reliability index. The analysis assumes an ADTT of 1000. For other ADTTs, the values of live load factor should have the same difference comparing to the one at ADTT = 1000 as in the old version of MBE. Based on the analysis, the live load factors for AASHTO legal loads at ADTT = 1000 adjusted to match with a 2.5 reliability index are shown in Table 2.4:

Table 2.4. Proposed live load factors for AASHTO legal trucks (Mlynarski, Wassef & Nowak, 2011)

Truck	Force Effect	Target β in MBE	γ_L in MBE (ADTT = 1,000)	β corresponding to current γ_L	γ_L corresponding to target β
AASHTO Type 3	Moment	2.5	1.65	3.5	1.15
	Shear			3.7	1.30
AASHTO Type 3-3	Moment			3.5	1.15
	Shear			3.5	1.10
AASHTO Type 3S2	Moment			3.7	1.10
	Shear			3.5	1.10

The comparison between the finalized adjusted live load factors and the old ones are shown in Table 2.5:

Table 2.5 Live load factors for routine commercial traffic (Mlynarski, Wassef & Nowak, 2011)

Traffic Volume (one direction)	Load Factor
Unknown	~~1.80~~ 1.45
ADTT ≥ 5000	~~1.80~~ 1.45
ADTT = 1000	~~1.65~~ 1.30

2.4. State Practices of Load Rating and Load Posting

Federal weigh limits have been placed to provide protection for the enormous Federal expense on the Interstate System Federal. However, the weight limits are not applied on non-interstate highways. States may have their own load rating and load posting practices according to the State laws. A survey on the State legal weight limits (Hearn, G., 2014) was conducted and the responses are presented in Table 2.6.

Table 2.6 State Legal Weight Limits (Hearn, G., 2014)

States	Single Axle Loads (kips)	Tandem Axle Loads (kips)	GVW Loads (kips)
Alabama	20	34	80
Alaska	20	38[d]	90
Arizona	20	34	80
Arkansas	20	34	80
California	20	34	80
Colorado	20	40[a]	85
Connecticut	22.4	36[e]	80
Delaware	22.4	40[b]	80
Florida	20	34	80
Georgia	18	40.68[b]	80
Hawaii	22.5	34	88
Idaho	20	34	129
Illinois	20	34	80
Indiana	20	34	80
Iowa	20	34	96
Kansas	20	34	85.5
Kentucky	20	34	80
Louisiana	20	34	88
Maine	22.4	41[b]	100
Maryland	22.4	34	80
Massachusetts	24	34	80
Michigan	20	34	164
Minnesota	20	34	80
Mississippi	20	34	80
Missouri	20	34	80
Montana	20	34	137.8
Nebraska	20	34	95
Nevada	20	34	129
New Hampshire	20	36[b]	80
New Jersey	22.4	34	80
New Mexico	21.6	37.44[f]	86.4
New York	22.4	34	80
North Carolina	21	38[b]	80
North Dakota	20	48[c]	105.5
Ohio	20	34	80
Oklahoma	20	40	90
Oregon	20	34	80
Pennsylvania	22.4	40.4[e]	80
Rhode Island	22.4	36[b]	80
South Carolina	20	36[b]	80

States	Single Axle Loads (kips)	Tandem Axle Loads (kips)	GVW Loads (kips)
South Dakota	20	34	155.5
Tennessee	20	34	80
Texas	20	34	80
Utah	20	34	80
Vermont	22.4	36[a]	80
Virginia	20	34	80
Washington	20	34	115
West Virginia	20	34	80
Wisconsin	20	34	80
Wyoming	20	36[c]	117

[a]Axle spacing not specified.

[b]Axle spacing 3'-4" minimum.

[c]Axle spacing greater than 3'-4".

[d]Axle spacing 3'-6" minimum.

[e]Axle spacing 6' minimum.

[f]Axle spacing 8' minimum

State legal weight limits are different than the Federal ones. Some states also developed state-specific configurations based on State legal weight limits. In NCHRP Project 12-63 (Sivakumar et al., 2007), 74 State posting vehicles were collected from 20 states. A comparison between state posting vehicles and Federal weight limits (both GVW and axle) are shown in Table 2.7.

Table 2.7 Formula B checks for State posting vehicles (Sivakumar et al., 2007)

State	Truck Designation	Total Axle Spacing (ft.)	No. of Axles	GVW (Kips)	FBF GVW (Kips)	Satisfies FBF GVW Limit?	Satisfies FBF Axle Weight Limit?
AL	Tandem	19	3	59	50.3	No	No
	Tri-Axle	19	4	75	54.7	No	No
	Concrete Truck	18	3	66	49.5	No	No
AR	T3	12	3	45	45	Yes	Yes
	T4	18	4	62	52.7	No	No
	T3S2	24	5	80	63	No	Yes
CT	Construction Vehicle	18.2	4	76.5	54.1	No	No
DE	DE 2	10	2	40	40	Yes	Yes
	DE 3 Interstate	16.83	3	54	48.6	No	No
	DE 3	16.83	3	70	48.6	No	No
	DE 4	17	4	73	52.9	No	No
FL	SU2	13	2	34	43	Yes	No
	SU3	15.17	3	66	47.4	No	No
	SU4	18.34	4	70	53.7	No	No
	C3	30	3	56	58.5	Yes	No
GA	H20-MOD	14	2	43	44	Yes	No
	Type 3	19	3	66	50.3	No	No
ID	Type 3	14	3	54	46.5	No	No
IL	Type 3	16	3	44	48	Yes	Yes
	Type 3-S1	28	4	58.5	60.8	Yes	Yes
	Type 3-S2	30	5	72	66.8	No	Yes
KY	Type 1	14	2	40	44	Yes	No
	Type 2	16	3	56.7	48	No	No
	Type 3	20	4	73.5	55.3	No	No
	Type 4	34	5	80	69.3	No	No
MI	No 1	9	2	33.4	39	Yes	Yes
	No.2	12.6	3	41.4	45.4	Yes	Yes
	No.3	16	4	54.4	52.7	No	Yes
	No.4	19.6	5	67.4	60.2	No	No
	No.5	28	6	78	70.8	No	No
	No.9	18	3	51.4	49.5	No	Yes
	No.10	21.6	4	59.4	56.3	No	Yes
	No.11	30.6	5	77.4	67.1	No	Yes

State	Truck Designation	Total Axle Spacing (ft.)	No. of Axles	GVW (Kips)	FBF GVW (Kips)	Satisfies FBF GVW Limit?	Satisfies FBF Axle Weight Limit?
MN	Type 3	14	3	48	46.5	No	Yes
MS	Concrete Truck	16	3	60	48	No	No
	HS-Short	30	5	80	66.8	No	No
NH	2-Axle Truck	14	2	33.4	44	Yes	No
	3-Axle Truck	16	3	55	48	No	No
	4-Axle Truck	18	4	60	54	No	No
NC (Interstate traffic)	SH	14	2	25	44	Yes	No
	S3A	13	3	45.5	45.8	Yes	No
	S3C	15	3	43	47.3	Yes	No
	S4A	17	4	53.5	53.3	Yes	No
	S5A	21	5	61	61.1	Yes	No
	S6A	25	6	69	69	Yes	No
	S7A	34	7	80	79.8	Yes	No
	S7B	29	7	77	76.9	Yes	No
	T4A	22	4	56.5	56.7	Yes	No
	T5B	26	5	64	64.3	Yes	No
	T6A	30	6	72	72	Yes	No
	T7A	34	7	80	79.8	Yes	No
	T7B	34	7	80	79.8	Yes	No
NC (Except Interstate Traffic)	SH	14	2	25	44	Yes	No
	S3A	13	3	50.1	45.8	No	No
	S3C	15	3	43	47.3	No	No
	S4A	17	4	58.9	53.3	No	No
	S5A	21	5	67.1	61.1	No	No
	S6A	25	6	75.9	69	No	No
	S7A	34	7	80	79.8	No	No
	S7B	29	7	80	76.9	No	No
	T4A	22	4	62.2	56.7	No	No
	T5B	26	5	70.4	64.3	No	No
	T6A	30	6	79.2	72	No	No
	T7A	34	7	80	79.8	No	No
	T7B	34	7	80	79.8	No	No
OH	2F1	10	2	30	40	Yes	Yes
	3F1	14	3	46	46.5	Yes	Yes
	4F1	18	4	52	54	Yes	Yes
PA	ML80	18	4	73.3	54	No	No

State	Truck Designation	Total Axle Spacing (ft.)	No. of Axles	GVW (Kips)	FBF GVW (Kips)	Satisfies FBF GVW Limit?	Satisfies FBF Axle Weight Limit?
	TK527	34	7	80	80	Yes	No
SD	Type 3	16	3	48	48	Yes	Yes
TN	TN4	19.17	4	74	54.8	No	No
TX	Single Delivery Truck	17	2	38	47	Yes	No
	Concrete Truck	14	3	69	51	No	No
VA	Single-Unit Truck	24	3	54	51.8	No	Yes

The posting for SHVs are based on the results of load rating. There are different practices of posting. *Manual on Uniform Traffic Control Devices for Streets and Highways* provides five standard weight limit signs as shown in Figure 2.12

R12-1 presents the GVW limit, R12-2 presents the axle-weight limit, R12-3 presents empty GVW limit, R12-4 presents a combination of axle-weight limit and GVW limit, R12-5 presents GVW limit for single, tractor-semi-trailer combination and truck-trailer combination vehicles, respectively.

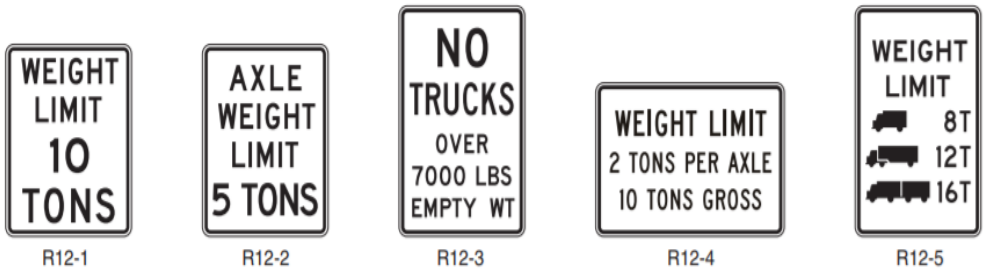


Figure 2.12. U.S. DOT weight limit signs. (MUTCD, 2009)

A survey on load posting practices were obtained from 43 states (Hearn, G., 2014), as shown in Table 2.8.

Table 2.8 - Summary of State Posting Signs (Hearn, G., 2014)

Type(s) of Posting Signs	States
R12-1	Arizona, Colorado, Hawaii, Indiana, Louisiana, Nevada, New York, Oklahoma
R12-5	Florida, Kansas, Maryland, Massachusetts, Nebraska, Ohio, South Dakota, Wyoming
R12-1, R12-2	Delaware, Illinois, North Dakota, Wisconsin
R12-1, R12-5	Alabama, California, Georgia, Iowa, Kentucky, Maine, Minnesota, Montana, New Mexico, Tennessee, Utah, Washington, West Virginia
R12-1, Other	New Hampshire, North Carolina, Virginia
R12-5, Other	Idaho
R12-1, R12-2, R12-5	Mississippi
R12-1, R12-2, Other	Texas
R12-1, R12-5, Other	Missouri, Oregon
R12-1, R12-2, R12-5, Other	Alaska
R12-1, R12-2, R12-4, R12-5, Other	Michigan

The most common types of the posting signs applied are R12-1 (gross-weight type) and R12-5 (silhouette type). Among the 43 states, 34 states implement R12-1 and 27 states implement R12-5. Fewer states implement R12-2 and R12-4 with 8 and 1 state(s). None of the states implement R12-3.

States also developed state-specific posting signs or modified the standard signs. Examples are shown in Figure 2.13, Figure 2.14, Figure 2.15, Figure 2.16, Figure 2.17 and Figure 2.18 present some of the modifications or state-specific posting signs.

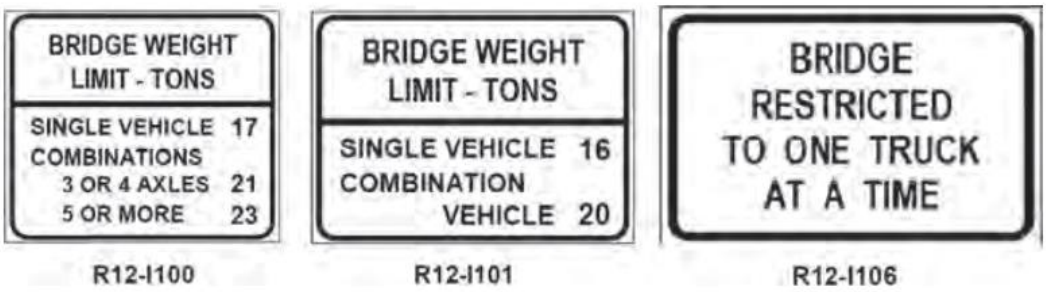


Figure 2.13. Illinois weight limit signs. (Hearn, G., 2014)

Figure 2.14. Nebraska weight limit signs. (Hearn, G., 2014)

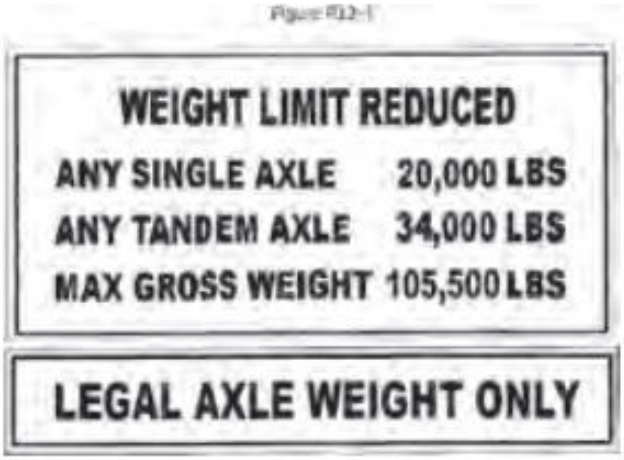


Figure 2.15. Oregon weight limit sign. (Hearn, G., 2014)

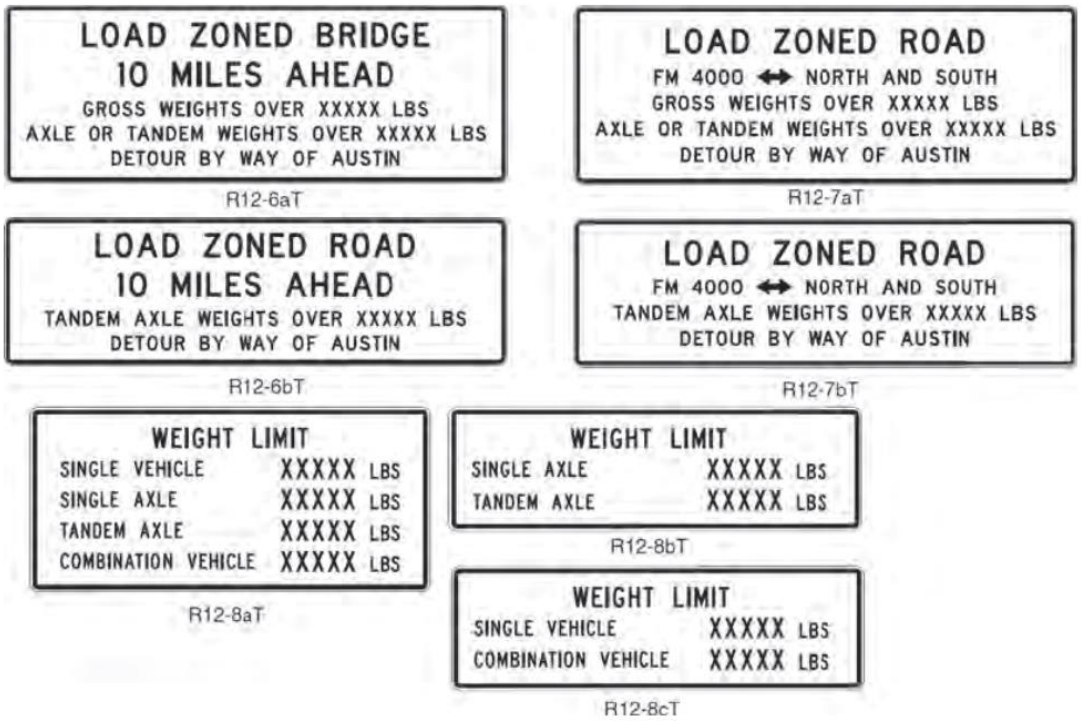


Figure 2.16. Texas weight limit signs. (Hearn, G., 2014)

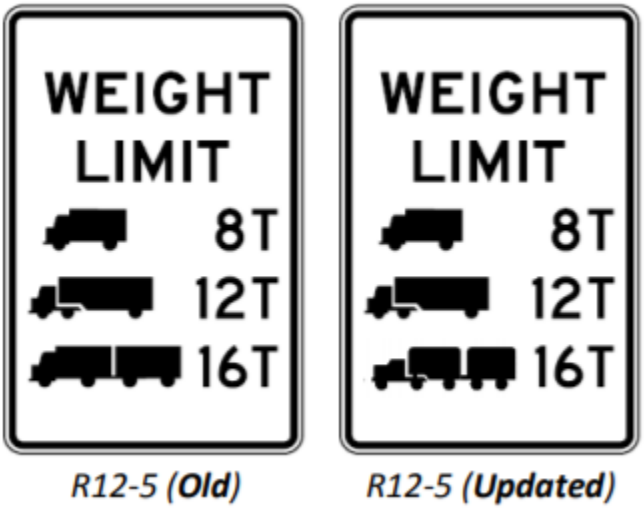
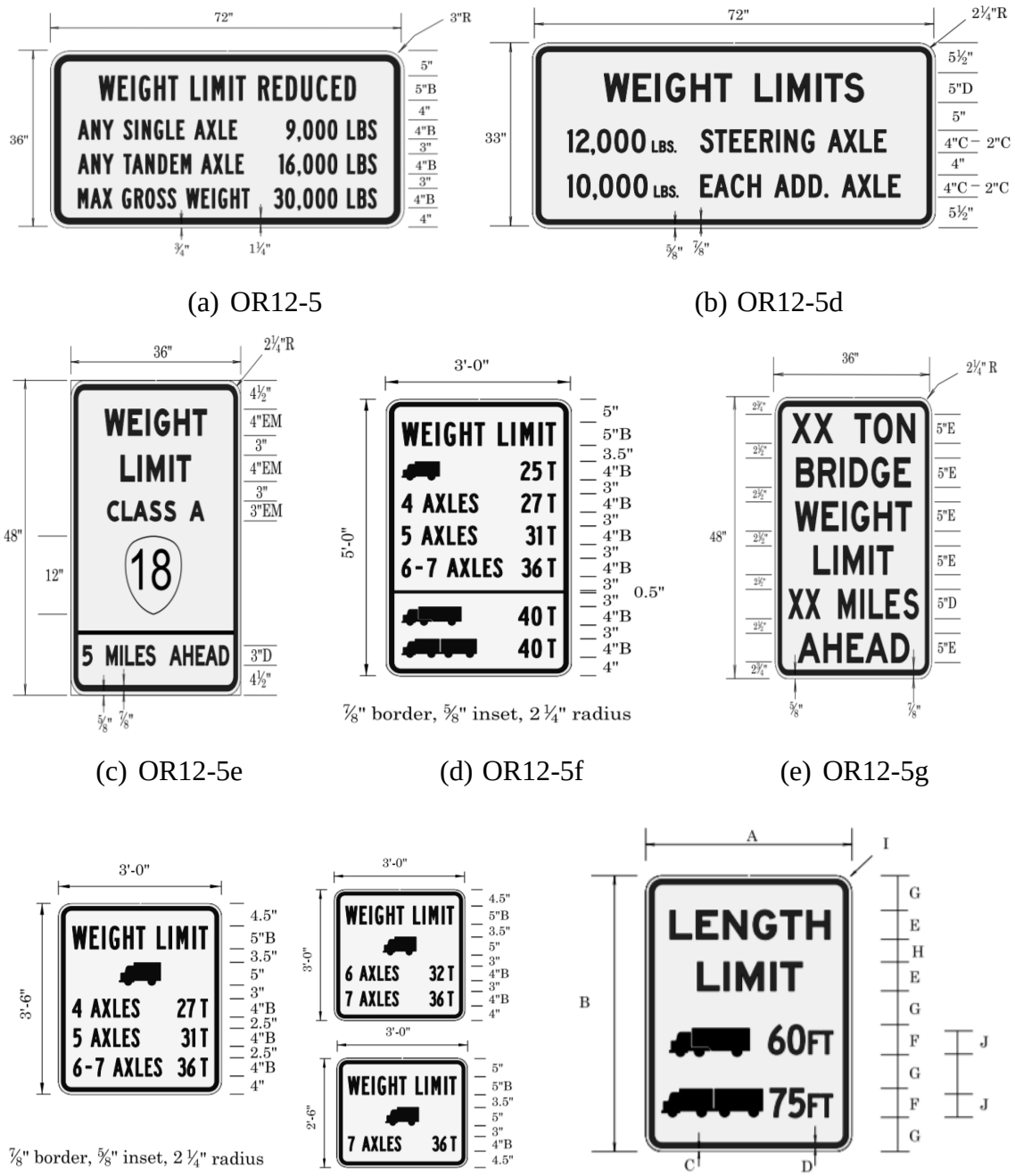


Figure 2.17. Michigan old and updated R12-5 weight limit signs. (MDOT, 2016)



(a) OR12-5 (b) OR12-5d

(c) OR12-5e (d) OR12-5f (e) OR12-5g

(f) OR 12-6 (g) OR 12-8

Figure 2.18. Oregon weight limit signs. (ODOT, 2018)

2.5. Methodology of Structural Reliability Analysis

Structural reliability analysis is an approach to evaluate how much the margin of safety of a structure is, given its inherent structural capacity and the loads to resist during its service years. The margin of safety is defined by limit state functions (performance functions). Based on the modes of failure and the attributes of capacity, performance and loading for evaluation, AASHTO LRFD Bridge Design Specifications (6th Edition, 2012) includes four categories: Strength (I, II, III, IV and V), Extreme Event (I and II), Service (I, II, III and IV) and Fatigue (I and II). Different live load factors are applied for different limit states.

Equation 2.17 (Nowak & Collins, 2012) shows the general form of limit state functions. The limit state (g = 0) represents the boundary between safeness and failure. g ≥ 0 indicates a structure is safe while g < 0 indicates the structure will fail.

$$\mathrm{g(R, Q)} = R - Q \qquad \text{Equation 2.17}$$

Where

R = resistance

Q = load effect

Since R and Q are random variables, the probability of failure could be calculated as shown in Equation 2.18 (Nowak & Collins, 2012). If R and Q are continuous random variables, the probability density functions (PDF) of R, Q and g = R – Q could be represented by the curves in Figure 2.19. The shaded area represents the probability of failure.

$$P_f = P(R - Q < 0) = P(g < 0) \qquad \text{Equation 2.18}$$

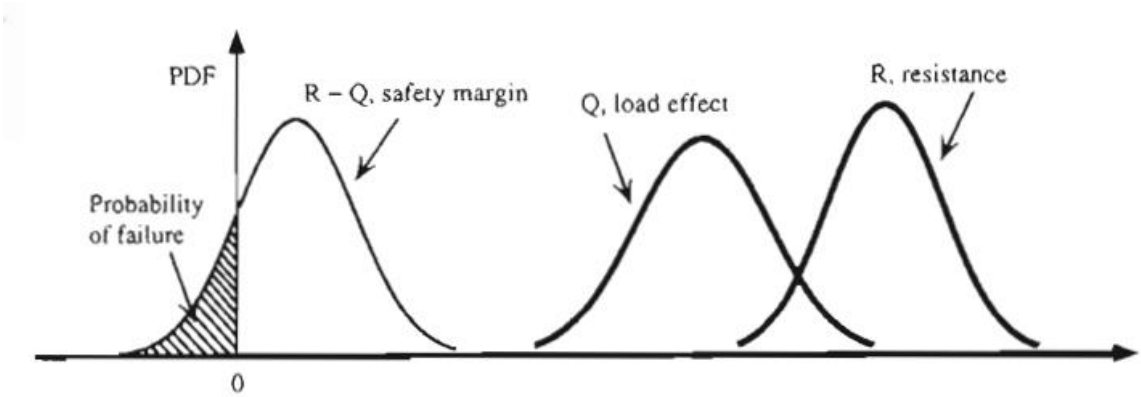


Figure 2.19 PDFs of Load, Resistance, and Safety Margin (Nowak & Collins, 2012)

The safety level of a structural member is assessed by the reliability index (β), which is defined in Equation 2.19 **(**Nowak & Collins, 2012**)**:

$$\beta = \frac{\mu_R - \mu_Q}{\sqrt{\sigma_R^2 + \sigma_Q^2}} \qquad \text{Equation 2.19}$$

where:
μ_R = Mean value of resistance
μ_R = Mean value of load
σ_R = Standard deviation of resistance
σ_R = Standard deviation of load

Mathematically, β is equal to the inverse of the coefficient of variation of g(R,Q) = R – Q. R and Q can be converted to the standard forms (reduced variables) as shown in Equation 2.20 **(**Nowak & Collins, 2012**)**:

$$Z_R = \frac{R - \mu_R}{\sigma_R} \qquad \text{Equation 2.20 (a)}$$

$$Z_Q = \frac{Q - \mu_Q}{\sigma_Q} \qquad \text{Equation 2.21 (b)}$$

β is also defined as the shortest distance between the origin of reduced variables (Z_R and Z_Q) and line $g(Z_R,Z_Q) = 0$ as shown in Figure 2.20:

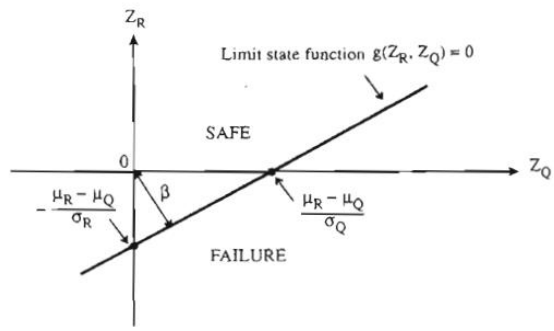


Figure 2.20. Reliability Index Is Defined as the Shortest Distance in the Space of Reduced Variables (Nowak & Collins, 2012)

If R and Q are normally distributed random variables, the probability of failure (P_f) is related to β as shown in Equation 2.22**(**Nowak & Collins, 2012**)**:

$$P_f = \Phi(-\beta) \qquad \text{Equation 2.22}$$

Table 2.9 provides the conversions between P_f and β:

Table 2.9 Reliability Index β and Probability of Failure P_f

P_f	β
10^{-1}	1.28
10^{-2}	2.33
10^{-3}	3.09
10^{-4}	3.71
10^{-5}	4.26
10^{-6}	4.75
10^{-7}	5.19
10^{-8}	5.62
10^{-9}	5.99

CHAPTER 3

WEIGH-IN-MOTION DATA PROCESSING

Weigh-In-Motion (WIM) technology has been developed to capture the weights and spacings of vehicles that are in a dynamic status. It is much more powerful and efficient than static scales, which require a complete stop of vehicles for the measurement. Therefore, the technology has been extensively in different fields such as law enforcement, regulation, research for pavement and bridges, etc. WIM system is made up of motion sensors and strain gages (Moses, 1979). The axle spacing data and axle weight data are essential for calculating the load effects of the vehicles operating on bridge spans. The speed and time data are utilized to assess the multiple-presence cases. The author utilized WIM data in two phases: I) traversing of SHV traffic fleet, and II) live load extrapolation of SHV traffic fleet. This chapter will present the methodology and results for Phase I. Phase II will be presented in the next chapter.

3.1. Algorithm for WIM Data Processing

The author has developed the algorithm to detect SHVs in WIM data. The algorithm consists of three steps: 1) filter cars, pickup trucks and any other erroneous readings from the data and keep trucks only, 2) filter overweight trucks and keep legal trucks only, and 3) extract SHVs from legal truck traffic.

For Step 1, the author referred to NCHRP web-only document 201 (Wassef et al., 2014). This step consists of 11 criteria:

1) Individual axle weight > 70 kips or < 2 kips;
2) GVW < 12 kips;
3) Total length > 120 ft;
4) Total length < 7 ft;
5) First axle spacing < 5 ft;
6) Individual axle spacing < 3.4 ft;
7) Speed < 10 mph;
8) Speed > 100 mph;
9) Difference between GVW and sum of axle weights > 10%;
10) FHWA Class < 3 or > 14;
11) Sum of axle spacings ≥ wheel base + 1 ft

Note that for criterion 10, the vehicles are divided into 13 classifications according to FHWA as shown in Figure 3.1.

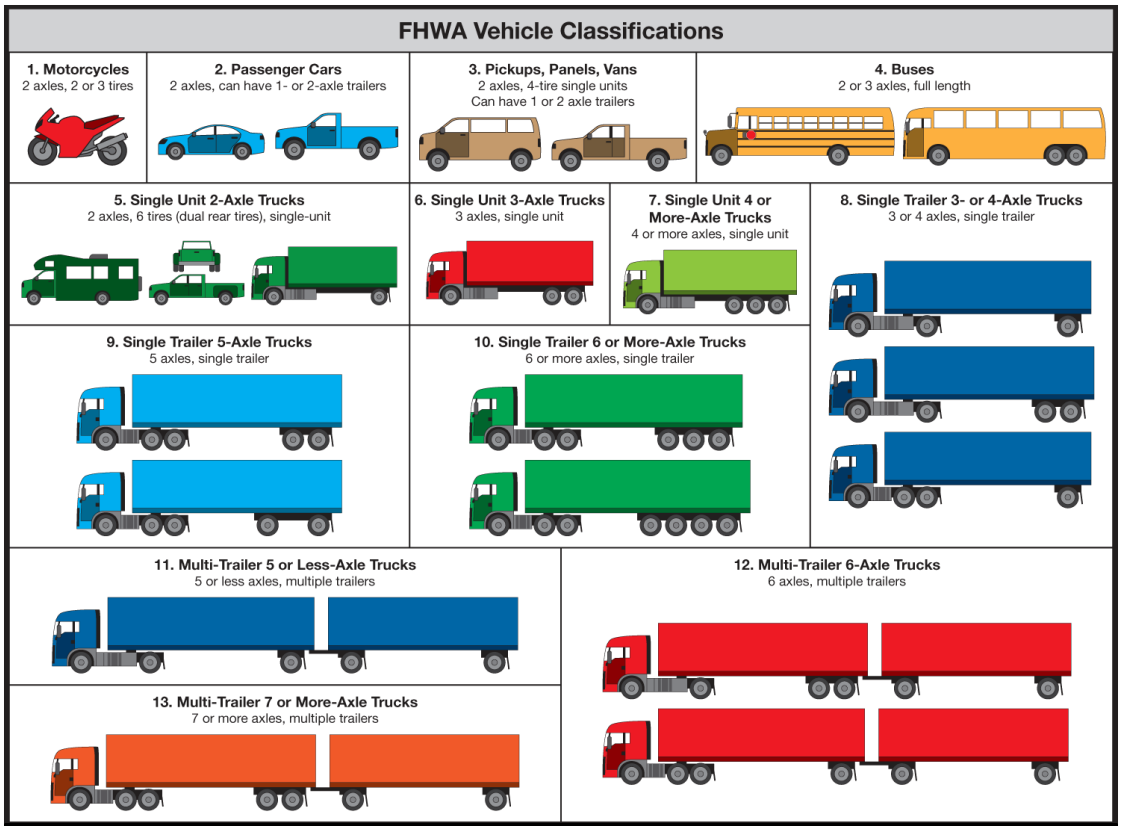


Figure 3.1. FHWA vehicle classification

For Step 2, the author referred to New Jersey Commercial Vehicle Size and Weight Guidebook. (New Jersey Motor Vehicle Commission, 2017) and *Weight Guidebook* and Code of Federal Regulation (23 CFR 658.17). This step consists of 4 criteria:

1) Single axle weight > 22.4 kips (NJ) / 20 kips (US). Single axle is defined as all wheels of one or combination of axles spaced more than 96 in or less than 40 in.

2) Tandem axles weight >34 kips. Tandem axle is defined as all wheels of consecutive axles spaced between 40 in and 96 in.

3) GVW > 80 kips.

4) Gross weight of groups of two or more axles < limit calculated by Formula B (Equation 3.1):

$$W=500(LN/(N-1)+12N+36) \qquad \text{Equation 3.1}$$

Where:

W = the gross weight on any group of two or more consecutive axles to the nearest 500 lbs;

L = the distance between the outer axles of any group of two or more consecutive axles;

N = the number of axles in the group under consideration.

Note that each one of the two consecutive tandem axles can weigh up to the tandem limit: 34 kips, provided that the total length of the two tandem sets is more than 36 ft. Under this regulation, two tandem sets can exceed the limit prescribed by the Formula B. For example, a group of two consecutive tandem sets with a total length of 36 ft can weight up to 68 kips instead of 66 kips given by the Formula B.

These limits are adopted in the algorithm to distinguish legal trucks from overweight trucks.

For Step 3, the author referred to NCHRP Report 575 (Sivakumar et al., 2007). In this step, SHVs will be identified and extracted. Since SHVs are legal trucks, overweight trucks filtered out by Step 2 will be excluded from Step 3. This step consists of 2 criteria:

1) Wheelbase < 35 ft;

2) Load effect by the truck > load effect by the three AASHTO legal trucks shown in Figure 3.2.

a. *AASHTO Trucks*—Apply for all span lengths and load effects.

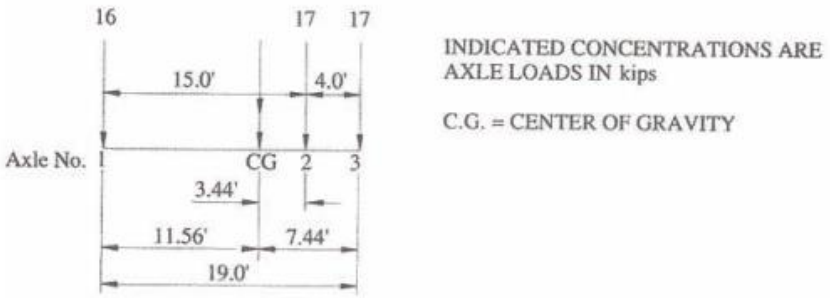


Figure D6A-1—Type 3 Unit; Weight = 50 kips (25 tons)

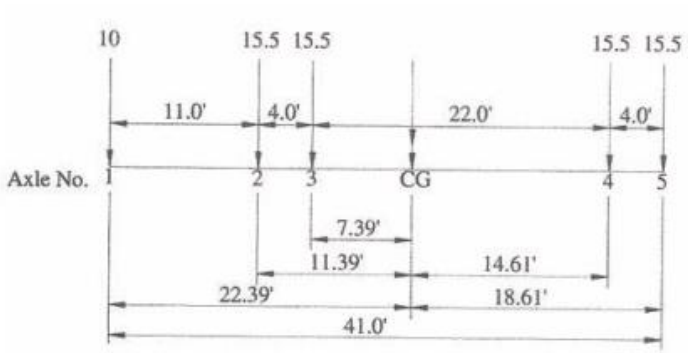


Figure D6A-2—Type 3S2 Unit; Weight = 72 kips (36 tons)

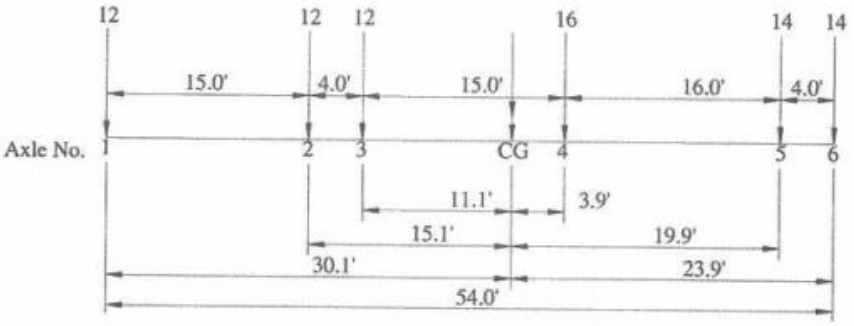


Figure D6A-3—Type 3-3 Unit; Weight = 80 kips (40 tons)

Figure 3.2 AASHTO legal trucks for routine commercial traffic (AASHTO MBE, 2018)

For criterion 2, the load effects include positive moment from simple spans and shear force from simple spans. The author developed an algorithm to simulate each individual truck running through spans, and then determine the absolute maximum values. In accordance to NCHRP Report 575 (Sivakumar et al., 2007), 11 span lengths are subjected to the simulation, including 10 ft (3.0 m), 20 ft (6.1 m), 40 ft (12.2 m), 60 ft (18.3 m), 80 ft (24.4 m), 100 ft (30.5 m), 120 ft (36.6 m), 140 ft (42.7 m), 160 ft (48.8 m), 180 ft (54.9 m) and 200 ft (61.0 m).

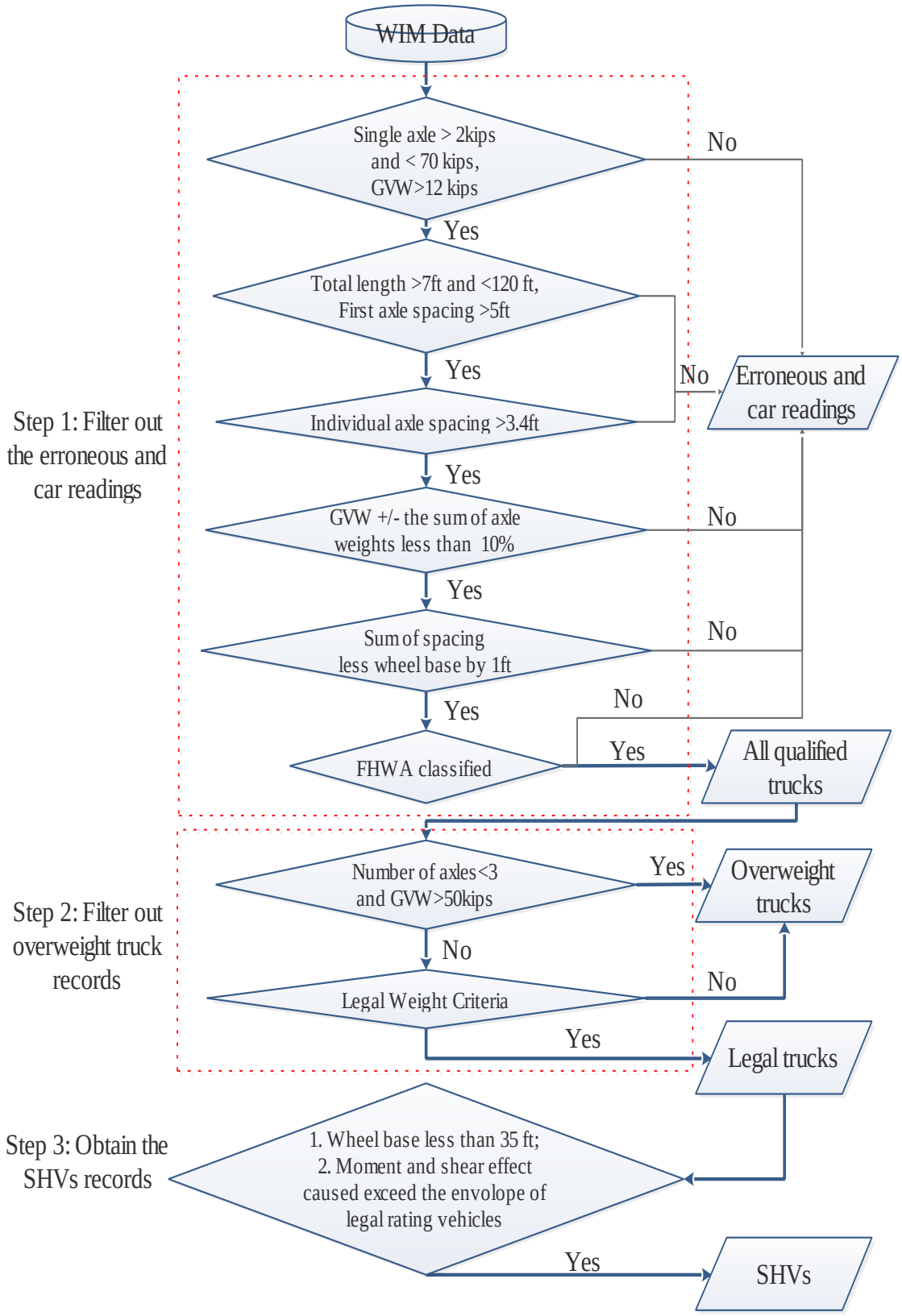


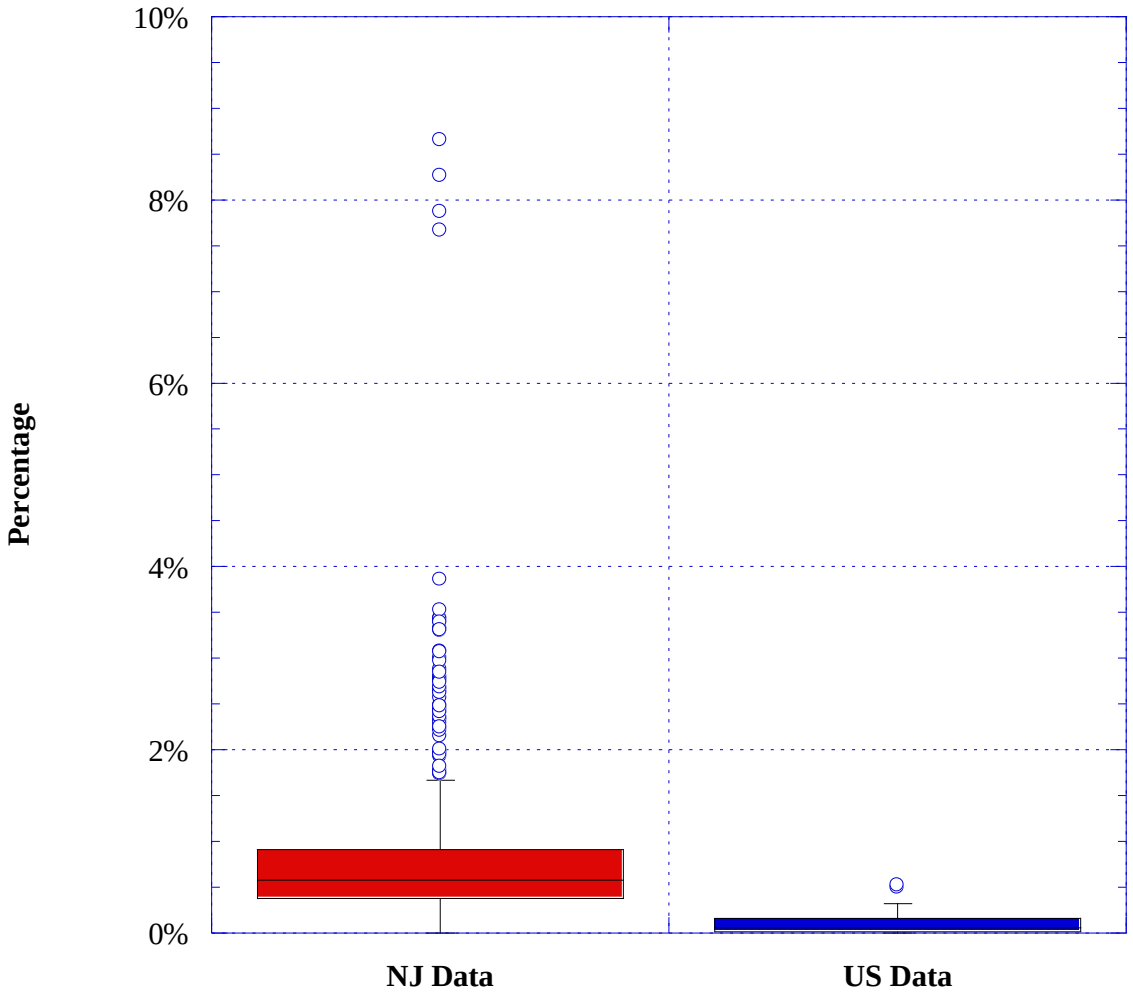
Figure 3.3. Program algorithm

3.2. Database of WIM Data

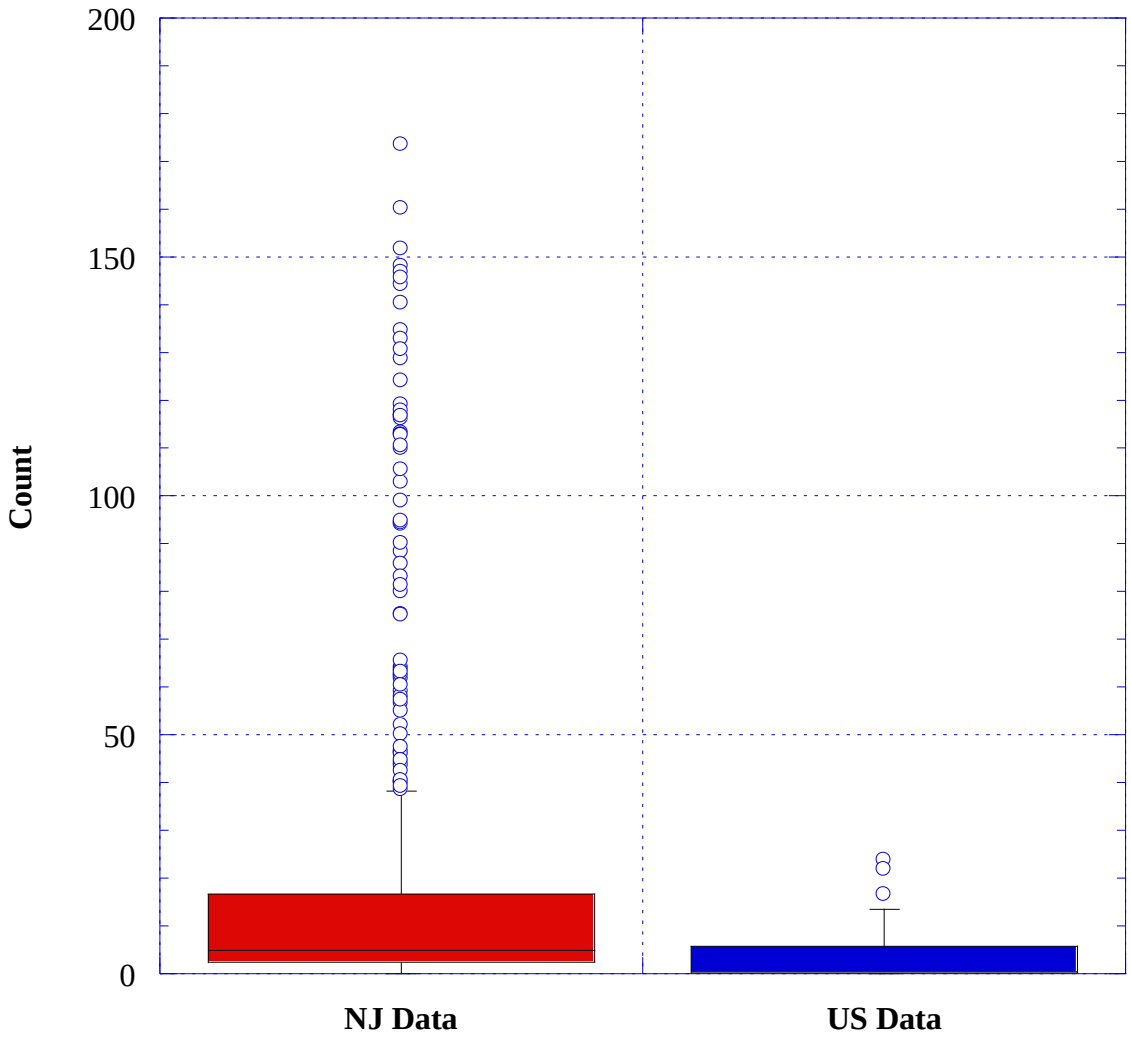
The author collected WIM data from various sources. The data were assigned into two datasets based on their origins. Dataset #1 consists of data from 93 WIM sites in New Jersey provided by New Jersey Department of Transportation. The data covers a period of 7 years from 2010 to 2016. This dataset is referred as “NJ Data” hereafter. Dataset #2 consists of data from 46 WIM sites of 21 other states across the US which included the following states: California, Florida, Indiana, Mississippi, New York, Arizona, Arkansas, Colorado, Delaware, Illinois, Indiana, Kansas, Louisiana, Maine, Maryland, Minnesota, New Mexico, Pennsylvania, Tennessee, Virginia and Wisconsin. This dataset is a collection of data from TRB’s second Strategic Highway Research Program (SHRP 2) Report S2- R19B-RW-1 (Kulicki et al., 2015) and will be referred as “US Data” hereafter. The NJ Data and US Data were processed separately to evaluate the SHV traffic fleet on the state-basis of New Jersey and on a national basis, respectively.

3.3. Traversing of SHVs

The author processed the WIM data and obtained the statistics of SHVs for both NJ Data and US Data. The percentage of SHV traffic fleet over all trucks and the average daily count of SHVs were investigated for each WIM site, as shown in Figure 3.4.



(a) SHV percentage (per site)



(b) SHV average daily count (per site)

Figure 3.4. Percentage of SHVs over all truck and daily average counts of SHVs

For the all the WIM sites, the mean of SHV percentage (over all trucks) is 0.85% for NJ Data and 0.10% for US Data while the mean of SHV average daily counts is 17.49 for NJ Data and 4.37 for US Data. An heatmap was also generated to describe the states of SHV operation in different regions of New Jersey. The data is from 2016, and the criteria is based on the average daily volume of SHVs captured by WIM sites. The heatmap is

shown in Figure 3.5. The demonstration indicates that the volume of SHV traffic in the northern region is significantly higher than that in the southern region.

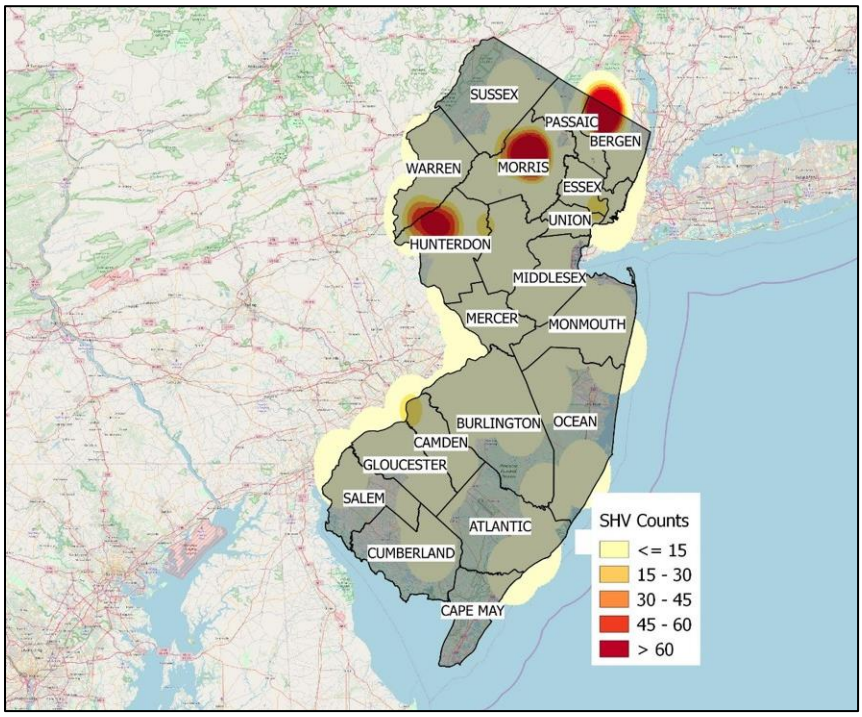


Figure 3.5. Heat map of the regional SHV operation conditions in New Jersey

The detailed site information and truck statistics for NJ Data and US data are presented in APPENDIX A in Table A.1 and Table A.2, respectively. Additionally, the SHVs are divided by the number of axles, with 2 axles minimum and 8 axles maximum. The statistics of SHVs of different numbers of axles for NJ Data and US data are shown in APPENDIX A in Table A.3 and Table A.4, respectively. The histogram of number of axles is shown in Figure 3.6.

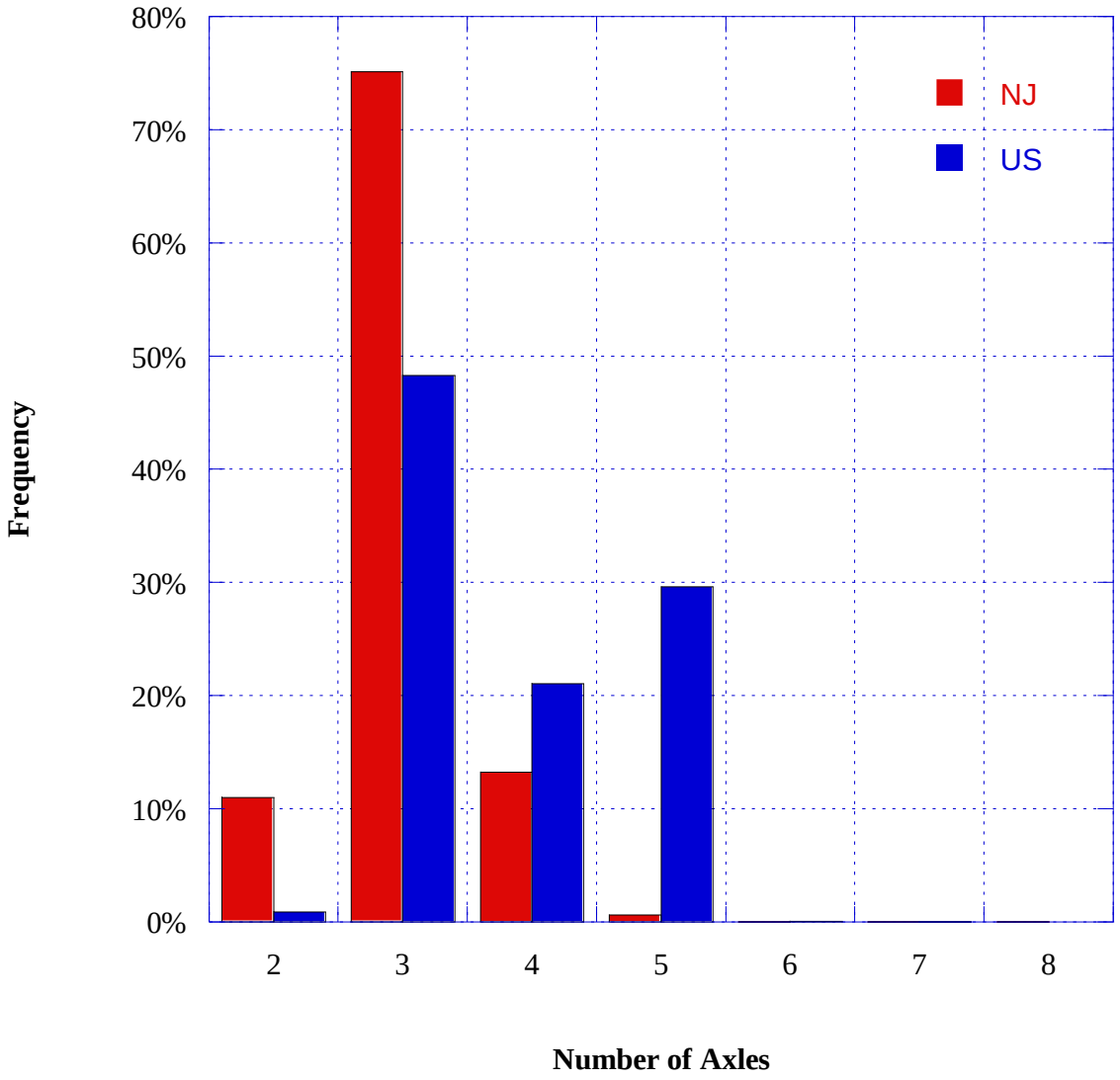
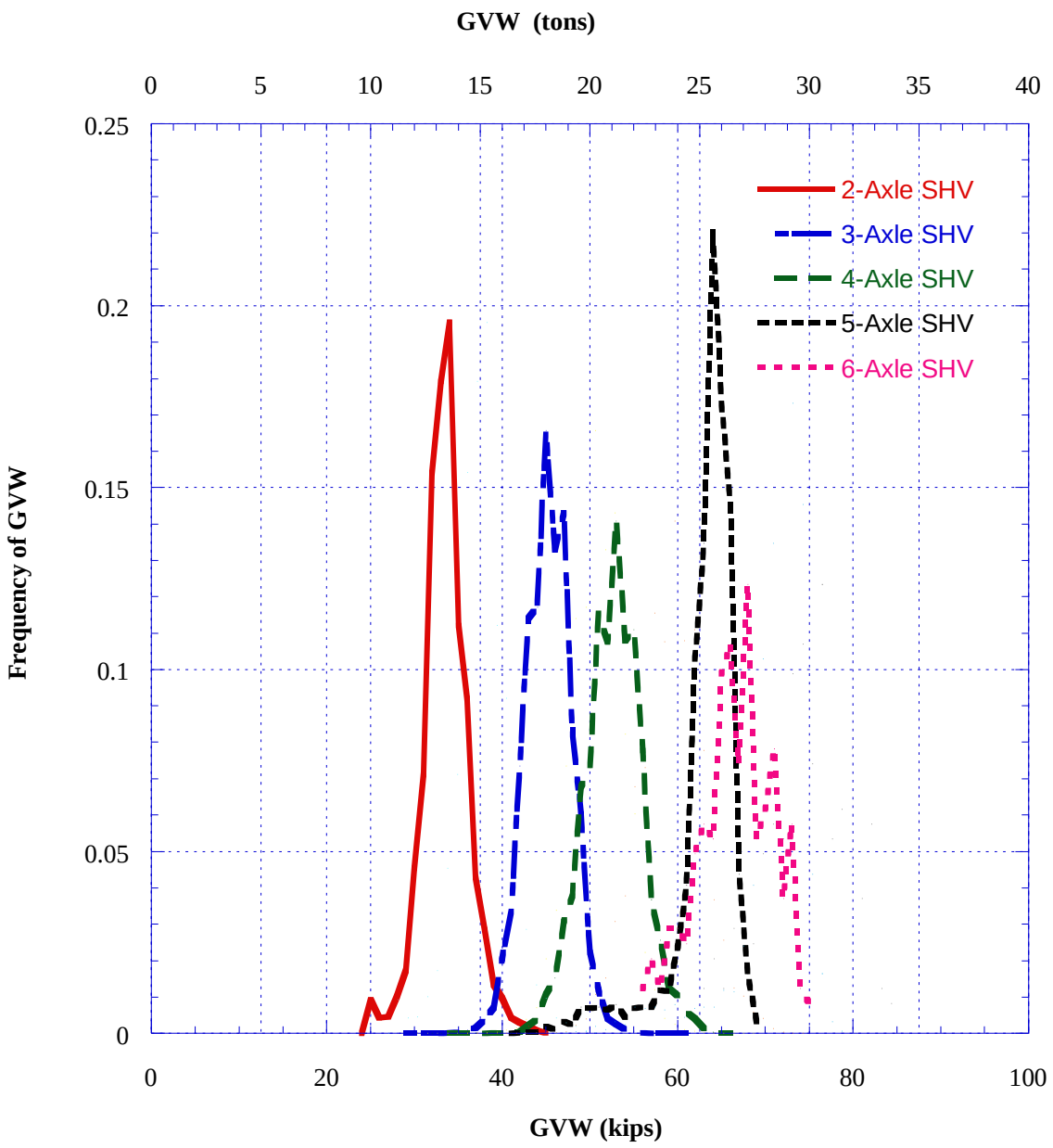


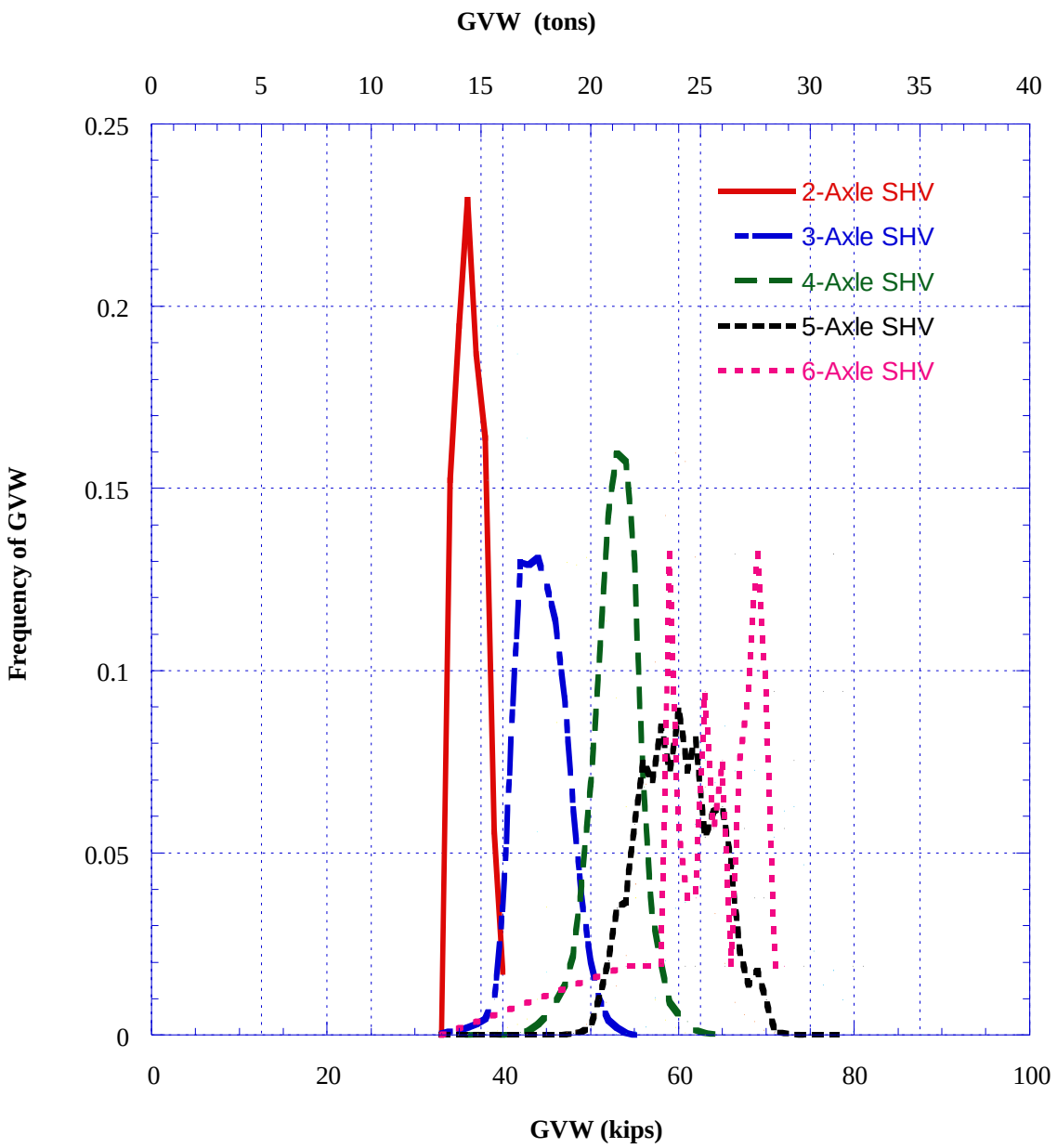
Figure 3.6 Frequency of SHVs with different numbers of axles

The majority of SHVs are 2-axle, 3-axle and 4-axle trucks according to NJ Data while the majority are 3-axle, 4-axle and 5-axle trucks according to US Data. Very few 6-axle, 7-axle and 8-axle SHVs were identified.

The distributions of gross vehicle weight (GVW) of SHVs with different numbers of axles were also investigated, and the results are shown in Figure 3.7.


GVW (tons)
0
5
10
15
20
25
30
35
40
0.25
0.2
0.15
0.1
0.05
0
Frequency of GVW
2-Axle SHV
3-Axle SHV
4-Axle SHV
5-Axle SHV
6-Axle SHV
0
20
40
60
80
100
GVW (kips)

(a) NJ Data



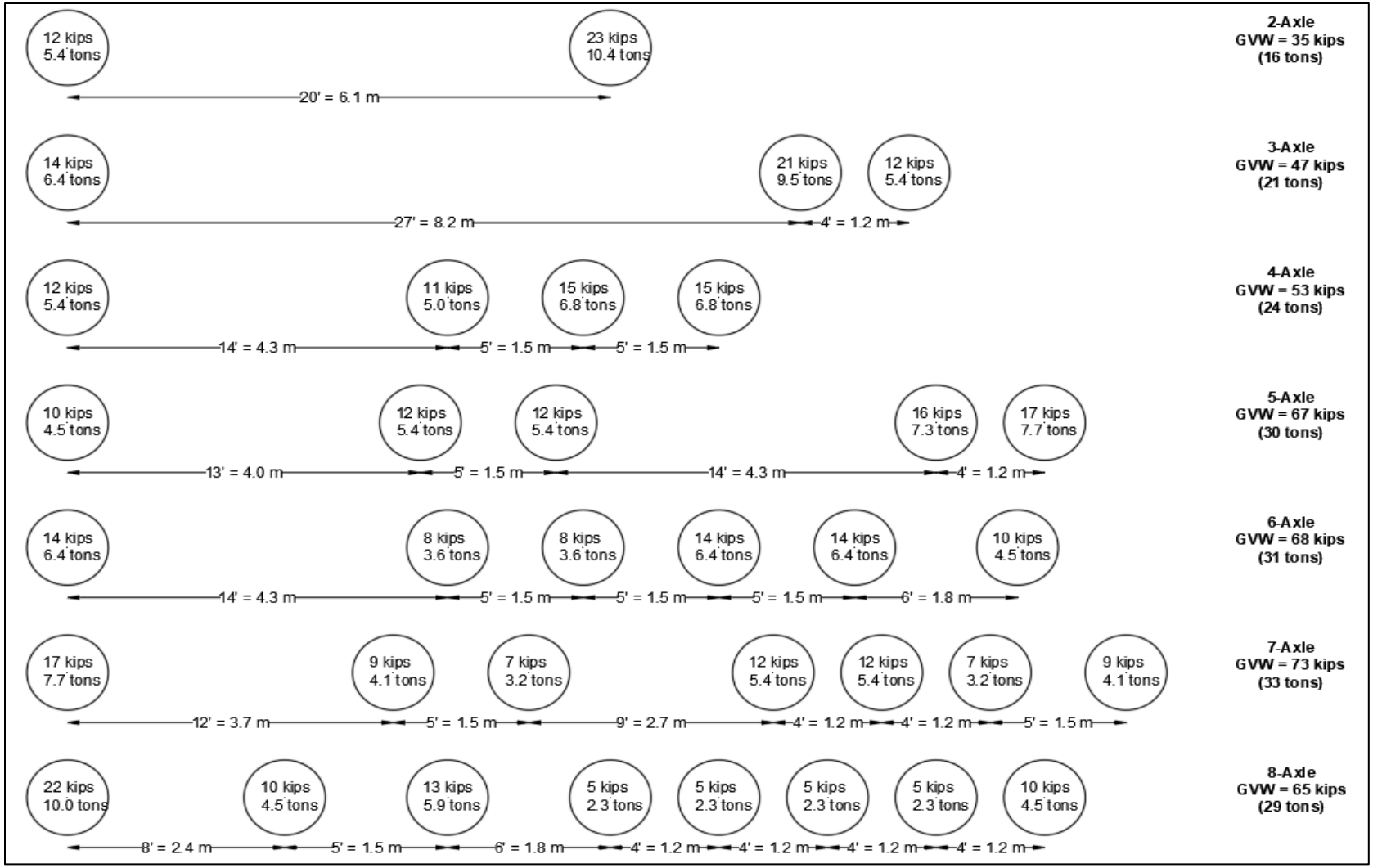
(b) US Data

Figure 3.7 GVW Distribution of SHVs with different numbers of axles

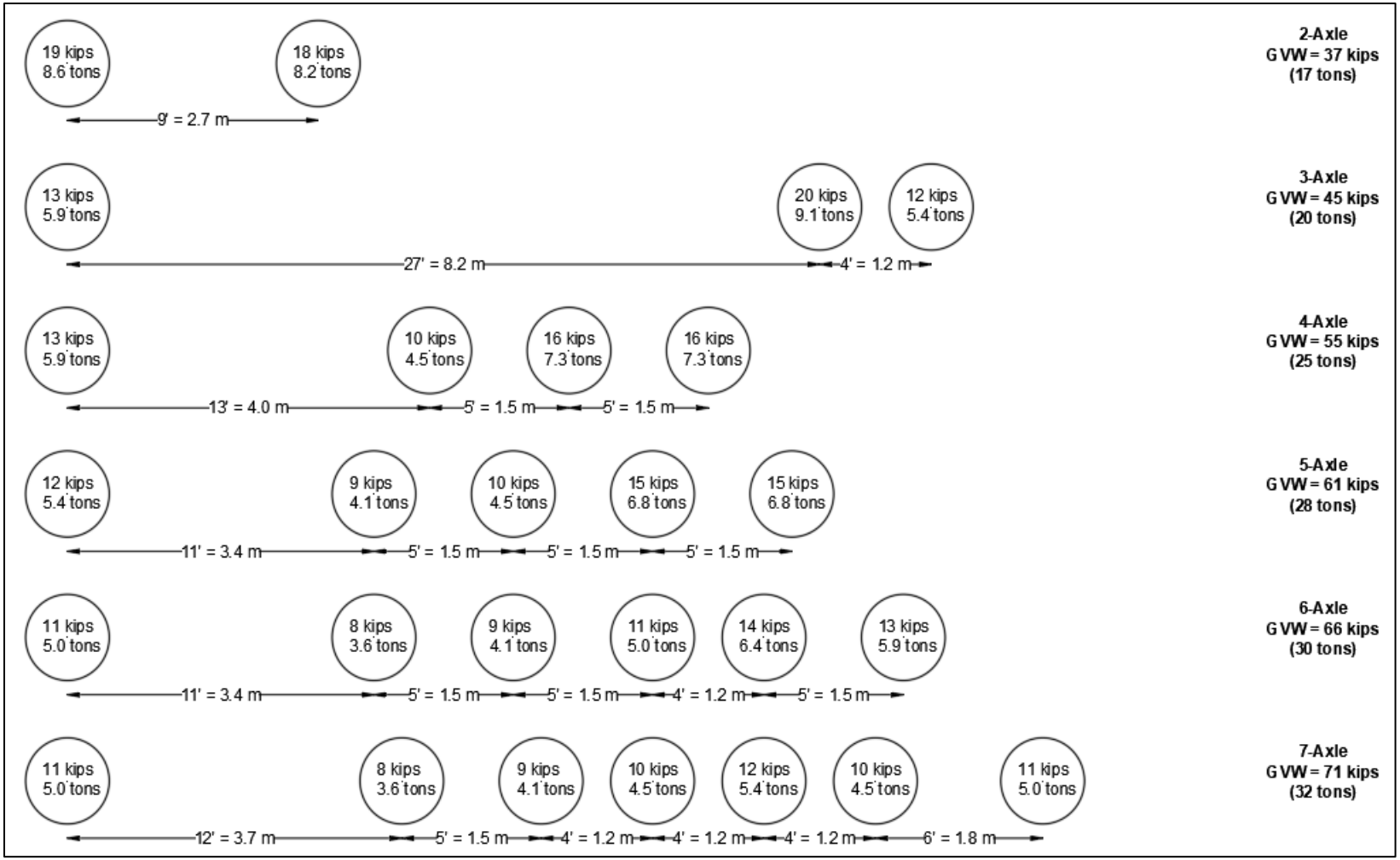
GVW value at the peak of a curve shifts to the right as the number of axles increase for both NJ Data and US Data.

Distributions of axle spacing and axle weight were investigated for SHVs with number of axles from 2 to 8. The median values of axle spacing and axle weight are used

to represent the typical configurations, as shown in Figure 3.8



(a) Derived from NJ Data



(b) Derived from US Data

Figure 3.8 Typical configurations of SHVs from NJ data

3.4. Multiple Presence of SHVs

Multiple-presence events of SHVs will be used to evaluate load effects of two-lane loading case. Multiple presence is subdivided into 3 cases: (Sivakumar, B., Ghosn, M., & Moses, F, 2011)

1) Side-By-Side: In this case, two trucks on the adjacent lanes have an overlapping length exceeding one-half of the leading truck's length.
2) Staggered: In this case, two trucks on the adjacent lanes have an overlapping length less than one-half of the leading truck's length.
3) Following: In this case, two trucks operate on the same lane with varying headway. Headway is defined as the distance between the rear axle of the front truck and the first axle of the truck behind.

Single loading case and the three multiple-presence cases are schematically represented in Figure 3.9. The headway should be less than span length for a multiple-presence event.

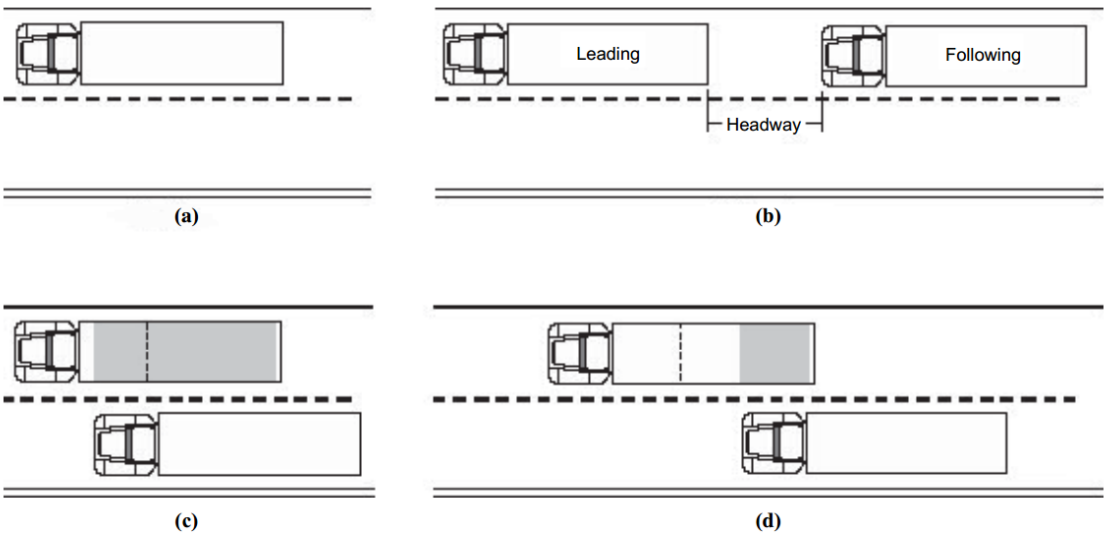


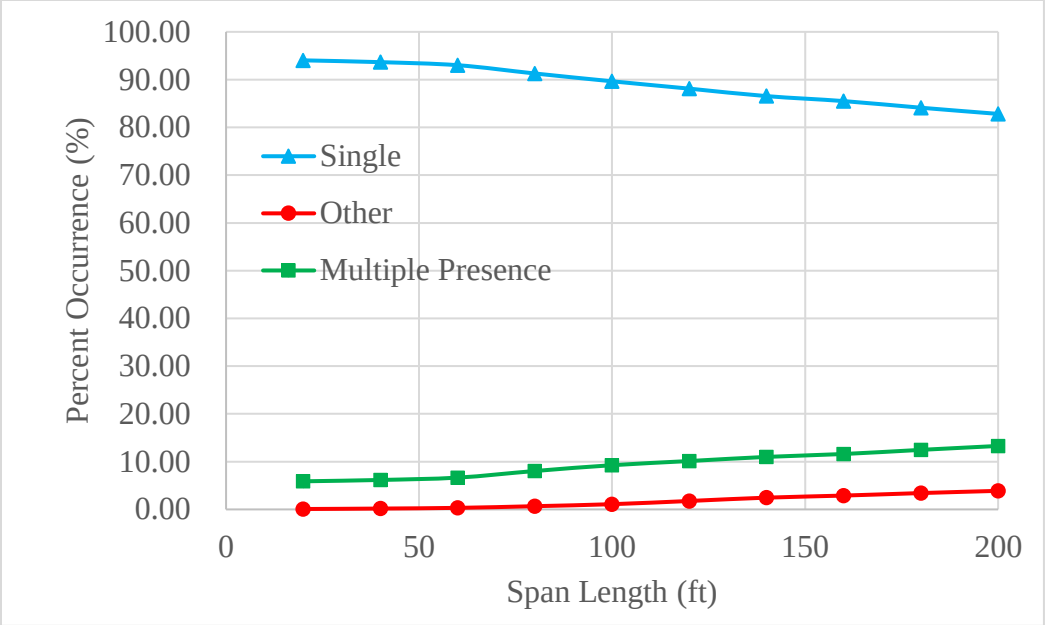
Figure 3.9 Loading cases: (a) single, (b) following, (c) side-by-side, and (d) staggered

The two trucks in an event of multiple presence for SHVs consists of one SHV and one random legal truck. The legal truck should create less load effects than the SHV. If more than two trucks are presented on the same bridge span, the loading case will be categorized as “other”. This case was not considered in this study. As the increase of bridges with more than two lanes, the involvement of multiple presence events with three or more trucks may be considered in the future study.

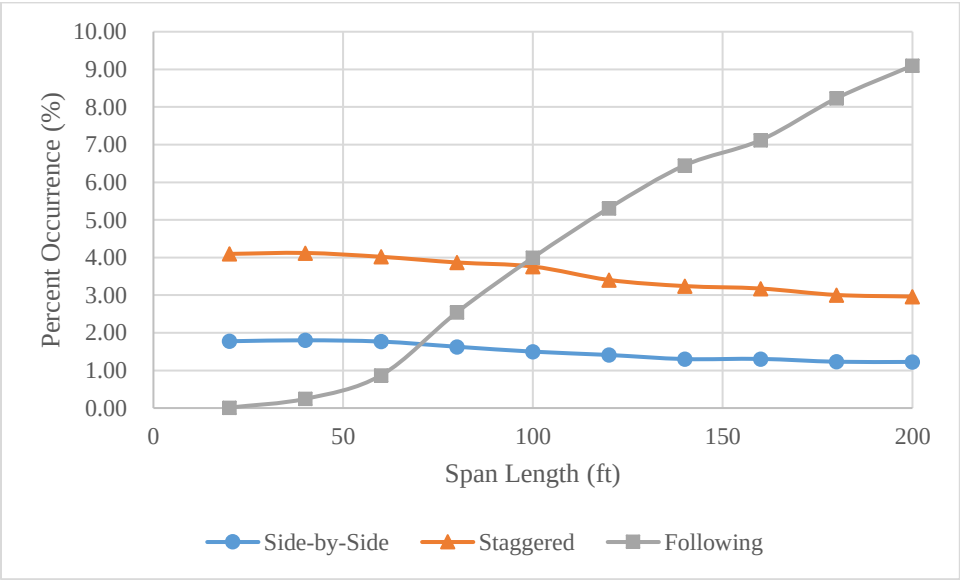
Since the investigation of multiple presence requires the accurate time up to 100th second, not many WIM sites generate data satisfying this criterion. For NJ Data, the data from Newark Bay Hudson County Extension (NBHCE) were used for the multiple-presence investigation. For US Data, the data from seven WIM sites in New York were processed for the multiple-presence investigation: site 8382 (year 2005), site 01990001 (year 2006), site 01990002 (year 2006), site 9121 (year 2005), site 82800000 (year 2006), site 05800001 (year 2006), site 05800002 (year 2006), site 96310000 (year 2006) and site 26800000 (year 2005).

The traffic of WIM data is simulated to run over span lengths of 20 to 200 ft. The statistics of multiple-presences at different sites and in different years is shown in APPENDIX A in Table A.5, Table A.6, Table A.7, Table A.8, Table A.9, Table A.10, Table A.11, Table A.12 and Table A.13.

The statistics of the average occurrence percentages for different loading cases versus various span lengths are shown in Figure 3.10. In part (a), “multiple presence” represents the summation of side-by-side, staggered and following cases. The “multiple presence” is broken down into the three subcategories in part (b) and the percent occurrence was calculated by dividing the occurrence of all cases, including single, other and multiple-presence.



(a) General cases



(b) Multiple-presence cases

Figure 3.10 Statistics for Different Loading Cases over Bridge Span Length

CHAPTER 4

STATISTICAL MODELS FOR LIVE LOAD

In this chapter, the statistical models for AASHTO SU4, SU5, SU6 and SU7 will be developed based on the SHV traffic identified in WIM data. Statistical model consists of bias factor (λ), coefficient of variation (CoV), and probability distribution. An accurate statistical model for live load is crucial for the subsequent reliability analysis.

There are three steps to obtain the maximum load effects for each WIM site: 1) calculate and normalize the load effects of SHVs, 2) simulate different ADTTs and obtain the inverse normal (z) values for a given time period, and 3) extrapolate the normalized load effects to the z values and obtain the predicted maximum values. Note that SHVs with 4 axles are normalized by SU4, 5 axles by SU5, 6 axles by SU6, and 7 axles by SU7.

The load effects considered are: 1) moment from simple spans, and 2) shear from simple sans. The span lengths considered are: 10ft (3.0m), 20ft (6.1m), 40ft (12.2m), 60ft (18.3m), 80ft (24.4m), 100ft (30.5m), 120ft (36.6m), 140ft (42.7m), 160ft (48.8m), 180ft (54.9m), 200ft (61.0m) and 300ft (91.4m).

The author developed an algorithm to calculate the load effects of the identified SHVs. The algorithm simulates a vehicle running through beam models with various span lengths. The algorithm will return the maximum load effect value during the process of the vehicle operating on the beam model of every span length. The output load effects are not distributed to girder yet, thus referred as load effects “per lane”.

Vehicular loading on bridge deck is distributed to the girder and could be caused by a single truck or by a combination of trucks. The case of multiple trucks simultaneously operating on a bridge is referred to as 'multiple presence'. In general, the maximum single truck loading is greater than the maximum loadings from either of the trucks in a multiple presence case. Due to the variation of loading distribution, the governing loading case may be different for bridges with different structural dimensions and layouts. Therefore, the author has developed models for both one-lane loading case and two-lane loading case.

4.1. One-Lane Loading Case

For one-lane loading case, all SHVs identified were used for the extrapolation to predict the maximum load effects. Load effects should be divided by the load effects created by a single AASHTO SU truck, as shown in Equation 4.1. The ratio is called bias factor.

$$\text{Bias Factor} = \frac{SHV\ Load\ Effect}{SU\ Load\ Effect} \qquad \text{Equation 4.1}$$

Note that this procedure can be done by using load effects per lane without distributing them to girder. This is because in one-lane loading case vehicular loadings are supposed to have the same distributing effect, thus being cancelled out in load effect normalization.

4.1.1. Statistical Distribution of Load Effects per Lane

In order to predict the maximum live load effects accurately, it is important to know their probability distribution. Two datasets have been investigated: 1) load effects of all data and 2) daily maximum load effects. The first one is assumed to follow Normal

distribution and the second one is assumed to follow Generalized Extreme Value (GEV) distribution.

The author performed hypothesis tests to examine the distribution assumptions. Four-axle SHVs from WIM site 01990001 in New York State of year 2006 were selected for the analysis. Simple span moments were examined. Anderson-Darling test was applied for all-data dataset since it assigns more weight on the tail end of the dataset. Kolmogorov-Smirnov test was applied for daily-maximum dataset. Figure 4.1 and Figure 4.2 show the testing results for the two datasets, respectively.

Anderson-Darling					
Sample Size Statistic Rank	227 0.84029 23				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	1.3749	1.9286	2.5018	3.2892	3.9074
Reject?	No	No	No	No	No

(a) 20 ft

Anderson-Darling					
Sample Size Statistic Rank	227 1.0837 9				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	1.3749	1.9286	2.5018	3.2892	3.9074
Reject?	No	No	No	No	No

(b) 80 ft

Anderson-Darling					
Sample Size Statistic Rank	227 0.59408 14				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	1.3749	1.9286	2.5018	3.2892	3.9074
Reject?	No	No	No	No	No

(c) 140 ft

Anderson-Darling					
Sample Size Statistic Rank	227 0.62678 23				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	1.3749	1.9286	2.5018	3.2892	3.9074
Reject?	No	No	No	No	No

(d) 200 ft

Figure 4.1. Anderson-Darling testing on Normal distribution for all-data dataset (obtained from EasyFit)

Kolmogorov-Smirnov					
Sample Size Statistic P-Value Rank	117 0.06611 0.66115 7				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	0.0992	0.11307	0.12555	0.14034	0.1506
Reject?	No	No	No	No	No

(a) 20 ft

Kolmogorov-Smirnov					
Sample Size Statistic P-Value Rank	117 0.09673 0.20963 20				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	0.0992	0.11307	0.12555	0.14034	0.1506
Reject?	No	No	No	No	No

(b) 80 ft

Kolmogorov-Smirnov					
Sample Size Statistic P-Value Rank	117 0.07187 0.55683 25				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	0.0992	0.11307	0.12555	0.14034	0.1506
Reject?	No	No	No	No	No

(c) 140 ft

Kolmogorov-Smirnov					
Sample Size Statistic P-Value Rank	117 0.0782 0.44898 24				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	0.0992	0.11307	0.12555	0.14034	0.1506
Reject?	No	No	No	No	No

(d) 200 ft

Figure 4.2. Kolmogorove-Smirnov testing on GEV distribution for daily-maximum dataset (obtained from EasyFit)

The simple span shear values at various span lengths were also examined and the same conclusions were drawn. The probability distribution of the load effects for other SU trucks are assumed to be the same as those for SU4.

4.1.2. Live Load Extrapolation for One Lane Load Effects

The prediction of the maximum load effects for SHVs is based on the 5-year bridge evaluation period. (AASHTO MBE, 2018) All-data load effects and daily-maximum load effects are extrapolated to the 5-Year Level based on Normal distribution and GEV distribution, respectively. The 5-Year Levels for Normal extrapolation were determined by Equation 4.2, and those for GEV extrapolation were determined by and Equation 4.3.

$$5\text{ Year Level} = \Phi^{-1}(1 - \frac{1}{5 \times 365 \times \mathrm{N}}) \qquad \text{Equation 4.2}$$

where:

N = the average daily count of SHVs

$$5\text{ Year Level} = \Phi^{-1}(1 - \frac{1}{5 \times 365}) \qquad \text{Equation 4.3}$$

The cumulative probability function for GEV distribution can be determined by Equation 4.4. The probability value of each data point can be converted to inverse standard normal values. The parameters of k, σ and μ for GEV distribution can be obtained by estimation theory.

$$\mathrm{CDF} = \exp(-(1 + kz)^{-\frac{1}{k}}) \qquad \text{Equation 4.4}$$

Where:

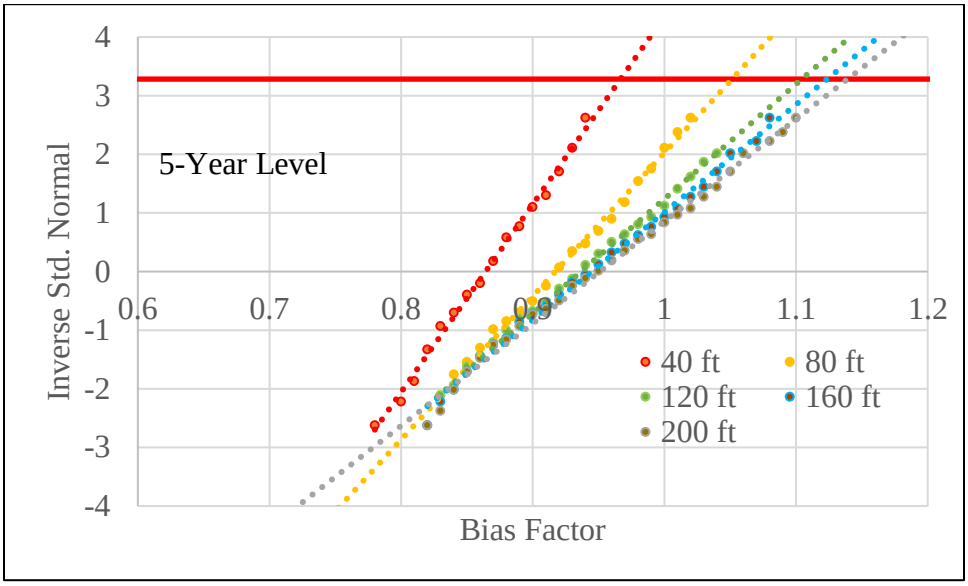
z = (x-μ)/σ

k = continuous shape parameter

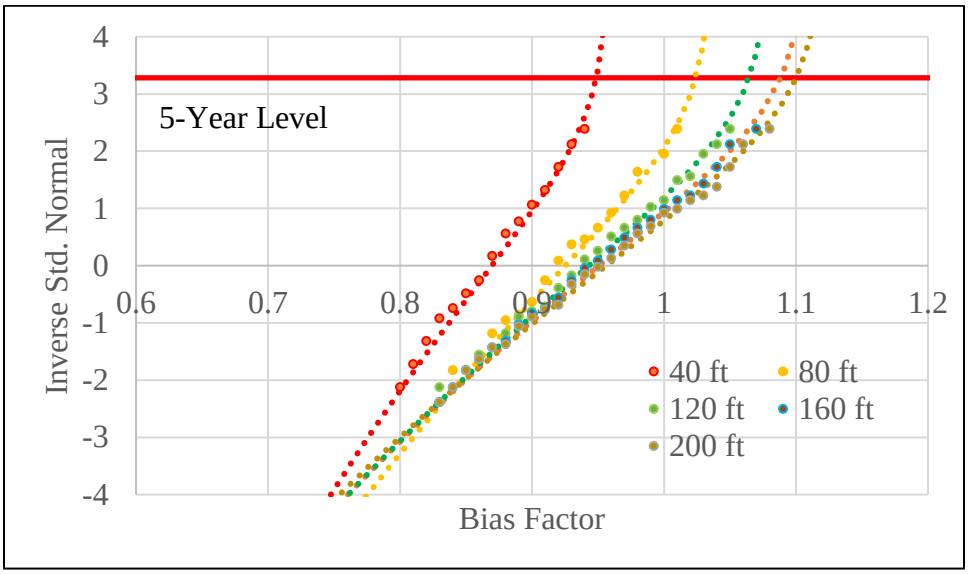
σ = continuous scale parameter (σ>0)

μ = continuous location parameter

The extrapolation approaches are demonstrated in Figure 4.3, using the simple span moments by four-axle SHV from WIM site 01990001.



(a) Normal extrapolation for all-data dataset



(b) GEV extrapolation for daily-maximum dataset

Figure 4.3. 5-Year extrapolation

It is found that the predicted values by Normal extrapolation can provide more conservative results in general. Therefore, the author used the Normal extrapolation to develop the statistical models for the sake of being conservative.

Normal extrapolation was performed to obtain the site maximum load effects for all WIM sites. NJ Data and US Data were processed separately. To be consistent with MBE, the live load models were developed for three ADTT ranges: 1) ADTT < 1000, 2) 1000 ≤ ADTT < 5000, and 3) 5000 ≤ ADTT. The SHV volume is not necessarily proportional to the actual ADTT at a WIM site. Therefore, the author simulated ADTT = 1000, ADTT = 3000 and ADTT = 5000 for all WIM sites to fulfill the three ADTT ranges. The ratio of SHV to truck traffic per site is assumed to be constant and the number of SHVs per site is calculated by multiplying the three simulated ADTTs by the ratio.

The bias factor is obtained by taking the average of the site maximum load effects. The coefficient of variation is calculated by dividing standard deviation of site maximum load effects by the average values. Coefficient of variation is an indicator of the dispersion of data. The author assumes the probability distribution of the site maximum load effects is Lognormal. Kolmogorov–Smirnov test was performed for the data of four-axle SHVs. The assumption was validated by the results shown in Figure 4.4.

Kolmogorov-Smirnov					
Sample Size Statistic P-Value Rank	10 0.16897 0.89396 9				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	0.3226	0.36866	0.40925	0.45662	0.48893
Reject?	No	No	No	No	No

(a) 20 ft

Kolmogorov-Smirnov					
Sample Size Statistic P-Value Rank	10 0.15913 0.92854 12				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	0.3226	0.36866	0.40925	0.45662	0.48893
Reject?	No	No	No	No	No

(b) 80 ft

Sample Size Statistic P-Value Rank	10 0.1562 0.9374 18				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	0.3226	0.36866	0.40925	0.45662	0.48893
Reject?	No	No	No	No	No

(c) 140 ft

Kolmogorov-Smirnov					
Sample Size Statistic P-Value Rank	10 0.16234 0.91807 18				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	0.3226	0.36866	0.40925	0.45662	0.48893
Reject?	No	No	No	No	No

(d) 200 ft

Figure 4.4. Kolmogorove-Smirnov testing on Lognormal for site-maximum data (obtained from EasyFit)

The statistical models for SU4, SU5 and SU6 were obtained by extrapolation. Since no SHVs with 7 axles were involved in the extrapolation, the statistical models for SU7 is assumed to be the same as those for SU6. Table 4.1 shows the statistical parameters for one-lane load effects.

Table 4.1 Statistical Parameters for Live Load Effects for One-Lane Loading Case
(a) 4-axle

Span (ft)	Moment						Shear					
	ADTT≤1000		1000<ADTT≤5000		5000<ADTT		ADTT≤1000		1000<ADTT≤5000		5000<ADTT	
	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV
10	1.03	0.04	1.04	0.04	1.05	0.04	1.00	0.03	1.02	0.03	1.02	0.03
20	1.02	0.02	1.03	0.02	1.04	0.02	0.98	0.02	0.99	0.02	1.00	0.02
40	0.98	0.02	0.99	0.02	1.00	0.02	1.01	0.02	1.03	0.02	1.03	0.02
60	1.02	0.02	1.03	0.02	1.04	0.02	1.05	0.02	1.07	0.02	1.08	0.02
80	1.05	0.02	1.07	0.02	1.07	0.02	1.08	0.03	1.10	0.03	1.11	0.03
100	1.08	0.02	1.09	0.02	1.10	0.02	1.10	0.03	1.12	0.03	1.13	0.03
120	1.09	0.02	1.11	0.02	1.12	0.02	1.12	0.03	1.14	0.03	1.14	0.03
140	1.11	0.03	1.13	0.03	1.13	0.03	1.13	0.03	1.15	0.03	1.15	0.03
160	1.12	0.03	1.14	0.03	1.14	0.03	1.13	0.03	1.15	0.03	1.16	0.03
180	1.13	0.03	1.14	0.03	1.15	0.03	1.14	0.03	1.16	0.03	1.17	0.03
200	1.13	0.03	1.15	0.03	1.16	0.03	1.15	0.03	1.17	0.03	1.18	0.03
300	1.15	0.03	1.17	0.03	1.18	0.03	1.16	0.03	1.18	0.03	1.19	0.03

(b) 5-axle

Span (ft)	Moment						Shear					
	ADTT≤1000		1000<ADTT≤5000		5000<ADTT		ADTT≤1000		1000<ADTT≤5000		5000<ADTT	
	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV
10	1.06	0.11	1.10	0.12	1.11	0.13	1.00	0.09	1.03	0.11	1.05	0.11
20	0.91	0.05	0.94	0.05	0.95	0.06	0.90	0.07	0.93	0.07	0.93	0.08
40	0.92	0.06	0.95	0.07	0.95	0.08	0.93	0.03	0.95	0.03	0.95	0.04
60	0.97	0.05	0.98	0.06	0.99	0.06	0.99	0.03	1.00	0.03	1.01	0.03
80	1.00	0.03	1.01	0.03	1.02	0.03	1.02	0.03	1.03	0.03	1.04	0.03
100	1.01	0.02	1.03	0.02	1.04	0.02	1.04	0.03	1.05	0.03	1.06	0.03
120	1.03	0.02	1.05	0.02	1.05	0.02	1.05	0.03	1.07	0.03	1.07	0.03
140	1.04	0.02	1.06	0.02	1.06	0.02	1.06	0.02	1.08	0.02	1.09	0.02
160	1.05	0.02	1.07	0.02	1.07	0.02	1.06	0.03	1.08	0.03	1.09	0.03
180	1.05	0.03	1.07	0.03	1.08	0.03	1.07	0.02	1.09	0.02	1.10	0.02
200	1.06	0.03	1.07	0.04	1.08	0.04	1.08	0.02	1.09	0.02	1.10	0.02
300	1.08	0.03	1.10	0.03	1.10	0.03	1.09	0.03	1.11	0.03	1.12	0.03

(c) 6-axle

Span (ft)	Moment						Shear					
	ADTT≤1000		1000<ADTT≤5000		5000<ADTT		ADTT≤1000		1000<ADTT≤5000		5000<ADTT	
	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV
10	0.87	0.18	0.91	0.18	0.92	0.19	0.87	0.15	0.91	0.16	0.92	0.17
20	0.83	0.13	0.86	0.15	0.87	0.15	0.88	0.10	0.91	0.11	0.92	0.11
40	0.84	0.09	0.87	0.09	0.87	0.10	0.91	0.10	0.94	0.10	0.95	0.11
60	0.90	0.06	0.92	0.06	0.93	0.06	0.94	0.09	0.96	0.09	0.97	0.09
80	0.93	0.05	0.96	0.05	0.97	0.06	0.96	0.07	0.98	0.07	0.99	0.07
100	0.95	0.06	0.98	0.05	0.99	0.05	0.97	0.06	1.00	0.06	1.01	0.06
120	0.96	0.06	0.99	0.05	1.00	0.06	0.98	0.06	1.00	0.06	1.01	0.06
140	0.97	0.06	1.00	0.06	1.01	0.06	0.98	0.05	1.01	0.05	1.02	0.05
160	0.97	0.06	1.00	0.06	1.01	0.06	0.98	0.06	1.01	0.05	1.02	0.05
180	0.98	0.06	1.00	0.06	1.01	0.06	0.99	0.06	1.02	0.06	1.03	0.06
200	0.98	0.06	1.01	0.06	1.02	0.06	0.99	0.06	1.02	0.06	1.03	0.06
300	0.99	0.06	1.02	0.06	1.03	0.06	1.00	0.06	1.03	0.05	1.04	0.05

4.2. Two-Lane Loading Case

A SHV along with another truck on a bridge span may create larger load effects than a single SHV. The influence of multiple presence should also be considered for the development of the statistical model. The author evaluated the load effects of the captured side-by-side events of one SHV along with another random legal truck to develop the statistical model for two-lane loading case.

4.2.1. Girder Distribution Factors

The author utilized AASHTO LRFD (AASHTO LRFD, 2012) girder distribution factors to calculate the load effects created by SHVs in individual girders, which will be referred as load effects "per girder". The bridges selected for the analysis satisfying the criteria shown in Figure 4.5.

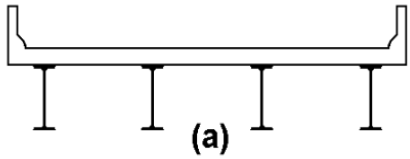
Supporting Components	Type Of Deck	Typical Cross-Section
Steel Beam	Cast-in-place concrete slab, precast concrete slab, steel grid, glued/spiked panels, stressed wood	

Figure 4.5 - AASHTO LRFD deck superstructure typical cross-section (a) (AASHTO LRFD, 2012)

The equations for one-lane and two-lane moment girder distribution factors are calculated by Equation 4.5 and Equation 4.6, respectively. (AASHTO LRFD, 2012) The equations for one-lane girder and two-lane shear girder distribution factors for moment are calculated by Equation **4.7** and Equation **4.8**, respectively. (AASHTO LRFD, 2012)

$$0.06 + \left(\frac{S}{14}\right)^{0.4} \left(\frac{S}{L}\right)^{0.3} \left(\frac{K_g}{12.0Lt_s^3}\right)^{0.1}$$ Equation 4.5

$$0.075 + \left(\frac{S}{9.5}\right)^{0.6} \left(\frac{S}{L}\right)^{0.2} \left(\frac{K_g}{12.0Lt_s^3}\right)^{0.1}$$ Equation 4.6

$$0.36 + \frac{S}{25.0}$$ Equation 4.7

$$0.2 + \frac{S}{12} - \left(\frac{S}{35}\right)^{2.0}$$ Equation 4.8

Where:

S = girder spacing

L = span length

K_g=longitudinal stiffness parameter

t_s=depth of concrete slab

Simplified value for $(K_g/12.0/L/t_s^3)^{0.1}$ is taken as 1.02 for cross-section (a) type of brides. (AASHTO LRFD, 2012) Note that the following criteria should be satisfied to use the two equations:

1) $3.5 \leq S \leq 16$
2) $4.5 \leqslant t_s \leqslant 12.0$
3) $20 \leqslant L \leqslant 240$
4) Number of girders $\geqslant 4$
5) $10{,}000 \leqslant K_g \leqslant 7{,}000{,}000$

4.2.2. Live Load Extrapolation for Two Lane Load Effect

Load effect of two-lane loading case is represented by the load effect per girder as described in 4.2.1. With the application of girder distribution factors, the load effect per girder created by the combination of a SHV and a side-by-side random truck. Girder spacings of 4 ft, 6 ft, 8 ft, 10 ft and 12 ft are considered. For span length, 10 ft and 300 ft are not considered since they are out of the applicable range of AASHTO GDF equations.

$$\text{Bias Factor} = \frac{GDF_1 \times SHV + (GDF_2 - GDF_1) \times Random\ Truck}{SU \times GDF_2} \qquad \text{Equation 4.9}$$

Where:

Bias Factor = ratio of load effect to nominal load effect

GDF_1 = one-lane GDF

GDF_2 = two-lane GDF

SHV = load effect created by SHV

Random Truck = load effect created by random truck

SU = load effect created by AASHTO SU truck

In this case, the random trucks should satisfy legal weight limits since SHVs are legal trucks.

The probability distributions of load effects for one-lane loading case is also used for two-lane loading case, i.e. Normal distribution for data per site and Lognormal distribution for site maximum data. Since no SHVs with 7 axles were involved in the

extrapolation, the statistical models for SU7 is assumed to be the same as those for SU6. The statistical parameters for two-lane simple span moment are presented in Table 4.2.

Table 4.2 Statistical Parameters for Simple Span Moment for Two-Lane Loading Case

(a) 4-axle Girder Spacing 4 ft

Span (ft)	Moment						Shear					
	ADTT≤1000		1000<ADTT≤5000		5000<ADTT		ADTT≤1000		1000<ADTT≤5000		5000<ADTT	
	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV
20	0.86	0.06	0.89	0.06	0.90	0.06	0.86	0.05	0.89	0.05	0.89	0.04
40	0.82	0.11	0.86	0.11	0.87	0.11	0.88	0.05	0.92	0.03	0.93	0.03
60	0.85	0.10	0.88	0.09	0.90	0.09	0.92	0.05	0.97	0.03	0.99	0.03
80	0.87	0.10	0.92	0.08	0.94	0.08	0.94	0.04	0.99	0.04	1.01	0.05
100	0.87	0.09	0.93	0.08	0.95	0.08	0.95	0.04	1.01	0.05	1.03	0.06
120	0.88	0.09	0.95	0.07	0.97	0.07	0.95	0.05	1.02	0.05	1.04	0.07
140	0.89	0.08	0.96	0.07	0.98	0.07	0.95	0.05	1.02	0.06	1.05	0.07
160	0.89	0.08	0.97	0.07	0.99	0.08	0.96	0.05	1.03	0.06	1.06	0.07
180	0.89	0.08	0.96	0.08	0.98	0.09	0.96	0.05	1.03	0.06	1.05	0.07
200	0.89	0.08	0.96	0.08	0.99	0.09	0.97	0.04	1.03	0.06	1.06	0.08

(b) 4-axle Girder Spacing 6 ft

Span (ft)	Moment						Shear					
	ADTT≤1000		1000<ADTT≤5000		5000<ADTT		ADTT≤1000		1000<ADTT≤5000		5000<ADTT	
	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV
20	0.85	0.07	0.88	0.07	0.89	0.07	0.84	0.07	0.87	0.07	0.88	0.07
40	0.82	0.11	0.85	0.11	0.86	0.11	0.86	0.07	0.90	0.06	0.91	0.05
60	0.84	0.11	0.88	0.11	0.89	0.11	0.90	0.06	0.94	0.04	0.96	0.04
80	0.86	0.10	0.92	0.09	0.94	0.09	0.92	0.06	0.98	0.05	1.00	0.05
100	0.87	0.10	0.92	0.09	0.94	0.09	0.92	0.06	0.98	0.05	1.00	0.06
120	0.88	0.10	0.94	0.08	0.97	0.08	0.93	0.06	1.00	0.05	1.02	0.06
140	0.88	0.09	0.95	0.08	0.98	0.08	0.94	0.06	1.01	0.06	1.04	0.07
160	0.89	0.09	0.96	0.08	0.99	0.08	0.95	0.06	1.02	0.06	1.04	0.07
180	0.89	0.09	0.95	0.08	0.98	0.09	0.94	0.06	1.01	0.07	1.04	0.08
200	0.89	0.09	0.96	0.09	0.99	0.09	0.94	0.05	1.00	0.07	1.03	0.08

(c) 4-axle Girder Spacing 8 ft

Span (ft)	Moment						Shear					
	ADTT≤1000		1000<ADTT≤5000		5000<ADTT		ADTT≤1000		1000<ADTT≤5000		5000<ADTT	
	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV
20	0.85	0.07	0.88	0.07	0.89	0.07	0.83	0.08	0.86	0.08	0.87	0.08
40	0.81	0.12	0.84	0.12	0.86	0.12	0.85	0.08	0.89	0.08	0.90	0.08
60	0.84	0.12	0.87	0.11	0.89	0.11	0.89	0.08	0.94	0.06	0.95	0.06
80	0.86	0.11	0.91	0.10	0.93	0.10	0.91	0.07	0.97	0.05	1.00	0.05
100	0.86	0.11	0.92	0.10	0.94	0.10	0.91	0.06	0.97	0.06	1.00	0.07
120	0.87	0.10	0.94	0.09	0.96	0.09	0.92	0.06	0.99	0.05	1.01	0.06
140	0.88	0.10	0.95	0.08	0.98	0.08	0.92	0.06	0.99	0.06	1.01	0.07
160	0.89	0.10	0.96	0.08	0.99	0.09	0.93	0.06	1.00	0.07	1.03	0.08
180	0.88	0.09	0.95	0.09	0.98	0.09	0.92	0.06	0.99	0.06	1.02	0.08
200	0.89	0.09	0.96	0.09	0.99	0.10	0.93	0.06	1.00	0.07	1.02	0.08

(d) 4-axle Girder Spacing 10 ft

Span (ft)	Moment						Shear					
	ADTT≤1000		1000<ADTT≤5000		5000<ADTT		ADTT≤1000		1000<ADTT≤5000		5000<ADTT	
	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV
20	0.85	0.07	0.88	0.07	0.89	0.08	0.83	0.09	0.86	0.09	0.87	0.09
40	0.81	0.12	0.84	0.12	0.86	0.12	0.85	0.09	0.88	0.08	0.90	0.08
60	0.83	0.12	0.88	0.11	0.89	0.11	0.88	0.09	0.93	0.07	0.95	0.07
80	0.85	0.12	0.90	0.11	0.92	0.11	0.91	0.08	0.97	0.06	0.99	0.06
100	0.86	0.11	0.92	0.09	0.94	0.09	0.90	0.07	0.96	0.07	0.99	0.07
120	0.87	0.11	0.93	0.09	0.96	0.09	0.91	0.07	0.97	0.06	1.00	0.06
140	0.88	0.10	0.95	0.09	0.97	0.09	0.91	0.06	0.99	0.06	1.01	0.06
160	0.89	0.10	0.96	0.09	0.99	0.09	0.92	0.07	0.99	0.06	1.02	0.07
180	0.88	0.10	0.96	0.09	0.99	0.10	0.92	0.07	0.99	0.07	1.01	0.08
200	0.89	0.10	0.96	0.09	0.99	0.10	0.92	0.07	0.99	0.07	1.02	0.09

(e) 4-axle Girder Spacing 12 ft

Span (ft)	Moment						Shear					
	ADTT≤1000		1000<ADTT≤5000		5000<ADTT		ADTT≤1000		1000<ADTT≤5000		5000<ADTT	
	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV
20	0.85	0.08	0.88	0.08	0.89	0.08	0.83	0.09	0.86	0.09	0.87	0.09
40	0.81	0.12	0.84	0.13	0.86	0.13	0.84	0.10	0.88	0.09	0.90	0.09
60	0.83	0.12	0.87	0.12	0.89	0.12	0.88	0.09	0.93	0.08	0.95	0.08
80	0.85	0.12	0.90	0.11	0.92	0.10	0.90	0.08	0.96	0.07	0.98	0.07
100	0.86	0.11	0.91	0.10	0.94	0.10	0.90	0.08	0.96	0.07	0.98	0.07
120	0.87	0.11	0.93	0.09	0.96	0.09	0.90	0.07	0.97	0.07	0.99	0.07
140	0.87	0.11	0.95	0.09	0.97	0.09	0.91	0.07	0.98	0.06	1.01	0.07
160	0.88	0.11	0.96	0.09	0.99	0.09	0.92	0.07	0.99	0.07	1.02	0.08
180	0.88	0.10	0.96	0.09	0.99	0.10	0.91	0.07	0.98	0.07	1.00	0.08
200	0.89	0.10	0.96	0.10	0.98	0.10	0.92	0.07	0.99	0.07	1.01	0.08

(f) 5-axle Girder Spacing 4 ft

Span (ft)	Moment						Shear					
	ADTT≤1000		1000<ADTT≤5000		5000<ADTT		ADTT≤1000		1000<ADTT≤5000		5000<ADTT	
	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV
20	0.73	0.14	0.76	0.15	0.78	0.15	0.79	0.14	0.83	0.17	0.84	0.18
40	0.74	0.13	0.78	0.16	0.80	0.17	0.84	0.06	0.86	0.08	0.87	0.09
60	0.78	0.11	0.81	0.14	0.82	0.15	0.89	0.06	0.91	0.08	0.92	0.09
80	0.78	0.12	0.79	0.15	0.80	0.15	0.90	0.07	0.92	0.09	0.92	0.10
100	0.79	0.13	0.81	0.15	0.81	0.16	0.91	0.08	0.93	0.10	0.94	0.11
120	0.80	0.14	0.82	0.16	0.83	0.17	0.92	0.08	0.94	0.10	0.95	0.11
140	0.81	0.13	0.82	0.13	0.82	0.13	0.93	0.07	0.94	0.08	0.94	0.08
160	0.81	0.13	0.82	0.14	0.83	0.14	0.93	0.07	0.95	0.08	0.95	0.08
180	0.82	0.14	0.83	0.14	0.83	0.14	0.94	0.07	0.95	0.08	0.96	0.08
200	0.82	0.14	0.82	0.14	0.83	0.15	0.94	0.07	0.95	0.08	0.96	0.08

(g) 5-axle Girder Spacing 6 ft

Span (ft)	Moment						Shear					
	ADTT≤1000		1000<ADTT≤5000		5000<ADTT		ADTT≤1000		1000<ADTT≤5000		5000<ADTT	
	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV
20	0.72	0.14	0.76	0.15	0.77	0.16	0.76	0.16	0.80	0.18	0.82	0.20
40	0.73	0.13	0.77	0.16	0.78	0.17	0.81	0.08	0.83	0.10	0.84	0.11
60	0.77	0.11	0.80	0.14	0.81	0.15	0.86	0.07	0.89	0.10	0.90	0.11
80	0.77	0.13	0.79	0.15	0.79	0.16	0.86	0.09	0.88	0.11	0.89	0.12
100	0.78	0.14	0.80	0.16	0.80	0.17	0.87	0.10	0.89	0.12	0.90	0.13
120	0.80	0.15	0.82	0.17	0.82	0.18	0.88	0.10	0.90	0.12	0.91	0.13
140	0.80	0.14	0.81	0.14	0.81	0.14	0.89	0.10	0.90	0.10	0.90	0.10
160	0.81	0.14	0.82	0.15	0.82	0.15	0.89	0.10	0.91	0.10	0.91	0.10
180	0.81	0.15	0.82	0.15	0.83	0.16	0.90	0.10	0.91	0.10	0.91	0.10
200	0.81	0.15	0.82	0.15	0.83	0.16	0.90	0.10	0.91	0.10	0.92	0.10

(h) 5-axle Girder Spacing 8 ft

Span (ft)	Moment						Shear					
	ADTT≤1000		1000<ADTT≤5000		5000<ADTT		ADTT≤1000		1000<ADTT≤5000		5000<ADTT	
	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV
20	0.72	0.15	0.75	0.16	0.76	0.17	0.75	0.16	0.78	0.19	0.80	0.20
40	0.73	0.13	0.77	0.16	0.78	0.17	0.80	0.08	0.83	0.11	0.84	0.12
60	0.76	0.11	0.80	0.14	0.81	0.15	0.85	0.09	0.88	0.12	0.89	0.13
80	0.76	0.14	0.78	0.16	0.79	0.17	0.84	0.11	0.86	0.13	0.87	0.14
100	0.78	0.14	0.79	0.17	0.80	0.18	0.85	0.12	0.87	0.14	0.88	0.14
120	0.79	0.15	0.81	0.17	0.82	0.18	0.86	0.12	0.88	0.14	0.89	0.15
140	0.79	0.14	0.80	0.15	0.81	0.15	0.87	0.11	0.88	0.11	0.88	0.11
160	0.80	0.15	0.81	0.15	0.81	0.15	0.87	0.11	0.88	0.12	0.88	0.12
180	0.81	0.15	0.82	0.16	0.82	0.16	0.87	0.11	0.89	0.11	0.89	0.11
200	0.80	0.16	0.81	0.16	0.82	0.16	0.88	0.11	0.89	0.12	0.90	0.12

(i) 5-axle Girder Spacing 10 ft

Span (ft)	Moment						Shear					
	ADTT≤1000		1000<ADTT≤5000		5000<ADTT		ADTT≤1000		1000<ADTT≤5000		5000<ADTT	
	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV
20	0.72	0.15	0.75	0.16	0.76	0.17	0.73	0.17	0.77	0.20	0.79	0.21
40	0.73	0.14	0.76	0.17	0.78	0.18	0.78	0.09	0.81	0.12	0.83	0.13
60	0.76	0.12	0.80	0.15	0.81	0.16	0.84	0.09	0.87	0.13	0.89	0.14
80	0.76	0.14	0.78	0.16	0.78	0.17	0.83	0.12	0.85	0.13	0.85	0.14
100	0.77	0.15	0.79	0.17	0.80	0.18	0.84	0.13	0.86	0.15	0.87	0.15
120	0.79	0.15	0.80	0.18	0.81	0.18	0.85	0.13	0.87	0.15	0.88	0.16
140	0.79	0.15	0.80	0.15	0.80	0.15	0.85	0.12	0.86	0.12	0.87	0.12
160	0.79	0.15	0.80	0.16	0.81	0.16	0.86	0.12	0.87	0.12	0.87	0.12
180	0.80	0.16	0.81	0.16	0.82	0.17	0.86	0.12	0.87	0.13	0.87	0.13
200	0.80	0.16	0.81	0.16	0.81	0.16	0.87	0.12	0.88	0.13	0.88	0.13

(j) 5-axle Girder Spacing 12 ft

Span (ft)	Moment						Shear					
	ADTT≤1000		1000<ADTT≤5000		5000<ADTT		ADTT≤1000		1000<ADTT≤5000		5000<ADTT	
	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV
20	0.72	0.15	0.75	0.16	0.76	0.17	0.73	0.18	0.77	0.20	0.79	0.21
40	0.72	0.14	0.77	0.17	0.78	0.18	0.78	0.09	0.81	0.12	0.82	0.13
60	0.76	0.11	0.80	0.15	0.81	0.16	0.83	0.10	0.87	0.13	0.88	0.14
80	0.75	0.15	0.77	0.17	0.78	0.18	0.82	0.13	0.84	0.15	0.85	0.16
100	0.77	0.15	0.79	0.18	0.79	0.18	0.83	0.13	0.85	0.15	0.86	0.16
120	0.78	0.16	0.80	0.18	0.81	0.19	0.84	0.14	0.86	0.16	0.87	0.16
140	0.78	0.15	0.79	0.16	0.80	0.16	0.84	0.13	0.85	0.13	0.85	0.13
160	0.79	0.16	0.80	0.16	0.81	0.16	0.85	0.13	0.86	0.13	0.86	0.13
180	0.79	0.16	0.81	0.17	0.81	0.17	0.85	0.13	0.86	0.13	0.87	0.13
200	0.79	0.17	0.80	0.17	0.81	0.17	0.85	0.13	0.87	0.13	0.87	0.13

(k) 6-axle Girder Spacing 4 ft

Span (ft)	Moment						Shear					
	ADTT≤1000		1000<ADTT≤5000		5000<ADTT		ADTT≤1000		1000<ADTT≤5000		5000<ADTT	
	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV
20	0.70	0.16	0.70	0.16	0.70	0.16	0.80	0.12	0.80	0.12	0.80	0.12
40	0.69	0.11	0.69	0.11	0.69	0.11	0.83	0.07	0.83	0.07	0.83	0.07
60	0.70	0.09	0.70	0.09	0.70	0.09	0.85	0.07	0.85	0.07	0.85	0.07
80	0.73	0.11	0.73	0.11	0.73	0.11	0.86	0.08	0.86	0.08	0.86	0.08
100	0.75	0.14	0.75	0.14	0.75	0.14	0.87	0.08	0.87	0.08	0.87	0.08
120	0.76	0.15	0.76	0.15	0.76	0.15	0.88	0.09	0.88	0.09	0.88	0.09
140	0.77	0.17	0.77	0.17	0.77	0.17	0.88	0.09	0.88	0.09	0.88	0.09
160	0.78	0.18	0.78	0.18	0.78	0.18	0.88	0.10	0.88	0.10	0.88	0.10
180	0.79	0.19	0.79	0.19	0.79	0.19	0.88	0.10	0.88	0.10	0.88	0.10
200	0.79	0.20	0.79	0.20	0.79	0.20	0.88	0.10	0.88	0.10	0.88	0.10

(l) 6-axle Girder Spacing 6 ft

Span (ft)	Moment						Shear					
	ADTT≤1000		1000<ADTT≤5000		5000<ADTT		ADTT≤1000		1000<ADTT≤5000		5000<ADTT	
	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV
20	0.70	0.17	0.70	0.17	0.70	0.17	0.78	0.12	0.78	0.12	0.78	0.12
40	0.68	0.12	0.68	0.12	0.68	0.12	0.80	0.09	0.80	0.09	0.80	0.09
60	0.69	0.10	0.69	0.10	0.69	0.10	0.82	0.10	0.82	0.10	0.82	0.10
80	0.71	0.12	0.71	0.12	0.71	0.12	0.84	0.11	0.84	0.11	0.84	0.11
100	0.74	0.14	0.74	0.14	0.74	0.14	0.84	0.12	0.84	0.12	0.84	0.12
120	0.76	0.16	0.76	0.16	0.76	0.16	0.85	0.13	0.85	0.13	0.85	0.13
140	0.77	0.18	0.77	0.18	0.77	0.18	0.86	0.12	0.86	0.12	0.86	0.12
160	0.77	0.18	0.77	0.18	0.77	0.18	0.86	0.12	0.86	0.12	0.86	0.12
180	0.78	0.20	0.78	0.20	0.78	0.20	0.86	0.13	0.86	0.13	0.86	0.13
200	0.78	0.20	0.78	0.20	0.78	0.20	0.86	0.13	0.86	0.13	0.86	0.13

(m) 6-axle Girder Spacing 8 ft

Span (ft)	Moment						Shear					
	ADTT≤1000		1000<ADTT≤5000		5000<ADTT		ADTT≤1000		1000<ADTT≤5000		5000<ADTT	
	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV
20	0.70	0.17	0.70	0.17	0.70	0.17	0.77	0.14	0.77	0.14	0.77	0.14
40	0.68	0.12	0.68	0.12	0.68	0.12	0.78	0.10	0.78	0.10	0.78	0.10
60	0.68	0.10	0.68	0.10	0.68	0.10	0.80	0.11	0.80	0.11	0.80	0.11
80	0.71	0.12	0.71	0.12	0.71	0.12	0.82	0.13	0.82	0.13	0.82	0.13
100	0.74	0.14	0.74	0.14	0.74	0.14	0.83	0.14	0.83	0.14	0.83	0.14
120	0.75	0.17	0.75	0.17	0.75	0.17	0.84	0.14	0.84	0.14	0.84	0.14
140	0.76	0.19	0.76	0.19	0.76	0.19	0.84	0.14	0.84	0.14	0.84	0.14
160	0.77	0.19	0.77	0.19	0.77	0.19	0.84	0.15	0.84	0.15	0.84	0.15
180	0.77	0.20	0.77	0.20	0.77	0.20	0.84	0.15	0.84	0.15	0.84	0.15
200	0.78	0.21	0.78	0.21	0.78	0.21	0.85	0.16	0.85	0.16	0.85	0.16

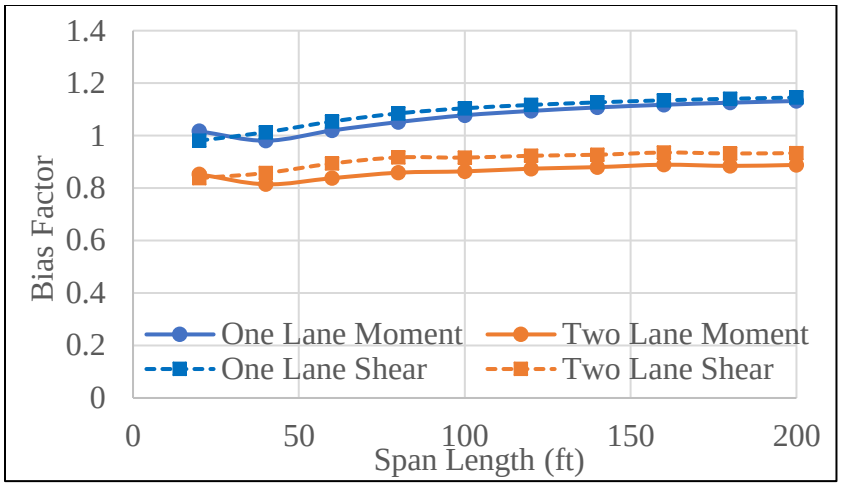
(n) 6-axle Girder Spacing 10 ft

Span (ft)	Moment						Shear					
	ADTT≤1000		1000<ADTT≤5000		5000<ADTT		ADTT≤1000		1000<ADTT≤5000		5000<ADTT	
	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV
20	0.69	0.16	0.69	0.16	0.69	0.16	0.76	0.14	0.76	0.14	0.76	0.14
40	0.67	0.13	0.67	0.13	0.67	0.13	0.77	0.10	0.77	0.10	0.77	0.10
60	0.68	0.12	0.68	0.12	0.68	0.12	0.79	0.12	0.79	0.12	0.79	0.12
80	0.71	0.13	0.71	0.13	0.71	0.13	0.81	0.13	0.81	0.13	0.81	0.13
100	0.73	0.15	0.73	0.15	0.73	0.15	0.82	0.15	0.82	0.15	0.82	0.15
120	0.75	0.18	0.75	0.18	0.75	0.18	0.82	0.16	0.82	0.16	0.82	0.16
140	0.76	0.19	0.76	0.19	0.76	0.19	0.83	0.15	0.83	0.15	0.83	0.15
160	0.77	0.19	0.77	0.19	0.77	0.19	0.84	0.16	0.84	0.16	0.84	0.16
180	0.77	0.20	0.77	0.20	0.77	0.20	0.84	0.16	0.84	0.16	0.84	0.16
200	0.78	0.21	0.78	0.21	0.78	0.21	0.84	0.17	0.84	0.17	0.84	0.17

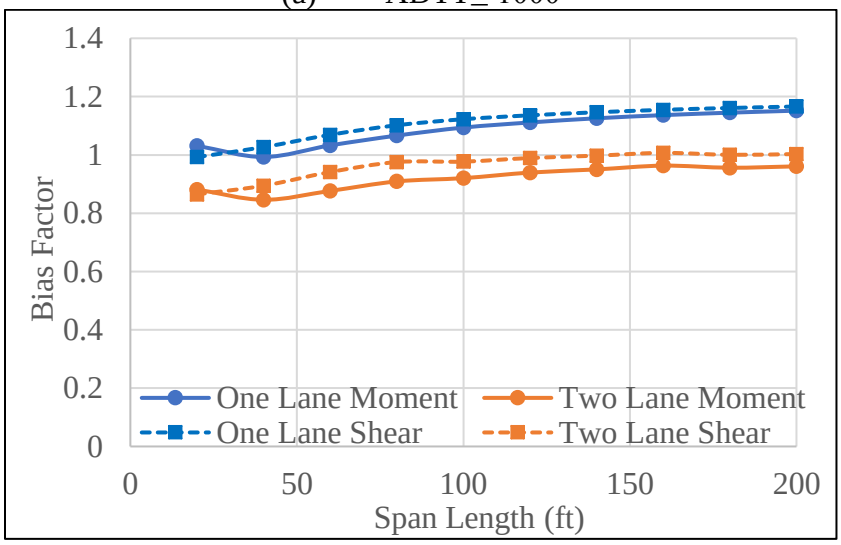
(o) 6-axle Girder Spacing 12 ft

Span (ft)	Moment						Shear					
	ADTT≤1000		1000<ADTT≤5000		5000<ADTT		ADTT≤1000		1000<ADTT≤5000		5000<ADTT	
	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV	Bias	COV
20	0.69	0.16	0.69	0.16	0.69	0.16	0.75	0.15	0.75	0.15	0.75	0.15
40	0.67	0.13	0.67	0.13	0.67	0.13	0.76	0.11	0.76	0.11	0.76	0.11
60	0.68	0.12	0.68	0.12	0.68	0.12	0.78	0.12	0.78	0.12	0.78	0.12
80	0.70	0.12	0.70	0.12	0.70	0.12	0.80	0.14	0.80	0.14	0.80	0.14
100	0.73	0.17	0.73	0.17	0.73	0.17	0.81	0.16	0.81	0.16	0.81	0.16
120	0.75	0.18	0.75	0.18	0.75	0.18	0.82	0.16	0.82	0.16	0.82	0.16
140	0.76	0.20	0.76	0.20	0.76	0.20	0.83	0.16	0.83	0.16	0.83	0.16
160	0.76	0.20	0.76	0.20	0.76	0.20	0.83	0.17	0.83	0.17	0.83	0.17
180	0.77	0.21	0.77	0.21	0.77	0.21	0.83	0.17	0.83	0.17	0.83	0.17
200	0.77	0.22	0.77	0.22	0.77	0.22	0.84	0.18	0.84	0.18	0.84	0.18

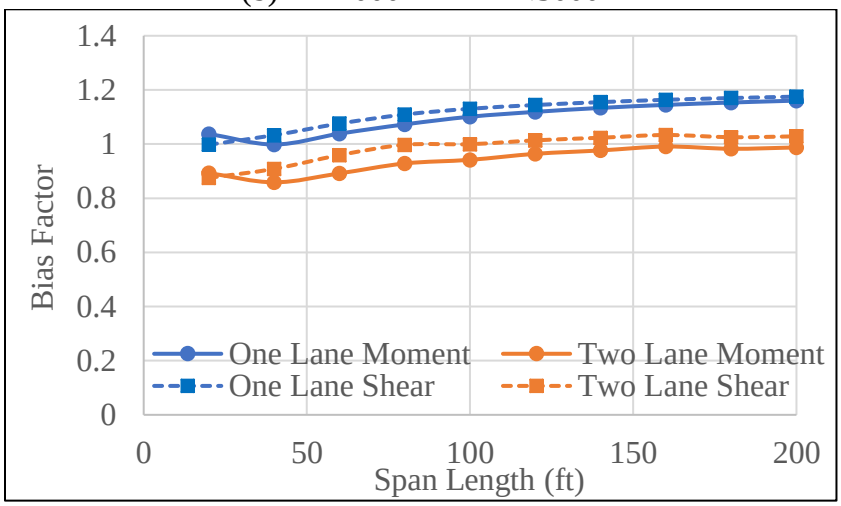
Bias factors for one-lane and two-lane loading cases are plotted versus span length for SU4, SU5 and SU6, as shown in Figure 4.6, Figure 4.7 and Figure 4.8, respectively. The average values of bias factors over different girder spacings for two-lane loading cases were used. It is found that span length and ADTT do not contribute significantly to the change of bias factors. It is also found that one-lane factors are always higher than the corresponding two-lane factors and factors for shear are higher than those for moment in most cases.



(a) ADTT≤ 1000

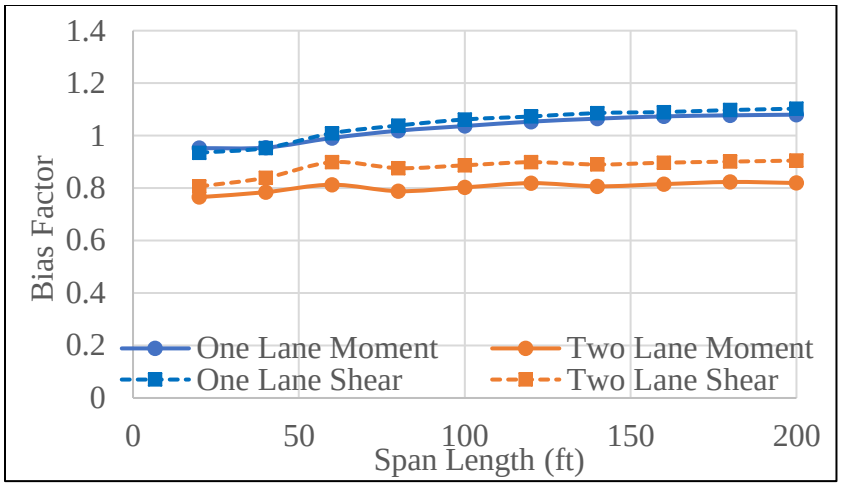


(b) 1000<ADTT≤5000

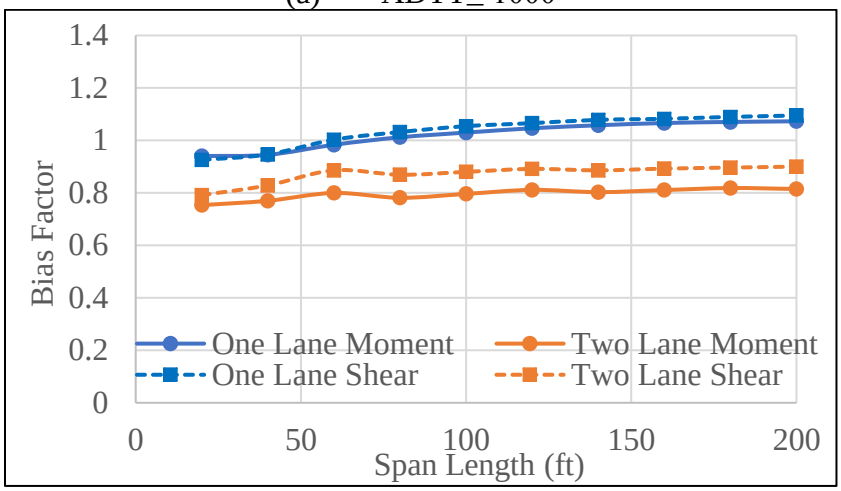


(c) 5000<ADTT

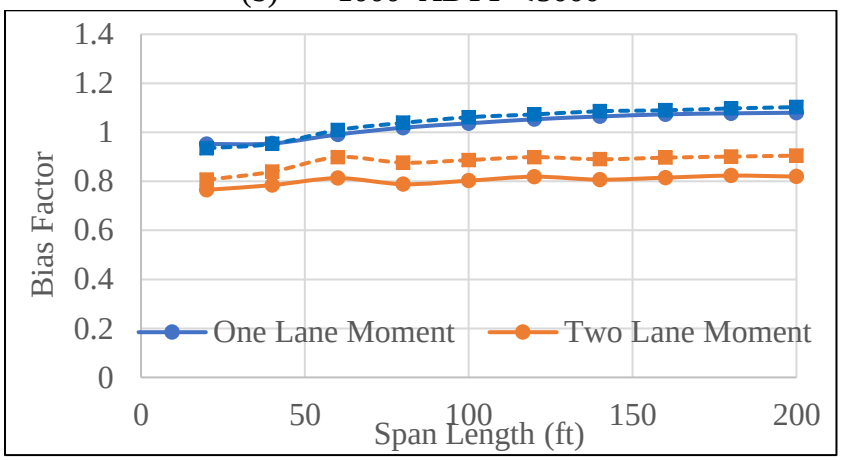
Figure 4.6 Bias factors versus span lengths for SU4



(a) ADTT≤ 1000

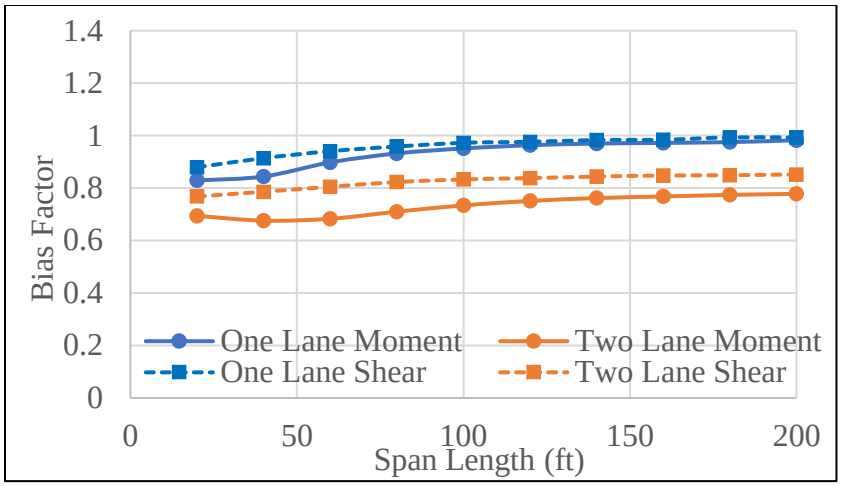


(b) 1000<ADTT⩽5000

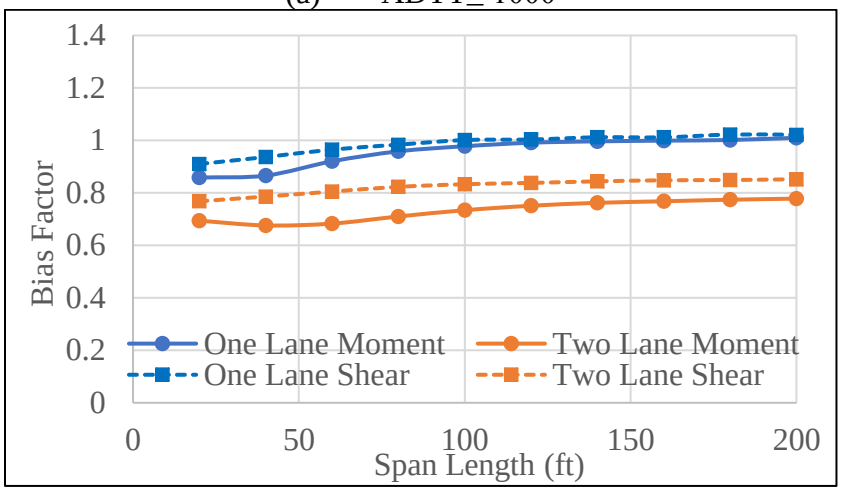


(c) 5000<ADTT

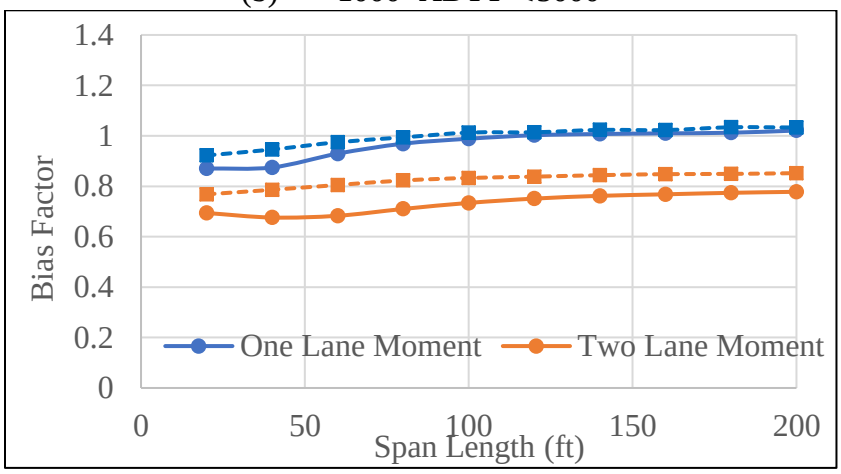
Figure 4.7 Bias factors versus span lengths for SU5



(a) ADTT≤ 1000



(b) 1000<ADTT≤5000



(c) 5000<ADTT

Figure 4.8 Bias factors versus span lengths for SU6

CHAPTER 5

ASSESSMENT OF LIVE LOAD FACTORS FOR STRENGTH I LIMIT STATE

5.1. Bridge Database

The primary objective of this study is to assess the live load factors for SHVs at Strength I limit state. Calculation was also performed to update the live load factors so that a bridge with a rating factor (RF) equal to 1.0 has a target reliability index (β) of 2.5. (Sivakumar, 2007) The author collected 131 existing composite steel girder bridges from NCHRP Project 12-62. (Mertz, 2006) The detailed data of these bridges are documented in APPENDIX B. A brief summary of these bridges is shown in Table 5.1.

Table 5.1. Summary of Selected Bridges for Analysis (Mertz, 2006)

	Span Length (ft)	Number of Girders	Girder Spacing (ft)	Slab Thickness (in)
Minimum	20.5	3	2.17	5.75
Maximum	205	13	15.5	12.01
Average	72.74	6.04	7.68	7.69

5.2. Load Rating and Reliability Analysis

The evaluation of the current live load factors can be done by checking if bridges with RF equal to 1 have $\beta = 2.5$. However, it is not practical to identify bridges with a RF exactly equal to 1. Instead, correlation between β and RF can be investigated. And based on the result, β can be predicted for a given RF. This approach is even more beneficial for the subsequent calculation of new load factors since the same set of bridges can still be utilized. For this purpose, it is required to obtain the rating factors and corresponding reliability indices of all the bridges in the bridge database.

The author load rate the bridges for SU4, SU5, SU6 and SU7 by Equation 2.1. According to MBE (AASHTO MBE, 2018), the live load factors for SHVs are the same for all SU trucks but different for different ADTTs. Three rating factors were obtained for each SU truck by assuming three ADTTs (1000, 3000 and 5000). Therefore, a total of 12 rating factors were obtained for each bridge.

Reliability analysis was performed on the same bridges and reliability indices were obtained to match up with their respective rating factors. Limit state function $g = 0$, consisting of a series of variables, should be first determined to define the boundary between “safe” and “unsafe”. The function could be in different forms and the variables could follow different probability distributions. In this study, First Order Reliability Method (FORM) was adopted for the analysis. It is based on the Taylor series expansion and use only the first-order term, as shown in Equation 5.1. In this manner, non-linear g can be linearized, and the reliability index can be evaluated by Equation 5.2.

$$g(X_1, X_2, \dots, X_n) \approx g(x_1^*, x_2^*, \dots, x_n^*) + \sum_{i=1}^{n} (X_i - x_i^*) \frac{\partial g}{\partial X_i} |_{evaluated\ at\ (x_1^*, x_2^*, \dots, x_n^*)}$$ Equation 5.1

Where:

g = limit state function

X_i = independent random variables

x_i^* = design points

$$\beta = \frac{a_0 + \sum_{i=1}^{n} a_i (\mu_{X_i} - x_i^*)}{\sqrt{\sum_{i=1}^{n} (a_i \sigma_{X_i})^2}}$$ Equation 5.2

Where

x_i^* = design points

$a_o = g(x_1^*, x_2^*, \dots, x_n^*) = 0$

a_i = partial derivative of g to x_i, evaluated at all design points

μ_{Xi} = mean of variable X_i

σ_{Xi} = standard deviation of variable X_i

Note that the procedure is done in an iterative manner. Different sets of points (design points) which the expansion is performed about should be tried until the results of design points and β converge.

Since the variables may not necessarily be Normal variables and Equation 5.2 only applies to Normal variables, Rackwitz-Fiessler procedure is implemented to obtain the Normal equivalent values of mean and standard deviation at the design points.

$$\mu_X^e = x^* - \sigma_X^e\left[\Phi^{-1}\left(F_X(x^*)\right)\right] \qquad \text{Equation 5.3}$$

$$\sigma_X^e = \frac{1}{f_X(x^*)}\phi\left(\frac{x^* - \mu_X^e}{\sigma_X^e}\right) = \frac{1}{f_X(x^*)}\phi\left(\Phi^{-1}\left(F_X(x^*)\right)\right) \qquad \text{Equation 5.4}$$

Where:

x^* = design point of a non-Normal variable

F_X = cumulative distribution function

f_X = probability density function

μ_X^* = equivalent normal mean

σ_{Xi} = equivalent normal std.

In this study, the limit state function is formed as shown in Equation 5.5.

$$\mathrm{G} = \mathrm{R} - \mathrm{DC1} - \mathrm{DC2} - \mathrm{DW} - IM \times GDF \times LL \qquad \text{Equation 5.5}$$

Where:

R = flexural resistance

DC1 = load effect from factor-made components

DC2 = load effect from cast-in-place components

DW = load effect from asphalt surface

IM = impact factor (1.33)

GDF = girder distribution factor

LL = live load effect per lane

Note that the GDFs were calculated based on AASHTO equations as shown in Equation 4.5, Equation 4.6, Equation 4.7 and Equation 4.8. The one-lane GDFs derived from Equation 4.5 for moment and Equation 4.7 for shear should be divided by the multiple presence factor m = 1.2 to be implemented in the limit state function shown in Equation 5.5.

The required input items are the statistical parameters and probability distribution of loads and resistance. These of dead loads and resistance were collected from the previous studies (Nowak, 1995) (Tabsh & Nowak, 1991), as shown in Table 5.2. The statistical parameters and probability distribution of live load were developed by the author in the previous chapter. First Order Reliability Method (FORM) was applied as the reliability analysis method. Both one-lane and two-lane loading models developed previously for live load were used and the minimum β was determined. Since the analysis is sensitive to CoV, live load λ and GDF alone may not be able to determine the controlling loading case. Since there were no 7-axle SHVs involved in the statistical model development for live load, the statistical inputs for SU7 were assumed to be the same as those for SU6.

A total of 12 reliability indices were obtained for each bridge corresponding to the 12 rating factors calculated previously.

Table 5.2. Statistical Parameters and Distribution Types for Dead Loads and Resistance (Nowak, 1995)

x	Bias factor	Coefficient of variation	Distribution type
DC1	1.03	0.08	Normal
DC2	1.05	0.1	Normal
DW	3 in*	0.25	Normal
R (Flexure)	1.11	0.12	Lognormal

DC1 = factory-made components

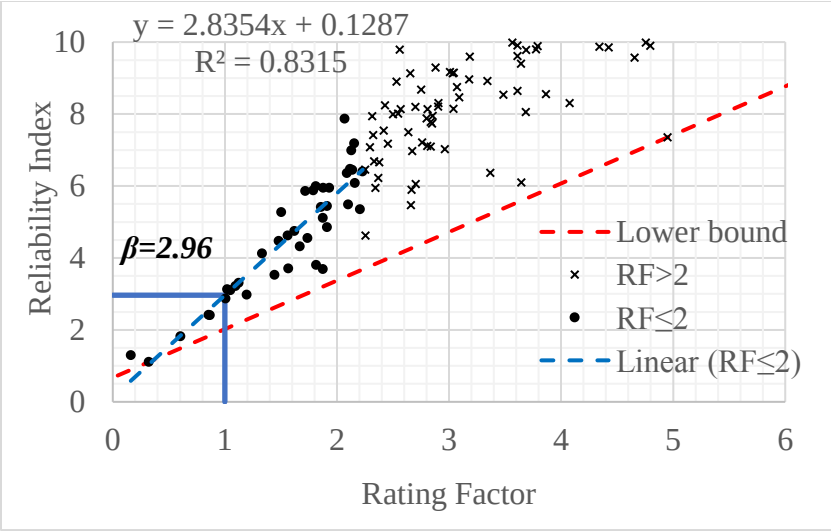
DC2 = cast-in-place components

DW = asphalt surface

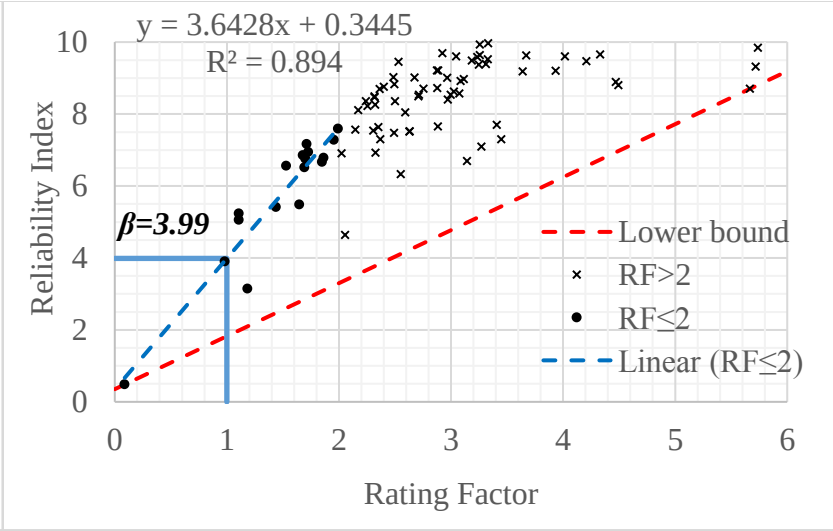
* Mean thickness

Assessment of Live Load Factor

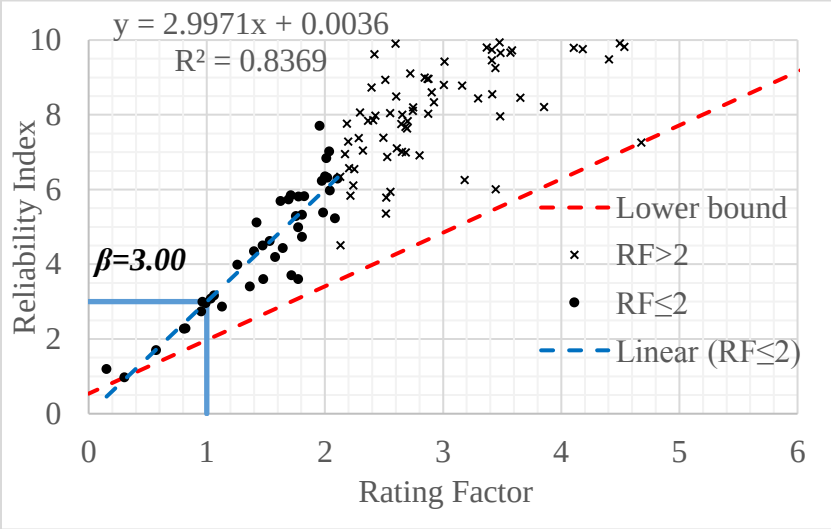
The author performed linear regression analysis of β vs. RF to predict β for RF = 1. Bridges with lower RF were subjected to the analysis since those bridges were more critical. If different bridges were used for the analysis for different SUs and ADTTs, the assessment results would not be consistent. Therefore, the author selected the bridges rated below 2.0 for SU4 at ADTT = 5000 for moment evaluation and at ADTT = 1000 for shear evaluation instead of using the respective bridges rated below 2.0 in each of the 12 loading scenarios. Twelve plots of β vs. RF were created for SU4, SU5, SU6 and SU7, as shown in Figure 5.1, Figure 5.2, Figure 5.3 and Figure 5.4, respectively. The lower bound of reliability indices is represented by the red dashed line in each of the plots.



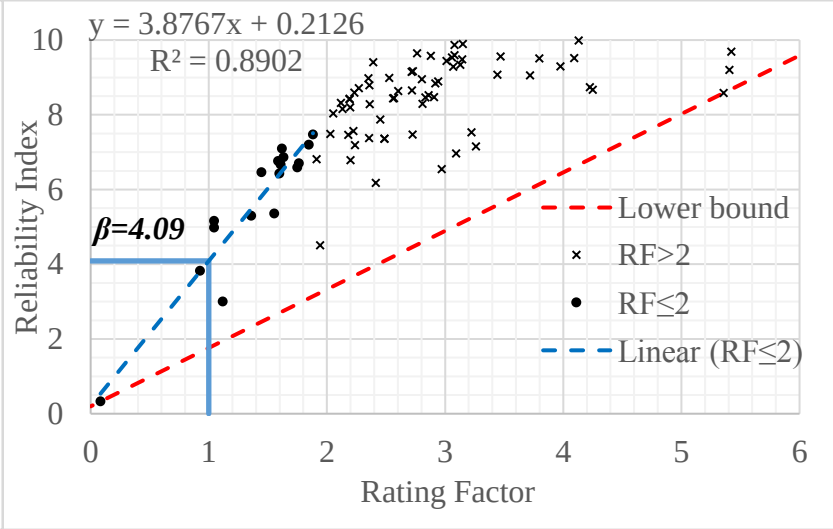
(a) Moment - ADTT≤1000



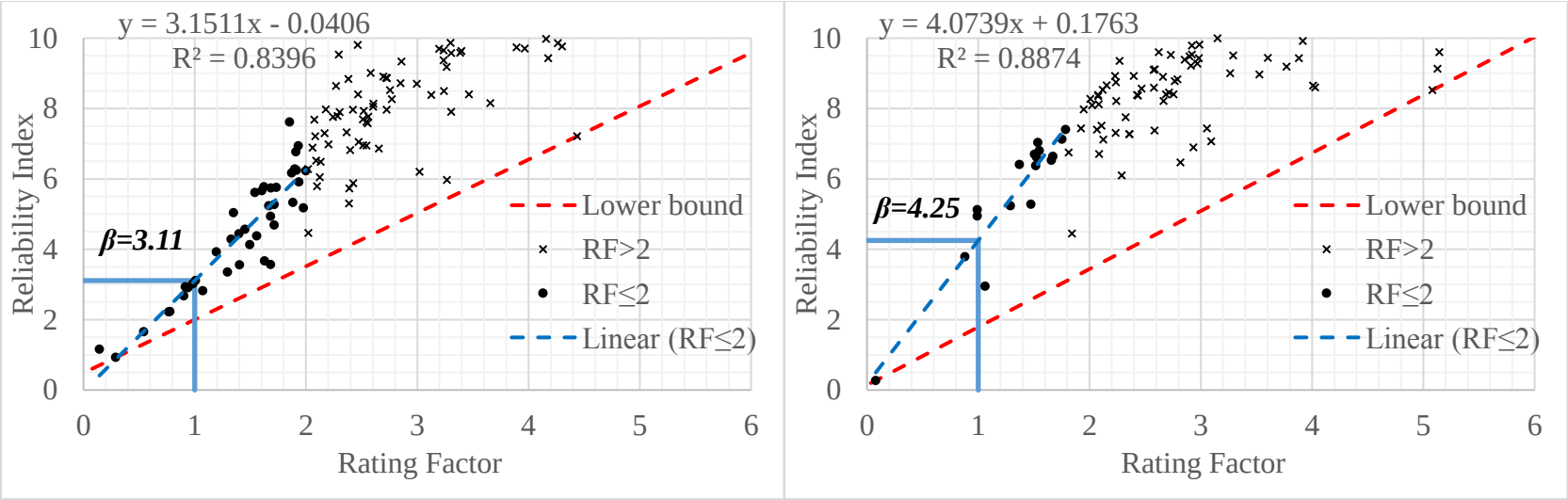
(b) Shear- ADTT≤1000



(c) Moment - 1000<ADTT≤5000

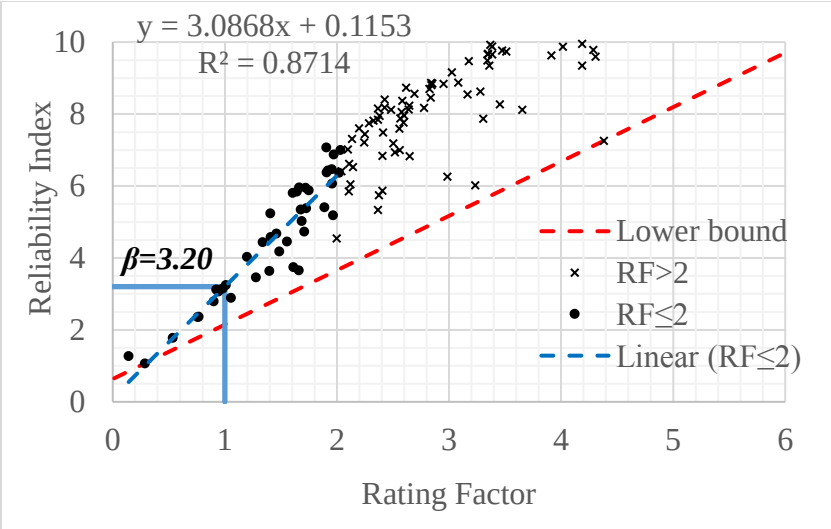


(d) Shear- 1000<ADTT≤5000

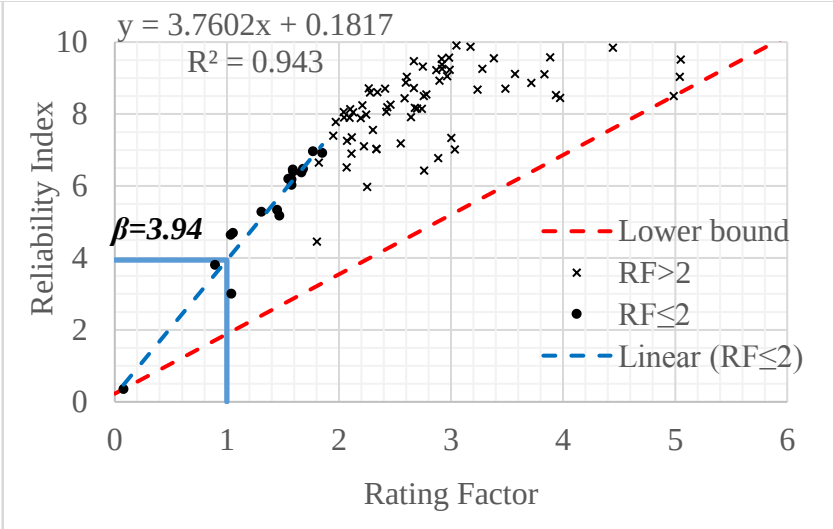


(e) Moment - 5000<ADTT (f) Shear - 5000<ADTT

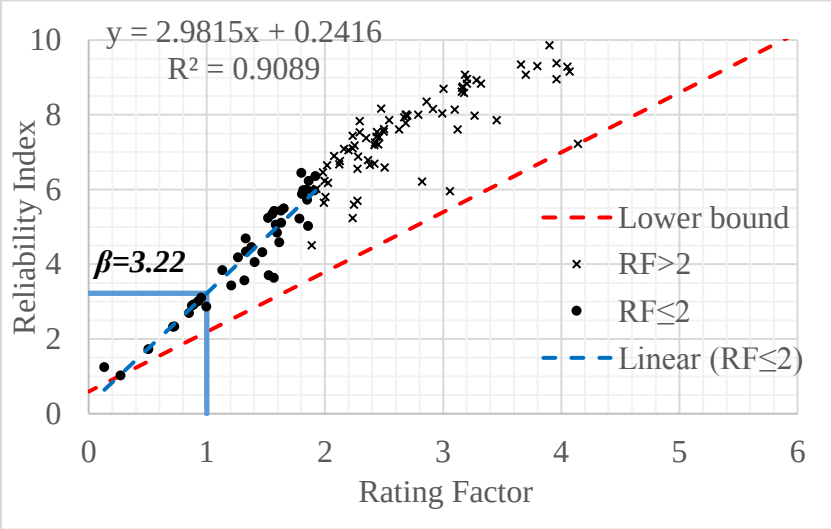
Figure 5.1. Reliability indices versus rating factors for SU4



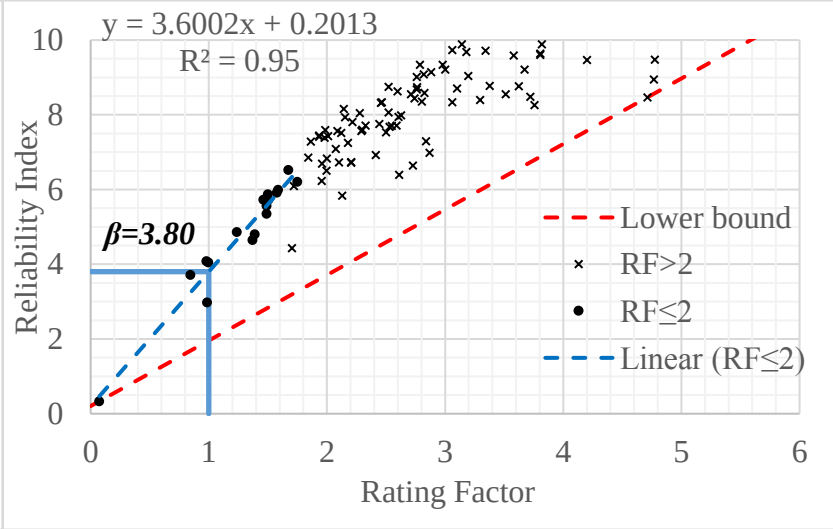
(a) Moment - ADTT≤1000



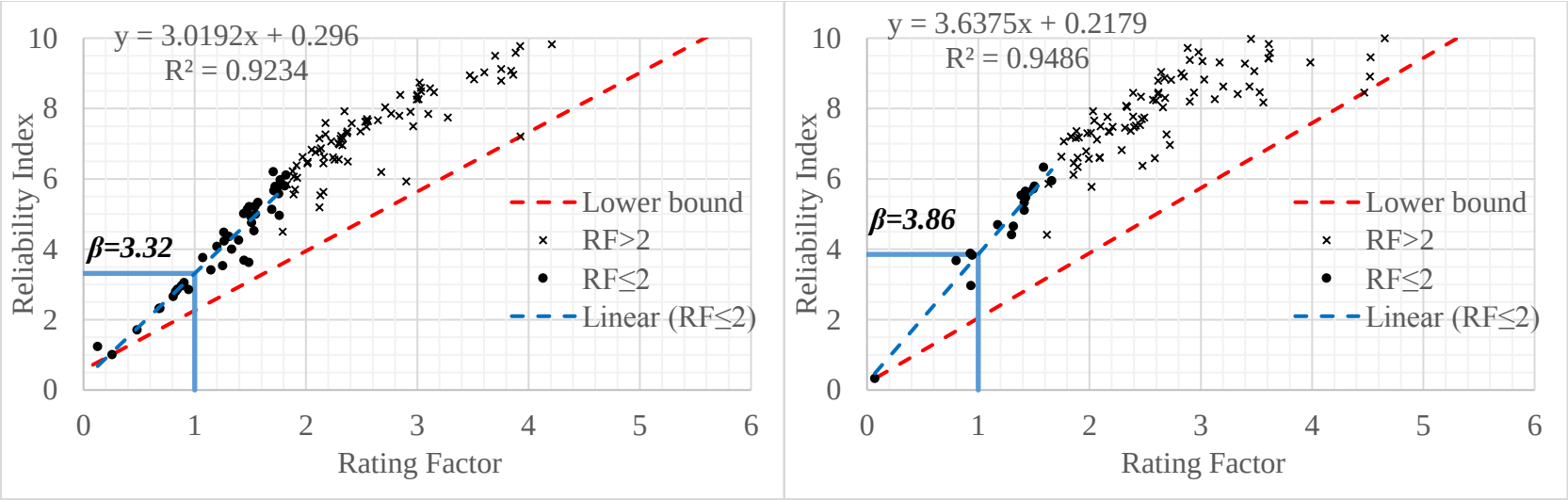
(b) Shear - ADTT≤1000



(c) Moment - 1000<ADTT≤5000

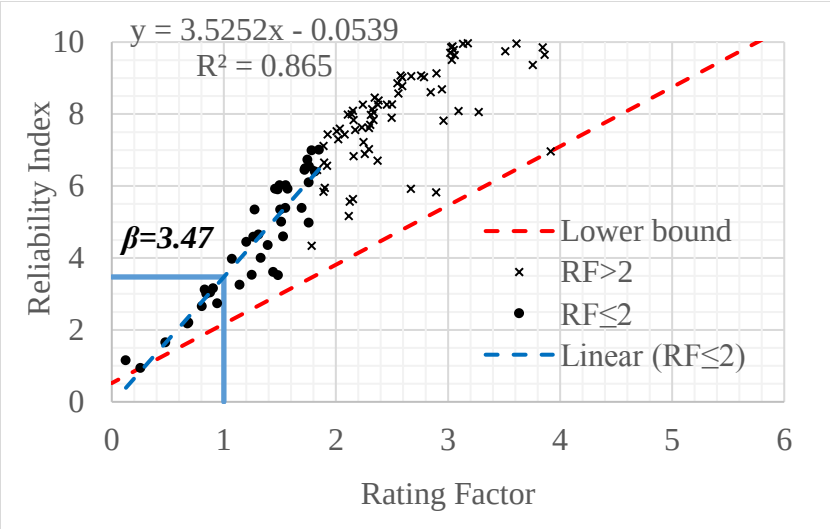


(d) Shear - 1000<ADTT≤5000

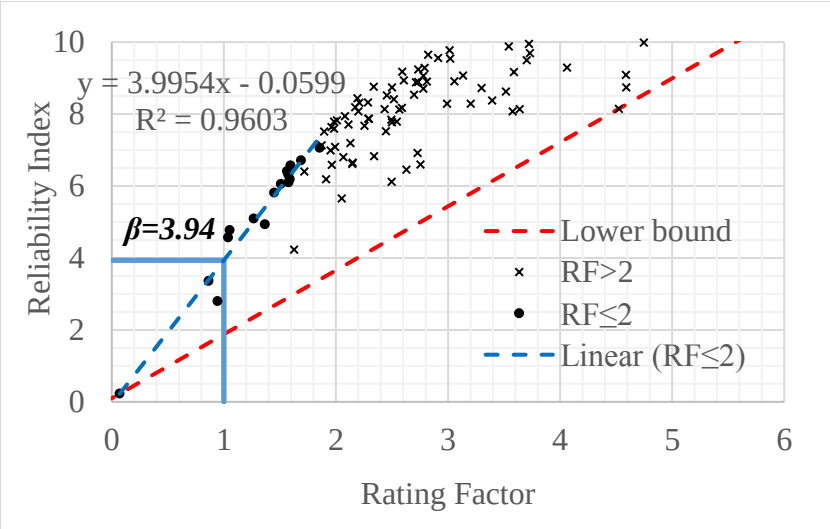


(e) Moment - 5000<ADTT (f) Shear - 5000<ADTT

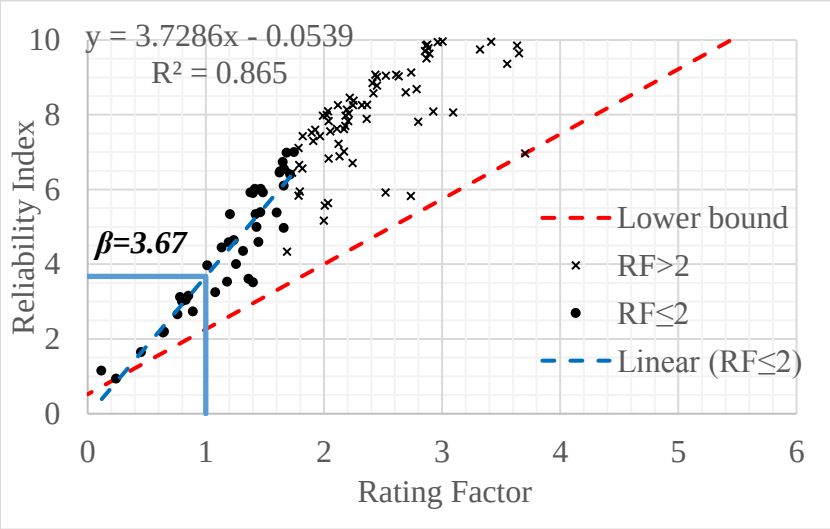
Figure 5.2. Reliability indices versus rating factors for SU5



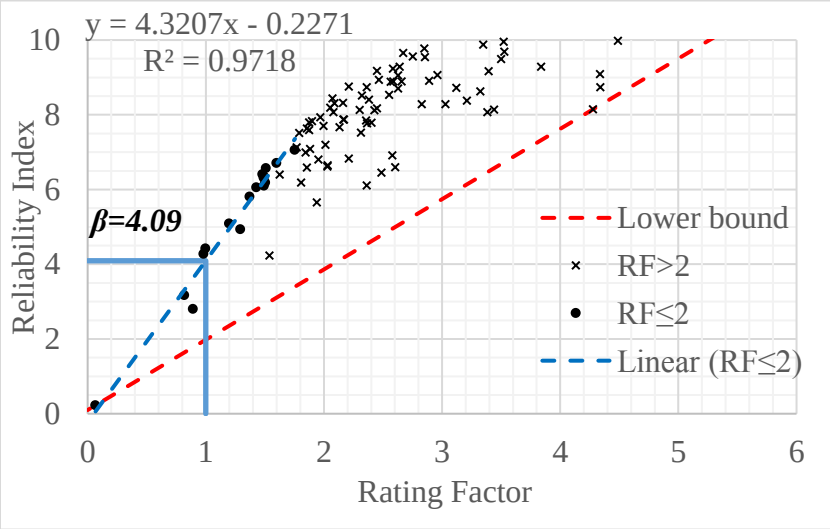
(a) Moment - ADTT≤1000



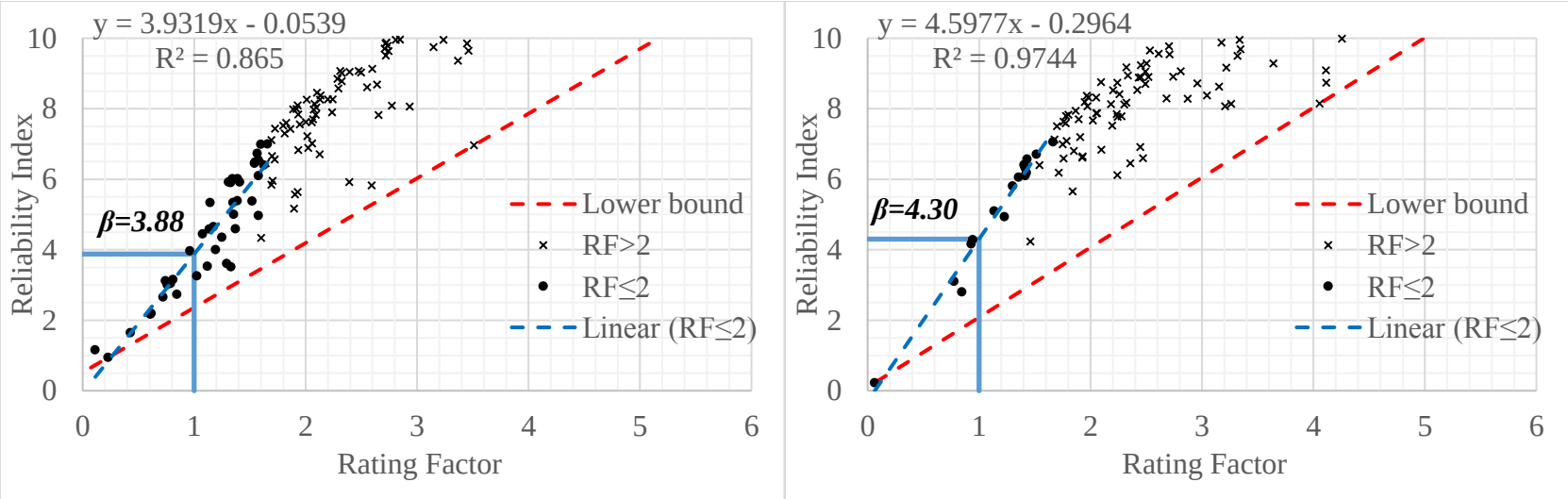
(b) Shear - ADTT≤1000



(c) Moment - 1000<ADTT≤5000

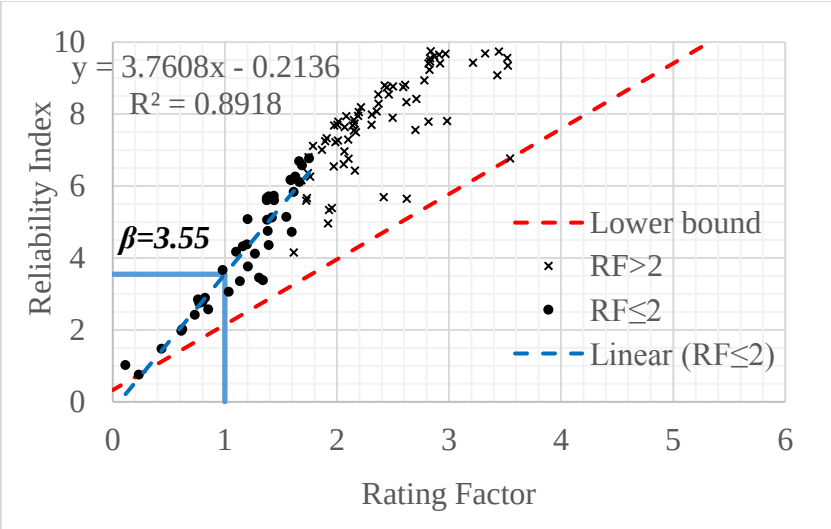


(d) Shear - 1000<ADTT≤5000

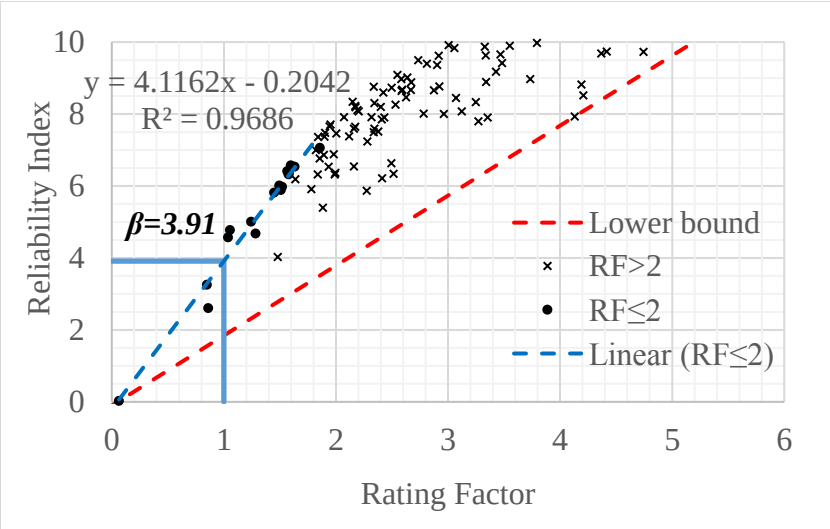


(e) Moment - 5000<ADTT (f) Shear - 5000<ADTT

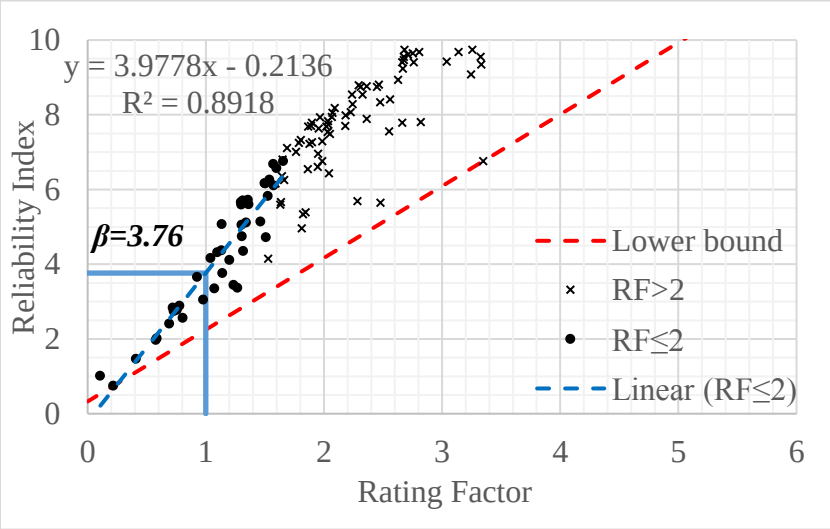
Figure 5.3. Reliability indices versus rating factors for SU6



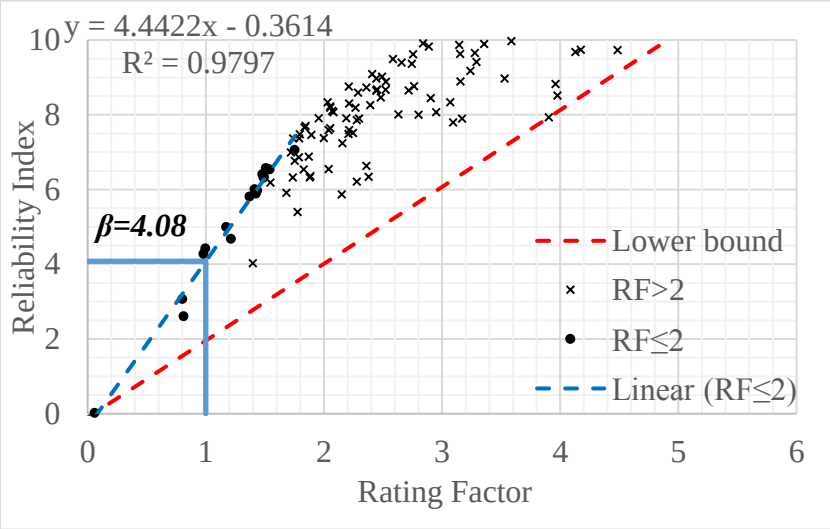
(a) Moment - ADTT≤1000



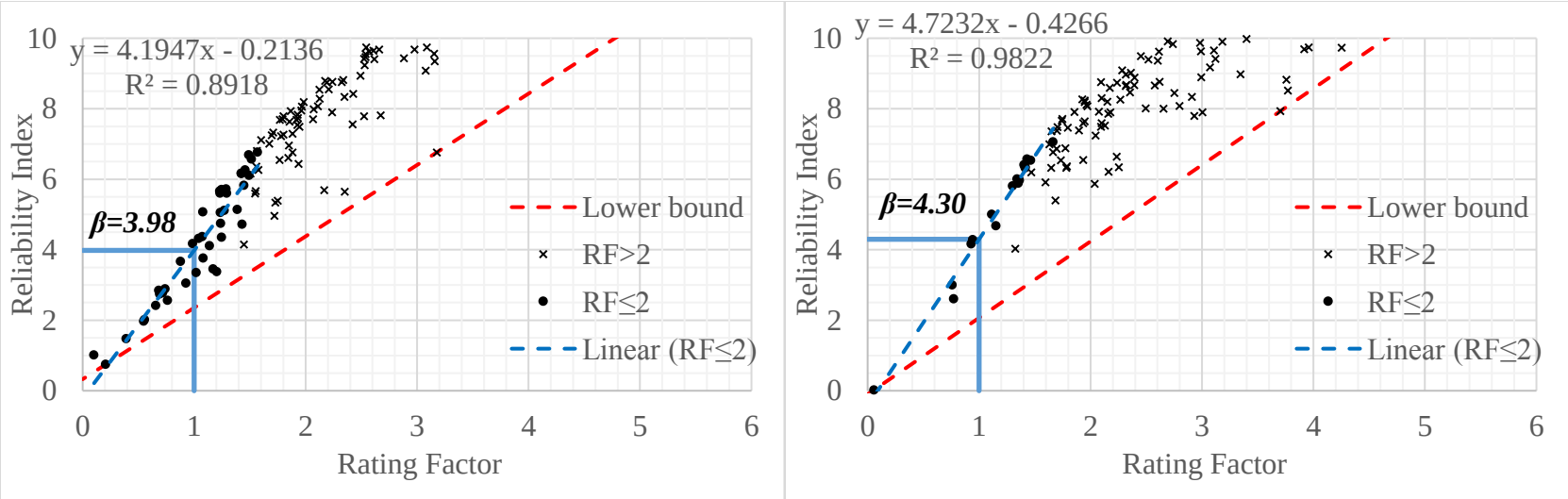
(b) Shear - ADTT≤1000



(c) Moment - 1000<ADTT≤5000



(d) Shear - 1000<ADTT≤5000



(e) Moment - 5000<ADTT (f) Shear - 5000<ADTT

Figure 5.4. Reliability indices versus rating factors for SU7

Based on the regression analysis, the current live load factors provide reliability level higher than the required reliability index of 2.5 for all 12 scenarios. This implies that the structural reliability level of a given bridge reflected by the current load rating is lower than the its actual capacity. The author used Equation 5.6 to adjust the live load factors so that the rating factor can reflect the actual structural capacity. The adjusted live load factors are presented in Table 5.3.

$$Adjusted\ factor = Current\ MBE\ factor \times \frac{RF(when\ \beta = 2.5)}{1} \qquad \text{Equation 5.6}$$

Table 5.3. Adjusted Live Load Factors for Single-Unit Bridge Posting Loads

ADTT* / SU Load	ADTT<1000		5000≤ADTT	
	Moment	Shear	Moment	Shear
SU4	1.09	0.77	1.17	0.83
SU5	1.00	0.80	1.06	0.91
SU6	0.94	0.83	0.94	0.88
SU7	0.94	0.85	0.94	0.90

* Linear interpolation will be used for ADTT between 1000 and 5000.

Since the adjusted live load factors are lower than the current live load factors, more rigorous studies need to be conducted to validate these values for the sake of conservativity. The incorporation of reinforced-concrete bridges, prestressed-concrete bridges and other bridge types should be considered in future studies. Also, more WIM sites across the US should be processed to reduce the regional bias on the results.

CHAPTER 6

SUMMARY AND CONCLUSIONS

6.1. Summary

This thesis presents a rational procedure to assess the live loads for SHVs for LRFR Strength I limit state through the utilization of WIM data and existing steel-girder bridges. Statistics, characteristics and multiple-presence events of SHVs were studied based on the data processing results. Both one-lane loading case and two-lane loading case were considered. For one-lane loading case, load effects from individual SHVs were calculated for various spans. The load effects then were normalized by AASHTO SU4 to SU7 according to the number of axles of the SHVs. The normalized load effects were extrapolated to predict the maximum values at each WIM site for a 5-year evaluation period. For two-lane loading case, the multiple-presence events of SHVs were first identified. The load effects of each multiple-presence event were calculated with AASTHO girder-distribution-factor equations. The same procedure for live load extrapolation as one-lane loading case was applied to predict the maximum live load effects for two-lane loading case. The statistical models for SHVs were then developed based on the site maximum load effects. The reliability indices (β) and rating factors (RF) of 131 steel-girder bridges were calculated. One-lane loading case and two-lane loading case are both evaluated to determine the governing case for each of the bridges. The calculations were done for

AASHTO SU4 to SU7 with ADTTs of 1000, 1000 to 5000 and 5000, resulting a total of twelve loading scenarios. Accordingly, twelve plots of β vs. RF with regression lines were created. The live load factors for SHVs were then adjusted until the intercept of regression line is equal to 2.5 at RF = 1.

6.2. Conclusions

Based on the work presented in this thesis, the conclusions of this study are summarized as follows:

(1) WIM data from 93 WIM sites of New Jersey and 46 WIM sites of other 21 states across the United States were processed separately. The statistics of SHVs and characteristics (number of axles, GVW and typical configurations) were investigated. In New Jersey, SHV traffic fleet is highly localized, as the northern part experiences significantly higher SHV traffic volume than the southern part. SHV with three axles is the most common type detected.

(2) Multiple-presence events of one SHV with one random legal truck were identified based on WIM data. The increase of span length reduces the occurrence of side-by-side and staggered events. This is because the chance of involving the third or more trucks increases on longer spans and the multiple-presence events will be converted to “other”.

(3) The probability distribution of normalized load effects at a WIM site was investigated by hypothesis testing. Several sites have been studied and it is shown that the data can be described by Normal distribution in general. Also, the daily maximum data at a WIM site were extracted and investigated in terms of probability distribution. It is shown that the data can be described by GEV distribution in general.

(4) The statistical models of live load for both one-lane and two-lane loading cases were developed for various spans (10 ft to 200 ft) in each of the twelve loading scenarios. Hypothesis testing shows the live load effects can be described by Lognormal distribution in general.

(5) For the developed models of live load, bias factors are uniform over various span lengths but not sensitive to ADTT. One-lane factors are always higher than the corresponding two-lane factors. Factors for shear are higher than moment in most cases.

(6) The results of the regression analysis of reliability indices and rating factors for the existing bridges indicate that the structural reliability level of a given bridge reflected by the current load rating is lower than the its actual capacity. The author adjusted the live load factors to match reliability index of 2.5 with rating factor equal to 1.0 for all loading scenarios. Although the values need to be further validated, the results can serve as a baseline for more comprehensive studies in the future.

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APPENDIX A

WIM DATA PROCESSING AND RESULTS

The statistics of the general truck fleet and SHV traffic fleet at the WIM sites used in this thesis are documented in this appendix. Section A.1 presents the site information and statistics of truck traffic fleet per site. Section A.2 presents the statistics of SHVs with different numbers of axles per site.

A.1 Site Information and Statistics of Trucks

Table A.1 New Jersey WIM Sites and Statistics

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
Co-539	CO0539	29.3	2010	N&S	149	64556	39160	331	0.51%	2.22
			2013	N&S	57	26473	14580	211	0.80%	3.70
			2014	N&S	355	203181	117699	2487	1.22%	7.01
			2015	S	305	74673	55938	469	0.63%	1.54
			2016	S	303	77248	64470	271	0.35%	0.89
CO-540	CO0540	4.76	2010	E&W	305	75568	58522	244	0.32%	0.80
			2011	E&W	359	90492	66885	296	0.33%	0.82
			2012	E&W	364	76640	64700	199	0.26%	0.55
			2013	E&W	364	74132	65149	277	0.37%	0.76
			2014	E&W	295	56114	47637	192	0.34%	0.65
			2015	E&W	334	70708	61238	213	0.30%	0.64
			2016	E&W	305	70160	59085	210	0.30%	0.69
CO-563	CO0563	8.75	2010	N&S	120	32650	26907	757	2.32%	6.31
			2011	N&S	365	121452	96314	4005	3.30%	10.97
			2012	N&S	327	95027	78628	2641	2.78%	8.08
			2013	N&S	340	96974	78997	2170	2.24%	6.38
			2014	N&S	266	86575	70354	2023	2.34%	7.61
			2015	S	123	18802	16141	241	1.28%	1.96
			2016	S	262	37632	33469	338	0.90%	1.29
CO-821	CO0821	2.4	2012	E&W	27	822	810	1	0.12%	0.04

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
			2013	E&W	346	16601	15424	117	0.70%	0.34
			2014	E&W	282	16236	14951	169	1.04%	0.60
			2015	E&W	273	15148	14082	125	0.83%	0.46
			2016	E&W	334	17604	16614	118	0.67%	0.35
I-195	000195	10.2	2010	E&W	19	44264	39504	507	1.15%	26.68
			2011	E&W	347	896270	729283	9089	1.01%	26.19
			2012	E&W	321	815245	672722	6952	0.85%	21.66
			2013	E&W	350	942561	815991	5829	0.62%	16.65
			2014	E&W	349	952758	787485	9339	0.98%	26.76
			2015	E&W	364	1037785	887063	8661	0.83%	23.79
			2016	E&W	266	745399	655866	6101	0.82%	22.94
I-195	00195B	4	2010	E&W	87	377429	342786	1717	0.45%	19.74
			2011	E	115	298847	258393	1974	0.66%	17.17
			2012	E	59	152245	140682	961	0.63%	16.29
			2013	E&W	77	315365	258947	1290	0.41%	16.75
			2013	E	30	12470	11018	97	0.78%	3.23
			2014	W	146	370661	301928	1178	0.32%	8.07
			2015	W	92	220790	174516	1343	0.61%	14.60
			2016	E	353	1006143	890805	2354	0.23%	6.67
I-280	000280	5.1	2012	W	31	48542	46605	245	0.50%	7.90
			2013	W	155	274149	248734	2450	0.89%	15.81
			2014	E&W	265	982064	875026	8370	0.85%	31.58
			2015	W	120	189377	176936	1146	0.61%	9.55
			2016	W	30	59069	57223	214	0.36%	7.13
I-287	000287	61.7	2010	N&S	250	1290023	1260232	3685	0.29%	14.74
			2011	N&S	243	1481446	1441824	2091	0.14%	8.60
			2012	N&S	247	1772801	1732250	1894	0.11%	7.67

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
			2013	S	108	335579	292997	990	0.30%	9.17
			2014	N&S	61	476900	446961	748	0.16%	12.26
			2015	N&S	119	959769	896699	1594	0.17%	13.39
			2016	N&S	162	1222595	1146464	2331	0.19%	14.39
I-287	00287A	31.7	2010	N	211	922166	824911	2272	0.25%	10.77
			2011	N	295	1332546	1217806	2411	0.18%	8.17
			2012	N	168	760768	712125	1151	0.15%	6.85
			2013	N	98	470861	442709	767	0.16%	7.83
			2014	N	30	154600	123471	461	0.30%	15.37
I-287	00287C	5.5	2010	N&S	284	2479392	2175946	7188	0.29%	25.31
			2011	N&S	328	2892661	2542696	11126	0.38%	33.92
			2012	N&S	358	3126552	2725458	13499	0.43%	37.71
			2013	N&S	297	2605548	2281391	11423	0.44%	38.46
			2014	N	118	519587	481212	1741	0.34%	14.75
			2015	N&S	61	592840	547982	1743	0.29%	28.57
			2016	N	265	1308628	1219925	5114	0.39%	19.30
I-295	000295	39.6	2010	N&S	275	1725731	1612281	5702	0.33%	20.73
			2011	N&S	242	1113372	975584	4343	0.39%	17.95
			2012	N&S	240	1313192	1136623	4531	0.35%	18.88
			2013	S	128	219351	195149	794	0.36%	6.20
			2014	N&S	354	2769904	2323260	9364	0.34%	26.45
			2015	N&S	362	2835662	2379155	9434	0.33%	26.06
			2016	N	302	1278624	1051021	4167	0.33%	13.80
I-295	00295C	35.7	2010	N&S	129	812708	778557	3892	0.48%	30.17
			2011	N&S	294	2264998	1936280	8326	0.37%	28.32
			2012	S	179	709404	627321	2594	0.37%	14.49
			2013	N&S	163	891807	781961	2339	0.26%	14.35

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
			2014	N&S	179	1492872	1355106	3553	0.24%	19.85
			2015	N&S	154	1321313	1200136	3323	0.25%	21.58
			2015	S	119	502305	458137	1101	0.22%	9.25
			2016	N&S	152	1128595	1026023	2540	0.23%	16.71
I-295	00295D	2.9	2010	N	48	73966	73395	161	0.22%	3.35
			2011	N	147	199503	195655	707	0.35%	4.81
			2012	N	214	370568	357813	1083	0.29%	5.06
			2013	N	177	329209	318340	520	0.16%	2.94
			2014	N	211	352973	337671	1192	0.34%	5.65
			2015	N	153	196726	191745	555	0.28%	3.63
			2015	N	31	38906	37762	150	0.39%	4.84
			2016	N	122	50346	48436	74	0.15%	0.61
I-295	00295L	15.2	2010	N&S	226	1384071	1199581	5927	0.43%	26.23
			2011	N&S	285	1841861	1624154	8147	0.44%	28.59
			2012	N&S	276	1961387	1781901	7064	0.36%	25.59
			2013	N&S	296	2006356	1821667	6312	0.31%	21.32
			2014	N&S	295	1740108	1543825	4995	0.29%	16.93
			2015	N&S	250	1465230	1312533	4729	0.32%	18.92
			2016	N	121	422749	387403	1027	0.24%	8.49
I-676	000676	2.6	2010	N&S	354	663630	586472	16317	2.46%	46.09
			2011	N&S	365	684615	621878	8774	1.28%	24.04
			2012	N&S	294	586959	534443	6395	1.09%	21.75
			2013	N&S	298	607897	555569	7210	1.19%	24.19
			2014	N&S	302	563325	507603	9406	1.67%	31.15
			2015	N&S	184	306793	269402	7017	2.29%	38.14
			2016	N&S	114	270794	240267	3896	1.44%	34.18
I-78	00078A	14.5	2010	E&W	312	4296079	3418482	32059	0.75%	102.75

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
			2011	E&W	306	4228447	3200706	41214	0.97%	134.69
			2012	E&W	359	5168260	3971962	51757	1.00%	144.17
			2013	E&W	359	5333361	4323723	53176	1.00%	148.12
			2014	E&W	358	5559317	4787527	50213	0.90%	140.26
			2015	E&W	303	4874274	4185166	38963	0.80%	128.59
			2016	E&W	243	4017700	3470623	32263	0.80%	132.77
I-78	00078D	7.9	2010	E&W	336	4863912	4259151	29653	0.61%	88.25
			2011	E&W	282	3725965	3244251	31912	0.86%	113.16
			2012	E&W	209	2730464	2416177	23589	0.86%	112.87
			2013	E&W	239	2543035	2215331	27918	1.10%	116.81
			2014	E&W	99	620606	557673	5851	0.94%	59.10
			2015	E	152	1302057	1197528	7071	0.54%	46.52
			2016	E	184	1591742	1437975	7385	0.46%	40.14
I-78	00078E	5.02	2012	E	31	210216	190472	1930	0.92%	62.26
			2013	E	326	2437475	2206227	20091	0.82%	61.63
			2014	E	221	1674794	1536083	14157	0.85%	64.06
			2015	E	139	1079835	982814	7226	0.67%	51.99
I-78	00078F	7.9	2010	W	20	120540	106086	800	0.66%	40.00
			2013	W	86	585272	508464	4862	0.83%	56.53
			2014	W	235	1764078	1518360	14941	0.85%	63.58
			2015	W	31	242036	215405	2332	0.96%	75.23
I-78	00078W	7.9	2010	E&W	354	2339802	2027050	33305	1.42%	94.08
			2011	E&W	307	2108786	1800188	28953	1.37%	94.31
			2012	E&W	351	2324439	2020076	38544	1.66%	109.81
			2013	E&W	317	2159803	1954176	30045	1.39%	94.78
			2014	E&W	296	1989352	1839875	23638	1.19%	79.86
			2015	E&W	142	972005	895208	9286	0.96%	65.39

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
			2016	E&W	153	1128464	1039020	13111	1.16%	85.69
I-80	00080A	8.3	2010	E&W	299	2103393	1905840	25638	1.22%	85.75
			2011	E&W	323	2176928	2009095	26836	1.23%	83.08
			2012	E	133	440992	410011	6126	1.39%	46.06
			2013	E&W	31	103541	84269	1797	1.74%	57.97
			2016	E&W	60	267309	237651	1635	0.61%	27.25
I-80	00080B	32.4	2010	E&W	210	1711976	1514359	17084	1.00%	81.35
			2011	E&W	129	757936	684879	6446	0.85%	49.97
			2012	E&W	121	463494	392371	5324	1.15%	44.00
			2016	E&W	123	1141319	1027110	14287	1.25%	116.15
I-80	00080C	38.1	2010	E	151	874486	688284	11324	1.29%	74.99
			2011	E&W	266	2650684	2192705	31669	1.19%	119.06
			2012	E&W	213	2126052	1739260	23989	1.13%	112.62
			2013	E&W	177	1681038	1403657	18664	1.11%	105.45
			2014	E	303	1702388	1355284	16624	0.98%	54.86
			2015	E	86	343429	283004	2834	0.83%	32.95
			2016	W	145	900125	778990	9067	1.01%	62.53
I-80	00080D	66.2	2010	E	38	242355	214351	4198	1.73%	110.47
			2011	W	24	52655	45346	1515	2.88%	63.13
I-80	0080DL	66.4	2016	W	61	249836	225196	2888	1.16%	47.34
I-80	0080DX	66.4	2011	E&W	299	1321484	1097698	45371	3.43%	151.74
			2012	E&W	351	1516708	1283227	51555	3.40%	146.88
			2013	E&W	347	1474184	1254232	50495	3.43%	145.52
			2014	E	199	341183	302472	12009	3.52%	60.35
			2016	E	22	12479	10209	957	7.67%	43.50
I-95	000095	1.2	2010	S	44	85494	74176	278	0.33%	6.32
			2011	N&S	159	361308	291204	1407	0.39%	8.85

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
			2012	S	362	686097	565023	2024	0.30%	5.59
			2013	S	81	133833	122602	258	0.19%	3.19
			2014	N	39	38075	31699	468	1.23%	12.00
			2015	N	124	122738	91534	501	0.41%	4.04
			2016	N&S	78	208837	171712	707	0.34%	9.06
I-95	00095B	6.3	2010	N&S	267	979923	777684	4591	0.47%	17.19
			2011	N&S	296	1069162	860223	4239	0.40%	14.32
			2012	N&S	266	925592	754511	3771	0.41%	14.18
			2013	N&S	284	909409	760599	3111	0.34%	10.95
			2014	N&S	145	468589	387080	1738	0.37%	11.99
			2015	N&S	205	623775	529833	2392	0.38%	11.67
			2016	N&S	167	559422	474202	1973	0.35%	11.81
NJ-124	000124	7.6	2010	E&W	221	37653	36023	324	0.86%	1.47
			2011	E&W	206	37061	34971	293	0.79%	1.42
			2012	E&W	203	24792	23531	214	0.86%	1.05
			2013	E&W	87	5209	5004	21	0.40%	0.24
			2014	E	91	4680	4510	21	0.45%	0.23
			2015	W	28	907	899	0	0.00%	0.00
NJ-138	000138	2.6	2010	E&W	328	137891	131467	378	0.27%	1.15
			2011	E&W	330	154775	145136	469	0.30%	1.42
			2012	E&W	277	107533	100965	456	0.42%	1.65
			2013	E&W	116	28348	25156	221	0.78%	1.91
			2014	E&W	210	78414	71331	409	0.52%	1.95
			2015	E	25	5234	4819	34	0.65%	1.36
			2016	E&W	244	123764	112448	684	0.55%	2.80
NJ-15	000015	7.1	2010	N&S	325	410425	324896	2540	0.62%	7.82
			2011	N&S	349	451172	350368	4008	0.89%	11.48

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
			2012	N&S	290	358751	285963	4026	1.12%	13.88
			2013	N	95	54475	50693	379	0.70%	3.99
			2015	S	92	62867	40803	1561	2.48%	16.97
			2016	S	265	268972	158452	4204	1.56%	15.86
NJ-168	000168	1.3	2010	N&S	180	36503	35898	40	0.11%	0.22
			2013	N&S	51	13085	12101	215	1.64%	4.22
			2014	N&S	327	77204	74547	386	0.50%	1.18
			2015	N	31	2849	2753	12	0.42%	0.39
NJ-17	000017	22.9	2016	S	215	732323	635900	19363	2.64%	90.06
NJ-17	00017B	22.9	2010	N&S	54	293585	243696	6304	2.15%	116.74
			2011	N&S	130	666673	566958	12857	1.93%	98.90
			2013	S	130	375689	349721	7434	1.98%	57.18
			2014	S	92	184949	164545	3271	1.77%	35.55
			2015	S	31	76009	68607	582	0.77%	18.77
			2016	N&S	48	341470	293124	8329	2.44%	173.52
NJ-173	000173	2.4	2010	W	182	6819	6385	36	0.53%	0.20
			2011	E&W	327	33655	30944	248	0.74%	0.76
			2012	E&W	318	38134	34475	278	0.73%	0.87
			2013	E&W	317	34585	31320	205	0.59%	0.65
			2014	E&W	55	4491	3952	39	0.87%	0.71
			2016	E&W	148	18128	16317	124	0.68%	0.84
NJ-18	000018	26.6	2010	N&S	257	847150	723020	7250	0.86%	28.21
			2011	N	210	348225	289119	4770	1.37%	22.71
			2012	N&S	113	298876	259390	2873	0.96%	25.42
			2013	N	55	91912	81047	996	1.08%	18.11
			2014	N	134	214190	183864	2348	1.10%	17.52
			2015	N&S	121	388994	340639	2973	0.76%	24.57

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
			2016	N&S	362	1141289	1017621	8000	0.70%	22.10
NJ-18	00018B	16	2010	N&S	290	603876	567751	3088	0.51%	10.65
			2011	N&S	340	688195	644754	4099	0.60%	12.06
			2012	N&S	260	518108	486984	3563	0.69%	13.70
			2013	N&S	202	421891	367143	1555	0.37%	7.70
			2014	N&S	208	411792	354868	1326	0.32%	6.38
			2015	N&S	174	401200	345445	1215	0.30%	6.98
			2016	N&S	330	720492	635970	2085	0.29%	6.32
NJ-18	00018C	42.5	2010	N&S	195	484505	439526	3124	0.64%	16.02
			2011	N&S	361	909914	822782	6492	0.71%	17.98
			2012	N&S	327	879426	741169	8072	0.92%	24.69
			2013	N&S	362	989287	818671	10260	1.04%	28.34
			2014	N&S	226	473086	407060	4515	0.95%	19.98
			2015	N	31	6845	6337	26	0.38%	0.84
NJ-18	00018D	44.6	2010	N&S	215	162872	153262	921	0.57%	4.28
			2011	N&S	237	223598	215359	888	0.40%	3.75
			2012	N&S	89	19936	18157	207	1.04%	2.33
			2013	N&S	83	110537	74518	2945	2.66%	35.48
			2014	N&S	204	255526	198130	6717	2.63%	32.93
			2015	N&S	219	250634	200255	6430	2.57%	29.36
			2016	N&S	90	104398	89846	1506	1.44%	16.73
NJ-208	000208	8.5	2012	N	27	15902	14617	90	0.57%	3.33
			2013	S	43	27341	22589	230	0.84%	5.35
			2014	S	202	145027	119553	1259	0.87%	6.23
			2015	S	123	100871	82318	742	0.74%	6.03
			2016	N&S	61	99244	86605	688	0.69%	11.28
NJ-23	000023	23.8	2010	N&S	225	123482	106894	848	0.69%	3.77

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
			2011	N&S	227	135796	116131	810	0.60%	3.57
			2012	N&S	232	115935	101665	1891	1.63%	8.15
			2013	N&S	238	119930	103625	1676	1.40%	7.04
			2014	N&S	177	108432	81762	999	0.92%	5.64
			2015	N	122	38747	23853	325	0.84%	2.66
NJ-23	ABC123	23.8	2016	N&S	29	20850	15792	120	0.58%	4.14
NJ-3	00003C	4.1	2015	E&W	61	293323	278248	2723	0.93%	44.64
			2016	E&W	212	1152720	1033312	27692	2.40%	130.62
NJ-3	00003R	6	2015	E&W	31	167119	161642	1235	0.74%	39.84
			2016	E&W	214	1549950	1407125	34284	2.21%	160.21
NJ-31	00031B	13	2010	N&S	171	251365	214110	834	0.33%	4.88
			2011	N&S	317	428277	363677	1265	0.30%	3.99
			2012	N&S	328	473604	408041	1241	0.26%	3.78
			2013	S	176	131488	117617	302	0.23%	1.72
			2015	N&S	36	46494	38888	119	0.26%	3.31
			2016	N&S	271	382233	320360	1040	0.27%	3.84
NJ-31	00031C	40.4	2010	N&S	302	284934	255779	1480	0.52%	4.90
			2011	N&S	338	306020	274584	2840	0.93%	8.40
			2012	N&S	259	224673	203827	1399	0.62%	5.40
			2013	N&S	61	49067	40160	209	0.43%	3.43
			2014	N&S	335	308649	254336	1399	0.45%	4.18
			2015	N&S	110	97068	79908	416	0.43%	3.78
			2016	N&S	61	51323	45934	165	0.32%	2.70
NJ-31	00031D	26.4	2010	N&S	107	83448	75240	326	0.39%	3.05
			2013	N&S	11	6963	6157	26	0.37%	2.36
			2014	N&S	99	91397	81085	423	0.46%	4.27
			2015	N&S	153	144328	127056	635	0.44%	4.15

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
			2016	N&S	365	345972	305518	1485	0.43%	4.07
NJ-33	000033	23.5	2010	E&W	242	210365	194760	855	0.41%	3.53
			2011	E&W	236	214701	191763	1145	0.53%	4.85
			2012	E&W	273	211235	193853	1006	0.48%	3.68
			2013	E	181	76853	67381	320	0.42%	1.77
			2014	E&W	258	174553	153886	685	0.39%	2.66
			2015	E&W	300	244351	216392	932	0.38%	3.11
			2016	E&W	149	131782	117927	497	0.38%	3.34
NJ-33	00033W	35.5	2011	E&W	288	526721	444069	2156	0.41%	7.49
			2012	E	27	18946	17757	120	0.63%	4.44
			2013	E&W	313	486498	426753	2132	0.44%	6.81
			2014	E&W	330	524504	457036	2350	0.45%	7.12
			2015	E&W	122	177193	150442	936	0.53%	7.67
			2016	W	292	261847	211723	1413	0.54%	4.84
NJ-34	000034	0.6	2010	N&S	286	148910	139860	615	0.41%	2.15
			2011	N&S	277	140639	134747	473	0.34%	1.71
			2012	N&S	349	192620	184537	692	0.36%	1.98
			2013	N&S	362	239397	218999	1116	0.47%	3.08
			2014	N&S	300	199068	179575	914	0.46%	3.05
			2015	N&S	153	90067	83340	522	0.58%	3.41
			2016	N&S	300	177415	163541	879	0.50%	2.93
NJ-34	00034B	5.7	2010	N&S	344	441526	406205	2067	0.47%	6.01
			2011	N	209	133611	128457	1165	0.87%	5.57
			2012	N	235	138212	130994	1487	1.08%	6.33
			2013	N&S	91	129562	109103	578	0.45%	6.35
			2013	N	206	152602	135254	702	0.46%	3.41
			2014	N&S	249	389582	331609	1897	0.49%	7.62

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
			2015	N	61	34324	29550	191	0.56%	3.13
			2016	N	271	175939	152893	960	0.55%	3.54
NJ-38	00038S	19.1	2010	E&W	159	126553	116317	762	0.60%	4.79
			2011	E&W	360	282066	258557	1804	0.64%	5.01
			2012	E&W	360	261854	244512	1588	0.61%	4.41
			2013	E&W	356	257756	240189	1518	0.59%	4.26
			2014	E&W	148	88356	82954	601	0.68%	4.06
			2015	E	61	17394	16867	76	0.44%	1.25
			2016	E&W	182	124115	114282	593	0.48%	3.26
			2016	W	90	26434	23804	199	0.75%	2.21
NJ-49	00049C	42.6	2010	E&W	53	12259	9490	101	0.82%	1.91
			2011	E&W	358	92588	70412	695	0.75%	1.94
			2012	E&W	211	1835	1377	5	0.27%	0.02
			2013	E&W	245	20820	15411	181	0.87%	0.74
			2013	E	59	4868	3588	41	0.84%	0.69
			2014	E&W	127	17920	12612	180	1.00%	1.42
			2015	E&W	222	46887	31123	313	0.67%	1.41
			2016	E&W	213	50342	34349	212	0.42%	1.00
NJ-49	00049M	37.6	2012	E&W	133	68391	60288	168	0.25%	1.26
			2013	E&W	362	187102	165405	524	0.28%	1.45
			2014	E&W	270	126246	111614	468	0.37%	1.73
			2015	E&W	335	173339	152549	589	0.34%	1.76
			2016	E	334	91460	76953	342	0.37%	1.02
NJ-55	000551	37	2010	N&S	110	329137	260267	1248	0.38%	11.35
			2011	N&S	302	903498	721132	3080	0.34%	10.20
			2012	N&S	356	1043038	836098	3236	0.31%	9.09
			2013	N&S	300	924902	717389	3416	0.37%	11.39

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
			2014	N&S	234	717522	543802	3140	0.44%	13.42
			2015	S	62	94441	76894	289	0.31%	4.66
			2016	S	310	513240	446632	1305	0.25%	4.21
NJ-55	000552	37	2010	N&S	355	1185754	1004913	5227	0.44%	14.72
			2011	N&S	301	979201	811159	4279	0.44%	14.22
			2012	N&S	350	1093877	930121	6697	0.61%	19.13
			2013	N&S	328	1027834	855295	5960	0.58%	18.17
			2014	N&S	171	639140	504940	3331	0.52%	19.48
			2015	N&S	122	411378	328061	2667	0.65%	21.86
			2016	N&S	233	869472	703303	7145	0.82%	30.67
NJ-57	00057A	3.5	2010	E&W	200	86084	78527	372	0.43%	1.86
			2011	E&W	117	41829	39236	130	0.31%	1.11
			2016	E	15	4033	3125	16	0.40%	1.07
NJ-57	00057B	20.6	2010	E&W	343	157223	140964	663	0.42%	1.93
			2011	E&W	358	158274	146081	807	0.51%	2.25
			2012	E&W	361	169133	154826	848	0.50%	2.35
			2013	E&W	293	115415	107823	451	0.39%	1.54
			2014	E	184	32416	29880	116	0.36%	0.63
			2015	E	67	17100	15269	61	0.36%	0.91
			2016	E&W	245	121122	112282	329	0.27%	1.34
NJ-68	000068	2.4	2010	N&S	199	63765	56569	730	1.14%	3.67
			2011	N&S	352	103871	97369	963	0.93%	2.74
			2012	N&S	279	80440	74366	574	0.71%	2.06
			2013	N&S	363	99118	86448	771	0.78%	2.12
			2014	N&S	325	98931	83319	818	0.83%	2.52
			2015	N&S	350	89524	79925	690	0.77%	1.97
			2016	N&S	164	38681	34863	322	0.83%	1.96

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
NJ-68	00068A	7	2010	N&S	356	147753	133563	1124	0.76%	3.16
			2011	N&S	263	104187	94243	718	0.69%	2.73
			2012	N&S	354	138639	126399	894	0.64%	2.53
			2013	N&S	364	137506	125774	878	0.64%	2.41
			2014	N&S	317	128770	115857	1096	0.85%	3.46
			2015	N&S	364	144784	130629	879	0.61%	2.41
			2016	N&S	243	103604	94711	756	0.73%	3.11
NJ-70	00070B	10.3	2010	E&W	227	164319	149666	669	0.41%	2.95
			2011	E&W	346	237436	217822	896	0.38%	2.59
			2012	E&W	360	252248	232965	788	0.31%	2.19
			2013	E&W	362	256743	236942	884	0.34%	2.44
			2014	E&W	355	246357	226961	800	0.32%	2.25
			2015	E&W	365	253292	235837	756	0.30%	2.07
			2016	E	271	91069	81809	320	0.35%	1.18
NJ-72	000072	2.1	2010	E&W	270	110481	91799	1196	1.08%	4.43
			2011	E&W	321	114981	100093	3448	3.00%	10.74
			2012	E&W	339	135644	114821	2648	1.95%	7.81
			2013	E	244	66560	57020	267	0.40%	1.09
			2014	E&W	146	47831	38588	217	0.45%	1.49
			2015	E	190	47622	42024	157	0.33%	0.83
			2016	E&W	212	119397	90576	601	0.50%	2.83
NJ-72	00072B	25	2010	E&W	279	116417	106214	594	0.51%	2.13
			2011	E&W	224	7167	6581	30	0.42%	0.13
			2012	E&W	277	122139	112452	602	0.49%	2.17
			2013	E&W	363	212960	188663	1092	0.51%	3.01
			2014	E&W	330	179189	156652	1040	0.58%	3.15
			2015	E&W	212	93323	78845	556	0.60%	2.62

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
			2016	E	263	60458	51400	431	0.71%	1.64
NJ-73	000073	11.9	2010	N&S	332	156896	138042	996	0.63%	3.00
			2011	N&S	358	152850	137316	1003	0.66%	2.80
			2012	N&S	349	148109	133392	769	0.52%	2.20
			2013	N&S	365	142355	132340	685	0.48%	1.88
			2014	N&S	358	130154	120144	737	0.57%	2.06
			2015	N	182	45620	41068	334	0.73%	1.84
			2016	N	153	36003	32865	288	0.80%	1.88
NJ-94	000094	33.8	2010	N	182	40562	31621	706	1.74%	3.88
			2011	N	234	56749	42214	1118	1.97%	4.78
			2012	N	54	11253	9174	112	1.00%	2.07
			2013	N	296	64352	56659	1075	1.67%	3.63
			2014	N	273	58755	54232	498	0.85%	1.82
			2015	N&S	104	43902	35016	248	0.56%	2.38
			2016	N&S	362	159074	131093	941	0.59%	2.60
US-1	000001	12.9	2010	N&S	212	464415	393651	2074	0.45%	9.78
			2011	N	183	230332	192721	958	0.42%	5.23
			2012	N	177	231870	206091	1019	0.44%	5.76
			2013	N	140	177818	160484	725	0.41%	5.18
			2014	N	178	172973	155200	1027	0.59%	5.77
			2015	N	121	156204	141699	685	0.44%	5.66
			2016	N	239	278795	248251	1421	0.51%	5.95
US-1	00001A	18	2010	N	30	22959	21006	131	0.57%	4.37
			2011	S	28	0	0	0	0.00%	0.00
			2013	N&S	162	21647	20088	35	0.16%	0.22
			2014	N&S	355	959176	857851	2244	0.23%	6.32
			2015	N&S	212	529322	483937	1197	0.23%	5.65

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
			2016	N&S	152	351898	326503	799	0.23%	5.26
US-1	00001M	1.7	2013	N&S	18	34938	29189	123	0.35%	6.83
			2014	N&S	298	746945	619123	4392	0.59%	14.74
			2015	N&S	218	521442	442656	3097	0.59%	14.21
			2016	N&S	51	117311	100958	613	0.52%	12.02
US-1&9	00001C	48.1	2010	S	21	68981	59892	889	1.29%	42.33
			2011	S	195	587212	518860	7877	1.34%	40.39
			2012	S	88	209630	190507	1743	0.83%	19.81
			2013	S	212	486073	444455	4913	1.01%	23.17
			2016	S	181	638357	572752	6127	0.96%	33.85
US-130	000130	3.4	2010	N&S	344	103541	101739	252	0.24%	0.73
			2011	N&S	249	58743	57215	144	0.25%	0.58
			2012	N&S	135	42661	39810	129	0.30%	0.96
			2013	N&S	176	55604	51491	311	0.56%	1.77
			2014	S	115	13184	12041	80	0.61%	0.70
			2015	S	30	4005	3498	78	1.95%	2.60
US-130	00130A	70.6	2013	N&S	319	535579	479978	2376	0.44%	7.45
			2014	N&S	327	541119	484043	2050	0.38%	6.27
			2015	N&S	362	544156	500809	1272	0.23%	3.51
			2016	N&S	364	555889	517767	1068	0.19%	2.93
US-130	00130B	57	2011	N&S	300	283896	251563	1292	0.46%	4.31
			2012	N&S	359	380347	334404	1611	0.42%	4.49
			2013	N&S	356	383723	345628	1418	0.37%	3.98
			2014	N&S	331	312729	284156	1001	0.32%	3.02
			2015	N&S	214	191800	178507	530	0.28%	2.48
			2016	N	243	107746	94565	407	0.38%	1.67
US-1T	0001TJ	3.9	2012	E&W	140	484991	414766	2604	0.54%	18.60

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
			2013	E&W	314	777592	675874	5235	0.67%	16.67
			2014	E&W	361	791638	692260	5061	0.64%	14.02
			2015	E	152	12158	10230	46	0.38%	0.30
			2016	E	354	26834	21846	57	0.21%	0.16
US-202	000202	3.5	2010	E&W	358	158169	116904	1333	0.84%	3.72
			2011	E&W	350	152613	125320	1006	0.66%	2.87
			2012	E&W	351	150121	133134	836	0.56%	2.38
			2013	E&W	299	137227	119488	814	0.59%	2.72
			2014	E&W	123	59242	51090	439	0.74%	3.57
			2015	N	31	496	434	13	2.62%	0.42
			2016	E&W	122	65498	57375	433	0.66%	3.55
			2016	N	61	14584	12244	120	0.82%	1.97
			2016	S	49	13628	12703	70	0.51%	1.43
US-202	00202B	19.2	2010	N&S	282	397748	383384	861	0.22%	3.05
			2011	N&S	219	291924	286082	855	0.29%	3.90
			2012	N&S	125	165557	162421	343	0.21%	2.74
			2013	N&S	302	450151	392458	2832	0.63%	9.38
			2014	N&S	274	398479	355481	2398	0.60%	8.75
			2015	N&S	129	162890	151627	678	0.42%	5.26
			2016	N&S	364	523786	492271	1922	0.37%	5.28
US-206	000206	22	2010	N&S	302	270676	251962	3978	1.47%	13.17
			2011	N&S	271	254378	233492	1780	0.70%	6.57
			2012	N&S	331	279325	259956	2380	0.85%	7.19
			2013	N&S	243	191678	176975	1919	1.00%	7.90
			2014	S	214	110643	98189	574	0.52%	2.68
			2015	S	215	104893	93629	503	0.48%	2.34
			2016	S	147	49013	43115	382	0.78%	2.60

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
US-206	00206A	9.8	2013	N&S	38	16215	14501	125	0.77%	3.29
			2014	N&S	235	122695	105450	1022	0.83%	4.35
			2015	N&S	123	64118	51125	407	0.63%	3.31
			2016	N&S	362	211392	169333	1383	0.65%	3.82
US-206	00206M	59.5	2010	N&S	343	185677	154382	789	0.42%	2.30
			2011	N&S	357	199087	161434	936	0.47%	2.62
			2012	N&S	230	121442	104578	508	0.42%	2.21
			2013	N&S	304	150403	132536	724	0.48%	2.38
			2014	N&S	234	113988	100562	422	0.37%	1.80
			2015	N	151	40680	36657	236	0.58%	1.56
			2016	N	360	76648	71141	300	0.39%	0.83
US-206	00206S	126.2	2013	N&S	58	9486	8483	62	0.65%	1.07
			2014	N&S	352	72460	62665	812	1.12%	2.31
			2015	N&S	212	43864	38402	354	0.81%	1.67
			2016	S	237	29844	27731	306	1.03%	1.29
US-22	000022	26.6	2010	E&W	355	242737	209625	1487	0.61%	4.19
			2011	E&W	323	207292	183829	876	0.42%	2.71
			2012	E	166	40335	36067	166	0.41%	1.00
			2013	E	162	45306	40290	228	0.50%	1.41
US-22	00022B	32.3	2010	E&W	299	247239	232847	744	0.30%	2.49
			2011	E&W	223	196951	184286	803	0.41%	3.60
			2012	E&W	182	116336	108000	478	0.41%	2.63
			2013	E&W	172	115171	107239	491	0.43%	2.85
			2014	E&W	178	114871	102275	631	0.55%	3.54
			2015	E&W	117	81885	75608	318	0.39%	2.72
			2016	E&W	331	285012	264510	916	0.32%	2.77
US-22	00022C	49.7	2010	E	356	207339	191434	1478	0.71%	4.15

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
			2011	E	337	201004	183548	1138	0.57%	3.38
			2012	E	324	187833	171996	1006	0.54%	3.10
			2013	E	362	230666	202673	3820	1.66%	10.55
			2014	E	142	57466	52082	642	1.12%	4.52
			2015	E	76	40683	35315	224	0.55%	2.95
			2016	E	88	49511	43304	900	1.82%	10.23
US-30	00030G	45.5	2013	E&W	41	15520	14680	365	2.35%	8.90
			2014	E&W	206	95973	91243	2684	2.80%	13.03
			2015	E&W	31	11841	11422	192	1.62%	6.19
			2016	E&W	122	100214	91760	2771	2.77%	22.71
US-30	00030M	33.5	2010	E&W	60	23352	20925	240	1.03%	4.00
			2011	E&W	264	113942	101477	1495	1.31%	5.66
			2012	E&W	241	95488	84673	1517	1.59%	6.29
			2013	E&W	302	117871	103890	4545	3.86%	15.05
			2014	E&W	343	129167	114320	4291	3.32%	12.51
			2015	E&W	115	40344	35788	906	2.25%	7.88
			2016	W	214	40426	36708	974	2.41%	4.55
US-322	000322	27.5	2010	E&W	230	92915	84993	574	0.62%	2.50
			2011	E&W	281	91465	84015	428	0.47%	1.52
			2012	E&W	195	50295	46246	360	0.72%	1.85
			2013	E&W	212	43302	40461	187	0.43%	0.88
			2014	E&W	89	12521	11919	115	0.92%	1.29
			2016	E&W	61	18867	17807	114	0.60%	1.87
US-322	00322H	27.5	2010	E&W	31	8440	7570	44	0.52%	1.42
			2011	E&W	136	44690	40178	375	0.84%	2.76
			2012	E&W	109	25956	24728	303	1.17%	2.78
			2013	E&W	148	43511	36698	328	0.75%	2.22

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
			2014	E&W	357	96919	82251	531	0.55%	1.49
			2015	W	152	18697	16962	76	0.41%	0.50
			2016	W	330	38242	35015	201	0.53%	0.61
US-40	000040	28.4	2010	E&W	308	281537	242636	964	0.34%	3.13
			2011	E&W	324	294755	251404	1010	0.34%	3.12
			2012	E&W	347	297291	255673	941	0.32%	2.71
			2013	E&W	362	307407	269678	969	0.32%	2.68
			2014	E&W	362	305900	275395	939	0.31%	2.59
			2015	E&W	365	312258	295230	890	0.29%	2.44
			2016	E&W	364	321877	305574	759	0.24%	2.09
US-40	00040A	3	2010	E&W	353	413418	401820	1666	0.40%	4.72
			2011	E&W	253	270165	259977	918	0.34%	3.63
			2012	E&W	210	247933	243512	1663	0.67%	7.92
			2013	E&W	71	80199	70963	216	0.27%	3.04
			2014	E&W	201	272508	241811	1603	0.59%	7.98
			2015	E&W	268	324164	284244	588	0.18%	2.19
			2016	E	103	59323	52642	113	0.19%	1.10
US-40	00040B	61.6	2013	E&W	19	9216	7891	247	2.68%	13.00
			2014	E&W	119	67245	57927	1665	2.48%	13.99
			2015	E	28	7659	6739	210	2.74%	7.50
			2016	E	143	41536	35637	1133	2.73%	7.92
US-46	000046	25.2	2010	E&W	353	179312	166074	567	0.32%	1.61
			2011	E&W	347	162945	154729	481	0.30%	1.39
			2012	E&W	171	75649	72620	219	0.29%	1.28
			2013	E&W	163	64800	62453	179	0.28%	1.10
			2014	E&W	209	101071	92447	434	0.43%	2.08
			2015	W	122	36835	33892	126	0.34%	1.03

Route	SiteID	Milepost*	Year	Bound	Collection period (days)	Trucks	Legal trucks	SHVs	SHV percentage **	Average. daily SHV count
US-46	00046A	8.9	2016	E&W	152	105509	85758	377	0.36%	2.48
US-9	00009A	111.8	2010	N&S	283	445726	391339	35089	7.87%	123.99
			2011	N&S	321	436868	396935	37808	8.65%	117.78
			2012	N&S	182	256885	234960	21237	8.27%	116.69
			2013	N&S	113	145285	136951	4304	2.96%	38.09
			2014	N&S	128	163672	154091	5022	3.07%	39.23
			2015	S	92	56515	51925	1914	3.39%	20.80
			2016	N&S	92	97090	91444	2976	3.07%	32.35
US-9	00009B	57.7	2010	N&S	303	67129	61649	605	0.90%	2.00
			2011	N&S	257	53073	49196	1756	3.31%	6.83
			2012	N&S	308	59248	55679	1958	3.30%	6.36
			2013	N&S	64	14422	13773	289	2.00%	4.52
			2014	N	177	19726	17986	561	2.84%	3.17
			2015	N&S	365	62502	57267	652	1.04%	1.79
			2016	N&S	332	71164	65944	874	1.23%	2.63

***** The milepost is obtained from http://www.state.nj.us/transportation/refdata/roadway/pdf/wim_sites.pdf

** The percentage of SHVs are calculated by dividing number of SHVs by number of trucks

Table A.2 US WIM Sites and Statistics

Site ID	State	Year	Collection period (days)	Trucks	Legal trucks	SHVs	SHV site percentage *	Average daily SHV count
035	Minnesota	2008	366	56347	52708	149	0.264%	0.41
158	Pennsylvania	2008	361	1500412	1316734	334	0.022%	0.93
ar1	Arkansas	2008	361	1681403	1510965	80	0.005%	0.22
az1	Arizona	2008	366	36962	28781	12	0.032%	0.03
az2	Arizona	2008	360	1438768	1287971	40	0.003%	0.11
co2	Colorado	2008	363	345945	313452	5	0.001%	0.01
de1	Delaware	2008	366	203442	158012	56	0.028%	0.15
il1	Illinois	2008	366	856883	733165	39	0.005%	0.11
in1	Indiana	2008	180	186256	164652	31	0.017%	0.17
ks1	Kansas	2008	366	480910	432864	45	0.009%	0.12
la1	Louisiana	2008	335	86943	74211	15	0.017%	0.04
md5	Maryland	2008	366	166152	147519	98	0.059%	0.27
me1	Maine	2008	366	184462	163274	3	0.002%	0.01
nm1	New Mexico	2008	245	117800	102677	1	0.001%	0.00
nm2	New Mexico	2008	240	610818	484065	3	0.000%	0.01
tn1	Tennessee	2008	341	1627677	1546531	96	0.006%	0.28
va1	Virginia	2008	366	260818	223417	138	0.053%	0.38
wi1	Wisconsin	2008	363	228278	206526	208	0.091%	0.57
Bowman_072	California	2006 & 2007	134	664082	653490	711	0.107%	5.31
WIM9916	Florida	2005	354	438563	383079	804	0.183%	2.27
LA710SB_059	California	2006 & 2007	365	4693633	4476504	2102	0.045%	5.76
WIM9919	Florida	2005	349	2113072	2083386	4019	0.190%	11.52
WIM9926	Florida	2005	265	2010644	1660969	3202	0.159%	12.08
WIM9927	Florida	2004	360	472453	429553	720	0.152%	2.00
WIM9936	Florida	2005	354	1669622	1325392	792	0.047%	2.24

Site ID	State	Year	Collection period (days)	Trucks	Legal trucks	SHVs	SHV site percentage *	Average daily SHV count
I-55RI	Mississippi	2006	349	204061	158920	136	0.067%	0.39
1200	Indiana	2006	359	1953605	1487080	37	0.002%	0.10
953200	Indiana	2006	357	525868	510776	893	0.170%	2.50
955200	Indiana	2006	345	215304	207153	82	0.038%	0.24
951100	Indiana	2006	358	4294450	4274079	3956	0.092%	11.05
953400	Indiana	2006	359	4383926	4274927	4845	0.111%	13.50
954400	Indiana	2006	337	7931187	7707792	2495	0.031%	7.40
US61PA	Mississippi	2006	319	13396	11969	3	0.022%	0.01
US49PA	Mississippi	2006	359	147292	120259	81	0.055%	0.23
I-55UI	Mississippi	2006	268	170135	142484	61	0.036%	0.23
I-10RI	Mississippi	2006	337	228306	224367	19	0.008%	0.06
LA710NB_060	California	2006 & 2007	333	4227218	3884386	4224	0.100%	12.68
8382	New York	2005	292	1563091	1248818	1098	0.070%	3.76
01990002	New York	2006	82	609771	489853	1948	0.319%	23.76
82800000	New York	2006	273	1746910	1477471	1095	0.063%	4.01
26800000	New York	2005	289	129177	99541	245	0.190%	0.85
96310000	New York	2006	254	262439	202248	810	0.309%	3.19
9121	New York	2005	329	1288528	1019636	3844	0.298%	11.68
05800002	New York	2006	353	1183560	890638	5832	0.493%	16.52
01990001	New York	2006	213	1850002	1463540	4646	0.251%	21.81
05800001	New York	2006	343	1438826	1076407	7483	0.520%	21.82

* The percentage of SHVs are calculated by dividing number of SHVs by number of trucks

A.2 Statistics of SHVs with Different Numbers of Axles

Table A.3 New Jersey Statistics

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
Co-539	CO0539	29.3	2010	36	16	271	8	0	0	0
			2013	27	32	150	2	0	0	0
			2014	118	154	2187	27	1	0	0
			2015	105	54	304	6	0	0	0
			2016	142	98	31	0	0	0	0
CO-540	CO0540	4.76	2010	114	54	74	2	0	0	0
			2011	159	88	46	3	0	0	0
			2012	83	72	39	5	0	0	0
			2013	96	83	98	0	0	0	0
			2014	61	46	79	6	0	0	0
			2015	101	50	56	6	0	0	0
			2016	85	39	82	3	1	0	0
CO-563	CO0563	8.75	2010	115	617	25	0	0	0	0
			2011	537	3412	49	7	0	0	0
			2012	375	2140	125	1	0	0	0
			2013	490	1629	50	1	0	0	0
			2014	415	1537	68	3	0	0	0
			2015	19	199	23	0	0	0	0
			2016	75	222	39	1	1	0	0
CO-821	CO0821	2.4	2012	0	1	0	0	0	0	0
			2013	58	52	7	0	0	0	0
			2014	86	81	2	0	0	0	0
			2015	88	35	2	0	0	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
			2016	48	62	8	0	0	0	0
I-195	000195	10.2	2010	25	82	400	0	0	0	0
			2011	1511	6907	651	20	0	0	0
			2012	1031	5028	882	11	0	0	0
			2013	773	3852	1188	16	0	0	0
			2014	1225	7381	709	24	0	0	0
			2015	1016	6473	1133	38	1	0	0
			2016	569	4627	871	32	2	0	0
I-195	00195B	4	2010	180	226	1233	78	0	0	0
			2011	220	275	1461	18	0	0	0
			2012	40	34	879	8	0	0	0
			2013	202	602	469	17	0	0	0
			2013	4	12	81	0	0	0	0
			2014	409	406	335	28	0	0	0
			2015	265	317	749	12	0	0	0
			2016	517	1009	724	100	4	0	0
I-280	000280	5.1	2012	16	156	72	1	0	0	0
			2013	420	1877	136	17	0	0	0
			2014	1300	5789	1215	66	0	0	0
			2015	170	820	141	15	0	0	0
			2016	36	100	71	7	0	0	0
I-287	000287	61.7	2010	218	590	2866	11	0	0	0
			2011	194	154	1715	28	0	0	0
			2012	223	137	1509	24	0	1	0
			2013	252	658	80	0	0	0	0
			2014	113	452	175	5	3	0	0
			2015	244	1097	216	20	17	0	0
			2016	283	1114	883	26	25	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
I-287	00287A	31.7	2010	835	1096	338	3	0	0	0
			2011	652	1246	509	3	0	1	0
			2012	231	625	290	5	0	0	0
			2013	149	412	203	3	0	0	0
			2014	133	285	41	2	0	0	0
I-287	00287C	5.5	2010	1933	4079	1072	104	0	0	0
			2011	2513	7224	1227	162	0	0	0
			2012	2855	9213	1266	165	0	0	0
			2013	2070	7200	2023	130	0	0	0
			2014	393	1010	261	77	0	0	0
			2015	359	950	393	41	0	0	0
			2016	730	3008	1215	161	0	0	0
I-295	000295	39.6	2010	870	657	4122	53	0	0	0
			2011	1122	2497	696	28	0	0	0
			2012	1330	2423	733	45	0	0	0
			2013	211	300	275	8	0	0	0
			2014	2638	5227	1379	120	0	0	0
			2015	2847	4891	1555	138	3	0	0
			2016	1208	2315	567	75	2	0	0
I-295	00295C	35.7	2010	195	114	3550	33	0	0	0
			2011	2325	4470	1455	76	0	0	0
			2012	650	1378	539	27	0	0	0
			2013	747	1046	526	20	0	0	0
			2014	769	1332	1379	73	0	0	0
			2015	667	1264	1329	63	0	0	0
			2015	250	357	456	38	0	0	0
			2016	579	795	1083	82	1	0	0
I-295	00295D	2.9	2010	2	130	29	0	0	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
			2011	42	636	28	1	0	0	0
			2012	27	1005	49	2	0	0	0
			2013	61	399	59	1	0	0	0
			2014	59	1035	96	2	0	0	0
			2015	29	426	96	2	2	0	0
			2015	3	125	20	1	1	0	0
			2016	13	46	14	0	1	0	0
I-295	00295L	15.2	2010	783	3781	1310	53	0	0	0
			2011	849	4935	2260	103	0	0	0
			2012	905	4357	1691	111	0	0	0
			2013	900	3338	1923	151	0	0	0
			2014	895	2111	1787	202	0	0	0
			2015	714	1538	2265	211	1	0	0
			2016	156	327	531	11	2	0	0
I-676	000676	2.6	2010	1664	14076	569	8	0	0	0
			2011	627	7451	683	13	0	0	0
			2012	510	5131	728	26	0	0	0
			2013	690	5667	842	11	0	0	0
			2014	630	7856	877	43	0	0	0
			2015	464	6098	436	19	0	0	0
			2016	343	3088	452	12	1	0	0
I-78	00078A	14.5	2010	1616	29108	1209	126	0	0	0
			2011	1772	38593	770	79	0	0	0
			2012	2138	48423	1043	151	2	0	0
			2013	1653	49972	1327	222	2	0	0
			2014	1190	46533	1959	516	15	0	0
			2015	1050	35648	1928	322	15	0	0
			2016	660	30171	1289	124	19	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
I-78	00078D	7.9	2010	1236	26413	1838	166	0	0	0
			2011	1093	29095	1537	187	0	0	0
			2012	679	21138	1590	179	3	0	0
			2013	844	25840	1077	155	2	0	0
			2014	241	5302	250	56	2	0	0
			2015	188	5923	945	10	5	0	0
			2016	351	6128	879	25	2	0	0
I-78	00078E	5.02	2012	34	1839	49	8	0	0	0
			2013	444	18740	809	98	0	0	0
			2014	311	13235	562	49	0	0	0
			2015	219	6617	383	7	0	0	0
I-78	00078F	7.9	2010	44	685	59	12	0	0	0
			2013	122	4428	264	48	0	0	0
			2014	427	13618	760	129	7	0	0
			2015	40	2143	137	11	1	0	0
I-78	00078W	7.9	2010	1041	30881	1154	229	0	0	0
			2011	1172	26315	1263	202	1	0	0
			2012	1011	35561	1722	246	4	0	0
			2013	610	26471	2715	248	1	0	0
			2014	475	20547	2367	247	2	0	0
			2015	318	7747	1091	130	0	0	0
			2016	296	11485	1245	84	1	0	0
I-80	00080A	8.3	2010	1422	23908	269	39	0	0	0
			2011	389	25863	522	60	2	0	0
			2012	67	5964	87	8	0	0	0
			2013	22	1744	31	0	0	0	0
			2016	29	1287	311	8	0	0	0
I-80	00080B	32.4	2010	878	15496	657	53	0	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
			2011	513	5568	343	22	0	0	0
			2012	421	4678	195	28	1	1	0
			2016	423	13213	613	33	5	0	0
I-80	00080C	38.1	2010	465	10138	711	10	0	0	0
			2011	1870	27393	2346	60	0	0	0
			2012	2390	20091	1459	46	3	0	0
			2013	1270	15446	1914	31	2	0	1
			2014	1101	13846	1651	17	9	0	0
			2015	168	2266	389	5	6	0	0
			2016	587	7521	873	84	2	0	0
I-80	00080D	66.2	2010	340	3730	125	3	0	0	0
			2011	35	1444	34	2	0	0	0
I-80	0080DL	66.4	2016	198	2471	175	41	3	0	0
I-80	0080DX	66.4	2011	1197	43841	311	22	0	0	0
			2012	1353	49866	310	26	0	0	0
			2013	1581	48523	376	15	0	0	0
			2014	352	11486	161	4	6	0	0
			2016	51	902	4	0	0	0	0
I-95	000095	1.2	2010	52	167	50	9	0	0	0
			2011	260	790	326	31	0	0	0
			2012	409	1282	309	24	0	0	0
			2013	59	89	104	6	0	0	0
			2014	16	25	420	7	0	0	0
			2015	175	215	99	12	0	0	0
			2016	167	398	127	15	0	0	0
I-95	00095B	6.3	2010	1161	2577	739	114	0	0	0
			2011	1208	2226	731	74	0	0	0
			2012	927	1501	1299	44	0	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
			2013	918	1349	761	83	0	0	0
			2014	471	891	341	35	0	0	0
			2015	727	876	750	39	0	0	0
			2016	511	806	587	68	1	0	0
NJ-124	000124	7.6	2010	309	6	9	0	0	0	0
			2011	262	21	10	0	0	0	0
			2012	190	17	7	0	0	0	0
			2013	9	6	6	0	0	0	0
			2014	15	5	1	0	0	0	0
			2015	0	0	0	0	0	0	0
NJ-138	000138	2.6	2010	144	93	140	1	0	0	0
			2011	259	119	91	0	0	0	0
			2012	179	121	155	1	0	0	0
			2013	85	110	26	0	0	0	0
			2014	150	192	65	2	0	0	0
			2015	8	23	3	0	0	0	0
			2016	211	397	76	0	0	0	0
NJ-15	000015	7.1	2010	352	1098	1079	11	0	0	0
			2011	628	2207	1170	3	0	0	0
			2012	554	1716	1748	8	0	0	0
			2013	64	179	136	0	0	0	0
			2015	88	189	1284	0	0	0	0
			2016	269	1111	2818	6	0	0	0
NJ-168	000168	1.3	2010	18	7	15	0	0	0	0
			2013	174	39	2	0	0	0	0
			2014	206	120	45	15	0	0	0
			2015	6	3	0	3	0	0	0
NJ-17	000017	22.9	2016	404	18670	263	25	1	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
NJ-17	00017B	22.9	2010	351	5870	72	11	0	0	0
			2011	594	11996	236	31	0	0	0
			2013	197	7053	180	4	0	0	0
			2014	155	3003	112	1	0	0	0
			2015	60	472	50	0	0	0	0
			2016	271	7929	113	16	0	0	0
NJ-173	000173	2.4	2010	24	10	2	0	0	0	0
			2011	185	53	10	0	0	0	0
			2012	162	110	3	3	0	0	0
			2013	146	49	6	4	0	0	0
			2014	29	9	1	0	0	0	0
			2016	71	39	13	1	0	0	0
NJ-18	000018	26.6	2010	1198	5261	640	151	0	0	0
			2011	494	3730	529	17	0	0	0
			2012	352	2083	412	26	0	0	0
			2013	126	756	106	8	0	0	0
			2014	435	1436	456	21	0	0	0
			2015	369	1849	677	78	0	0	0
			2016	1021	5076	1662	240	1	0	0
NJ-18	00018B	16	2010	112	49	2916	10	1	0	0
			2011	222	148	3696	33	0	0	0
			2012	147	142	3243	31	0	0	0
			2013	570	672	308	4	1	0	0
			2014	505	481	337	3	0	0	0
			2015	407	437	368	3	0	0	0
			2016	830	724	511	16	4	0	0
NJ-18	00018C	42.5	2010	1042	630	1405	47	0	0	0
			2011	3093	987	2343	68	1	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
			2012	5190	1565	1308	9	0	0	0
			2013	7021	1925	1301	13	0	0	0
			2014	3035	716	753	11	0	0	0
			2015	10	11	5	0	0	0	0
NJ-18	00018D	44.6	2010	370	137	414	0	0	0	0
			2011	273	92	519	4	0	0	0
			2012	148	21	38	0	0	0	0
			2013	2680	197	67	1	0	0	0
			2014	6208	328	181	0	0	0	0
			2015	5838	424	166	1	1	0	0
			2016	1289	126	88	3	0	0	0
NJ-208	000208	8.5	2012	9	46	35	0	0	0	0
			2013	45	166	18	1	0	0	0
			2014	130	854	271	3	1	0	0
			2015	75	493	171	2	1	0	0
			2016	111	470	105	1	1	0	0
NJ-23	000023	23.8	2010	83	138	625	2	0	0	0
			2011	102	110	588	10	0	0	0
			2012	93	56	1720	22	0	0	0
			2013	160	538	958	20	0	0	0
			2014	205	486	308	0	0	0	0
			2015	15	40	270	0	0	0	0
NJ-23	ABC123	23.8	2016	19	67	33	1	0	0	0
NJ-3	00003C	4.1	2015	67	843	1808	5	0	0	0
			2016	1302	25403	873	111	3	0	0
NJ-3	00003R	6	2015	49	556	624	6	0	0	0
			2016	1905	31136	1133	107	3	0	0
NJ-31	00031B	13	2010	156	247	428	3	0	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
			2011	259	498	502	6	0	0	0
			2012	245	491	494	11	0	0	0
			2013	47	93	157	5	0	0	0
			2015	35	57	27	0	0	0	0
			2016	339	422	273	6	0	0	0
NJ-31	00031C	40.4	2010	161	82	1236	1	0	0	0
			2011	259	132	2449	0	0	0	0
			2012	147	61	1189	2	0	0	0
			2013	64	78	66	1	0	0	0
			2014	489	404	486	20	0	0	0
			2015	147	142	121	6	0	0	0
			2016	22	41	98	3	1	0	0
NJ-31	00031D	26.4	2010	88	118	119	1	0	0	0
			2013	16	4	6	0	0	0	0
			2014	162	184	76	1	0	0	0
			2015	197	293	141	4	0	0	0
			2016	455	713	308	8	1	0	0
NJ-33	000033	23.5	2010	112	115	626	2	0	0	0
			2011	399	380	365	1	0	0	0
			2012	266	248	490	2	0	0	0
			2013	170	101	48	1	0	0	0
			2014	311	216	152	5	1	0	0
			2015	422	262	240	8	0	0	0
			2016	232	150	112	3	0	0	0
NJ-33	00033W	35.5	2011	913	797	417	29	0	0	0
			2012	4	2	113	1	0	0	0
			2013	890	711	504	27	0	0	0
			2014	739	994	564	53	0	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
			2015	237	339	353	7	0	0	0
			2016	480	669	256	7	1	0	0
NJ-34	000034	0.6	2010	177	33	405	0	0	0	0
			2011	127	33	313	0	0	0	0
			2012	173	64	454	1	0	0	0
			2013	494	247	375	0	0	0	0
			2014	472	208	233	1	0	0	0
			2015	180	124	218	0	0	0	0
			2016	402	234	240	3	0	0	0
NJ-34	00034B	5.7	2010	500	93	1471	3	0	0	0
			2011	28	15	1122	0	0	0	0
			2012	75	29	1382	1	0	0	0
			2013	290	127	160	1	0	0	0
			2013	323	91	288	0	0	0	0
			2014	898	421	576	2	0	0	0
			2015	96	33	62	0	0	0	0
			2016	321	251	386	1	1	0	0
NJ-38	00038S	19.1	2010	165	477	119	1	0	0	0
			2011	410	1155	238	1	0	0	0
			2012	342	990	255	1	0	0	0
			2013	324	817	374	3	0	0	0
			2014	116	353	131	1	0	0	0
			2015	19	8	49	0	0	0	0
			2016	104	317	172	0	0	0	0
			2016	51	130	18	0	0	0	0
NJ-49	00049C	42.6	2010	18	5	78	0	0	0	0
			2011	74	36	581	4	0	0	0
			2012	1	1	3	0	0	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
			2013	35	77	62	7	0	0	0
			2013	18	14	7	2	0	0	0
			2014	55	32	92	1	0	0	0
			2015	149	99	63	2	0	0	0
			2016	72	71	63	4	2	0	0
NJ-49	00049M	37.6	2012	104	29	34	1	0	0	0
			2013	285	140	92	7	0	0	0
			2014	222	99	139	8	0	0	0
			2015	123	189	264	13	0	0	0
			2016	111	159	68	4	0	0	0
NJ-55	000551	37	2010	362	277	600	9	0	0	0
			2011	786	1070	1195	29	0	0	0
			2012	1002	1180	1024	30	0	0	0
			2013	961	1661	770	24	0	0	0
			2014	946	1505	676	13	0	0	0
			2015	126	51	102	10	0	0	0
			2016	318	184	749	54	0	0	0
NJ-55	000552	37	2010	767	1144	3143	173	0	0	0
			2011	958	1415	1795	111	0	0	0
			2012	858	1328	4338	173	0	0	0
			2013	1137	1366	3344	113	0	0	0
			2014	1000	1190	1082	59	0	0	0
			2015	560	722	1322	61	2	0	0
			2016	1152	1302	4536	154	1	0	0
NJ-57	00057A	3.5	2010	66	21	281	4	0	0	0
			2011	32	13	85	0	0	0	0
			2016	9	3	4	0	0	0	0
NJ-57	00057B	20.6	2010	376	247	40	0	0	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
			2011	559	184	64	0	0	0	0
			2012	567	243	38	0	0	0	0
			2013	262	141	46	2	0	0	0
			2014	43	18	47	8	0	0	0
			2015	33	17	11	0	0	0	0
			2016	165	114	49	1	0	0	0
NJ-68	000068	2.4	2010	49	153	528	0	0	0	0
			2011	37	119	807	0	0	0	0
			2012	57	99	418	0	0	0	0
			2013	108	412	249	2	0	0	0
			2014	46	267	501	4	0	0	0
			2015	54	179	454	3	0	0	0
			2016	33	50	239	0	0	0	0
NJ-68	00068A	7	2010	105	592	425	2	0	0	0
			2011	76	341	301	0	0	0	0
			2012	106	414	374	0	0	0	0
			2013	86	328	464	0	0	0	0
			2014	128	546	419	3	0	0	0
			2015	103	372	404	0	0	0	0
			2016	69	275	410	2	0	0	0
NJ-70	00070B	10.3	2010	275	310	82	2	0	0	0
			2011	367	399	129	1	0	0	0
			2012	292	347	149	0	0	0	0
			2013	320	343	218	3	0	0	0
			2014	306	306	187	1	0	0	0
			2015	280	268	206	2	0	0	0
			2016	109	95	108	2	6	0	0
NJ-72	000072	2.1	2010	48	31	1105	12	0	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
			2011	25	9	3412	2	0	0	0
			2012	55	18	2574	1	0	0	0
			2013	116	66	85	0	0	0	0
			2014	81	43	93	0	0	0	0
			2015	69	39	48	1	0	0	0
			2016	124	116	360	1	0	0	0
NJ-72	00072B	25	2010	283	201	110	0	0	0	0
			2011	19	5	6	0	0	0	0
			2012	297	149	156	0	0	0	0
			2013	551	204	337	0	0	0	0
			2014	502	360	178	0	0	0	0
			2015	322	116	118	0	0	0	0
			2016	165	92	173	0	1	0	0
NJ-73	000073	11.9	2010	437	403	146	10	0	0	0
			2011	415	420	160	8	0	0	0
			2012	290	255	204	20	0	0	0
			2013	273	215	170	27	0	0	0
			2014	329	128	247	33	0	0	0
			2015	76	53	204	1	0	0	0
			2016	75	31	181	1	0	0	0
NJ-94	000094	33.8	2010	50	35	619	2	0	0	0
			2011	65	46	997	10	0	0	0
			2012	44	18	45	5	0	0	0
			2013	68	57	938	12	0	0	0
			2014	65	119	314	0	0	0	0
			2015	100	60	88	0	0	0	0
			2016	240	283	415	3	0	0	0
US-1	000001	12.9	2010	319	958	715	82	0	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
			2011	409	477	59	13	0	0	0
			2012	294	531	186	8	0	0	0
			2013	161	360	193	11	0	0	0
			2014	157	515	328	27	0	0	0
			2015	103	287	281	14	0	0	0
			2016	353	558	294	214	2	0	0
US-1	00001A	18	2010	38	42	31	20	0	0	0
			2011	0	0	0	0	0	0	0
			2013	9	8	16	2	0	0	0
			2014	406	815	906	117	0	0	0
			2015	228	424	508	36	1	0	0
			2016	132	276	371	19	1	0	0
US-1	00001M	1.7	2013	56	18	49	0	0	0	0
			2014	1127	895	2346	24	0	0	0
			2015	630	536	1917	14	0	0	0
			2016	118	79	413	3	0	0	0
US-1&9	00001C	48.1	2010	94	739	40	16	0	0	0
			2011	1117	6130	408	222	0	0	0
			2012	400	1244	39	60	0	0	0
			2013	1199	3471	156	87	0	0	0
			2016	1080	4518	254	273	2	0	0
US-130	000130	3.4	2010	30	5	216	1	0	0	0
			2011	22	10	112	0	0	0	0
			2012	55	14	60	0	0	0	0
			2013	240	30	41	0	0	0	0
			2014	55	21	4	0	0	0	0
			2015	69	8	1	0	0	0	0
US-130	00130A	70.6	2013	430	1658	281	7	0	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
			2014	377	1269	391	12	1	0	0
			2015	324	613	299	36	0	0	0
			2016	208	543	253	64	0	0	0
US-130	00130B	57	2011	448	602	236	6	0	0	0
			2012	477	839	284	11	0	0	0
			2013	398	582	433	5	0	0	0
			2014	305	354	332	10	0	0	0
			2015	215	152	156	7	0	0	0
			2016	155	104	137	11	0	0	0
US-1T	0001TJ	3.9	2012	469	2024	83	28	0	0	0
			2013	672	4376	144	42	1	0	0
			2014	652	4211	155	41	2	0	0
			2015	17	23	4	2	0	0	0
			2016	26	19	10	2	0	0	0
US-202	000202	3.5	2010	219	661	453	0	0	0	0
			2011	182	443	378	3	0	0	0
			2012	166	321	349	0	0	0	0
			2013	166	285	357	6	0	0	0
			2014	110	183	145	0	0	1	0
			2015	3	9	1	0	0	0	0
			2016	109	154	169	1	0	0	0
			2016	23	25	72	0	0	0	0
			2016	20	44	6	0	0	0	0
US-202	00202B	19.2	2010	138	169	549	5	0	0	0
			2011	85	19	747	4	0	0	0
			2012	41	26	271	5	0	0	0
			2013	769	1823	237	3	0	0	0
			2014	502	1653	235	8	0	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
			2015	146	417	112	3	0	0	0
			2016	363	1169	379	11	0	0	0
US-206	000206	22	2010	154	40	3743	41	0	0	0
			2011	138	37	1569	36	0	0	0
			2012	112	29	2192	47	0	0	0
			2013	210	139	1566	4	0	0	0
			2014	180	140	253	1	0	0	0
			2015	179	152	172	0	0	0	0
			2016	132	103	147	0	0	0	0
US-206	00206A	9.8	2013	21	28	73	3	0	0	0
			2014	157	212	641	12	0	0	0
			2015	160	153	92	2	0	0	0
			2016	549	466	361	7	0	0	0
US-206	00206M	59.5	2010	294	363	131	1	0	0	0
			2011	362	367	205	2	0	0	0
			2012	215	163	130	0	0	0	0
			2013	170	132	421	1	0	0	0
			2014	80	93	246	2	1	0	0
			2015	46	15	174	1	0	0	0
			2016	62	27	209	2	0	0	0
US-206	00206S	126.2	2013	23	25	14	0	0	0	0
			2014	234	552	26	0	0	0	0
			2015	138	190	22	3	1	0	0
			2016	62	218	26	0	0	0	0
US-22	000022	26.6	2010	553	879	54	1	0	0	0
			2011	479	311	83	3	0	0	0
			2012	64	57	44	1	0	0	0
			2013	80	52	96	0	0	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
US-22	00022B	32.3	2010	299	346	90	9	0	0	0
			2011	355	357	89	2	0	0	0
			2012	217	199	60	2	0	0	0
			2013	243	175	72	1	0	0	0
			2014	324	263	40	4	0	0	0
			2015	188	89	41	0	0	0	0
			2016	447	289	175	5	0	0	0
US-22	00022C	49.7	2010	391	965	117	5	0	0	0
			2011	321	627	186	4	0	0	0
			2012	273	627	104	2	0	0	0
			2013	737	2980	101	2	0	0	0
			2014	134	440	68	0	0	0	0
			2015	58	99	65	2	0	0	0
			2016	127	625	147	1	0	0	0
US-30	00030G	45.5	2013	42	312	11	0	0	0	0
			2014	185	2466	33	0	0	0	0
			2015	17	173	2	0	0	0	0
			2016	150	2577	44	0	0	0	0
US-30	00030M	33.5	2010	38	172	28	2	0	0	0
			2011	225	1039	222	9	0	0	0
			2012	165	1236	108	8	0	0	0
			2013	263	4064	212	6	0	0	0
			2014	303	3888	100	0	0	0	0
			2015	98	774	33	1	0	0	0
			2016	49	906	19	0	0	0	0
US-322	000322	27.5	2010	176	210	188	0	0	0	0
			2011	145	183	100	0	0	0	0
			2012	122	158	80	0	0	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
			2013	68	38	81	0	0	0	0
			2014	94	16	5	0	0	0	0
			2016	20	9	83	2	0	0	0
US-322	00322H	27.5	2010	17	9	18	0	0	0	0
			2011	93	139	143	0	0	0	0
			2012	4	5	294	0	0	0	0
			2013	118	171	38	1	0	0	0
			2014	237	212	81	1	0	0	0
			2015	28	30	17	1	0	0	0
			2016	54	104	41	1	1	0	0
US-40	000040	28.4	2010	462	352	138	12	0	0	0
			2011	506	373	122	9	0	0	0
			2012	518	305	107	11	0	0	0
			2013	573	255	131	10	0	0	0
			2014	470	203	255	10	1	0	0
			2015	324	94	425	47	0	0	0
			2016	290	57	356	56	0	0	0
US-40	00040A	3	2010	35	15	1614	2	0	0	0
			2011	67	55	795	1	0	0	0
			2012	18	24	1621	0	0	0	0
			2013	35	60	121	0	0	0	0
			2014	1042	178	379	4	0	0	0
			2015	130	269	185	4	0	0	0
			2016	17	27	57	12	0	0	0
US-40	00040B	61.6	2013	211	31	5	0	0	0	0
			2014	1394	237	34	0	0	0	0
			2015	163	46	1	0	0	0	0
			2016	912	203	18	0	0	0	0

Route	SiteID	Milepost*	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
US-46	000046	25.2	2010	286	95	186	0	0	0	0
			2011	162	31	288	0	0	0	0
			2012	86	18	115	0	0	0	0
			2013	93	29	57	0	0	0	0
			2014	302	55	77	0	0	0	0
			2015	16	27	81	2	0	0	0
US-46	00046A	8.9	2016	93	109	174	1	0	0	0
US-9	00009A	111.8	2010	899	34063	121	6	0	0	0
			2011	733	36956	111	8	0	0	0
			2012	415	20697	118	7	0	0	0
			2013	194	4067	41	2	0	0	0
			2014	195	4751	75	1	0	0	0
			2015	69	1769	74	2	0	0	0
			2016	120	2812	43	1	0	0	0
US-9	00009B	57.7	2010	64	392	149	0	0	0	0
			2011	125	1595	36	0	0	0	0
			2012	107	1663	187	1	0	0	0
			2013	22	230	37	0	0	0	0
			2014	52	486	20	3	0	0	0
			2015	104	428	120	0	0	0	0
			2016	81	702	90	1	0	0	0

Table A.4 US Statistics

Site	State	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
035	Minnesota	2008	0	0	91	58	0	0	0
158	Pennsylvania	2008	13	3	317	1	0	0	0
ar1	Arkansas	2008	0	11	54	14	0	1	0
az1	Arizona	2008	0	1	5	6	0	0	0
az2	Arizona	2008	4	4	10	21	1	0	0
co2	Colorado	2008	0	3	1	1	0	0	0
de1	Delaware	2008	1	6	46	3	0	0	0
il1	Illinois	2008	1	12	25	1	0	0	0
in1	Indiana	2008	1	4	9	17	0	0	0
ks1	Kansas	2008	0	4	41	0	0	0	0
la1	Louisiana	2008	0	2	13	0	0	0	0
md5	Maryland	2008	1	3	92	2	0	0	0
me1	Maine	2008	0	1	2	0	0	0	0
nm1	New Mexico	2008	0	0	1	0	0	0	0
nm2	New Mexico	2008	3	0	0	0	0	0	0
tn1	Tennessee	2008	1	2	93	0	0	0	0
va1	Virginia	2008	3	8	74	53	0	0	0
wi1	Wisconsin	2008	0	8	41	159	0	0	0
Bowman_072	California	2006 & 2007	5	698	8	0	0	0	0
WIM9916_2005_ASCII	Florida	2005	76	99	629	0	0	0	0
LA710SB_059	California	2006 & 2007	5	312	1139	646	0	0	0
WIM9919_2005_ASCII	Florida	2005	0	340	3643	35	1	0	0
WIM9926_2005_ASCII	Florida	2005	360	1083	1736	22	1	0	0
WIM9927_2004_ASCII	Florida	2004	0	413	294	13	0	0	0
WIM9936_2005_ASCII	Florida	2005	0	711	72	9	0	0	0
I-55RI	Mississippi	2006	0	129	2	5	0	0	0

Site	State	Year	2-axle	3-axle	4-axle	5-axle	6-axle	7-axle	8-axle
2006-01-01__2006-12-31-1200	Indiana	2006	0	0	1	36	0	0	0
2006-01-01__2006-12-31-953200	Indiana	2006	0	0	5	888	0	0	0
2006-01-01__2006-12-31955200	Indiana	2006	0	0	0	72	9	1	0
2006-01-01__2006-12-31-951100	Indiana	2006	0	0	1	3941	13	1	0
2006-01-01__2006-12-31-953400	Indiana	2006	0	0	11	4834	0	0	0
2006-01-01__2006-12-31-954400	Indiana	2006	0	0	15	2472	8	0	0
US61PA	Mississippi	2006	0	3	0	0	0	0	0
US49PA	Mississippi	2006	0	75	1	5	0	0	0
I-55UI	Mississippi	2006	0	59	1	1	0	0	0
I-10RI	Mississippi	2006	0	17	0	2	0	0	0
LA710NB_060	California	2006 & 2007	45	284	1065	2829	1	0	0
8382	New York	2005	0	950	132	15	1	0	0
01990002	New York	2006	0	755	792	400	1	0	0
82800000	New York	2006	0	812	274	9	0	0	0
26800000	New York	2005	0	73	170	2	0	0	0
96310000	New York	2006	0	760	48	2	0	0	0
9121	New York	2005	0	3534	288	16	6	0	0
05800002	New York	2006	0	5549	250	33	0	0	0
01990001	New York	2006	0	4144	215	279	8	0	0
05800001	New York	2006	0	6915	423	142	3	0	0

A.3 Statistics of Multiple Presence of SHVs

Table A.5 WIM Site 01990001 Results

Span (ft)	Side-by-Side	Staggered	Following	Other	Single	All
20	22	31	0	2	704	759
40	21	32	6	4	696	759
60	20	30	29	8	672	759
80	17	24	72	15	631	759
100	13	19	115	26	586	759
120	10	17	140	37	555	759
140	9	16	156	49	529	759
160	9	15	164	66	505	759
180	8	13	174	79	485	759
200	7	13	177	98	464	759

Table A.6 WIM Site 01990002 Results

Span (ft)	Side-by-Side	Staggered	Following	Other	Single	All
20	49	29	0	6	1141	1225
40	48	28	2	9	1138	1225
60	45	27	16	13	1124	1225
80	44	23	50	22	1086	1225
100	38	20	85	45	1037	1225
120	31	17	122	64	991	1225
140	25	14	151	88	947	1225
160	24	12	171	105	913	1225
180	19	8	195	129	874	1225
200	20	7	213	140	845	1225

Table A.7 WIM Site 05800001 Results

Span (ft)	Side-by-Side	Staggered	Following	Other	Single	All
20	12	12	1	1	748	774
40	13	11	2	3	745	774
60	13	10	6	4	741	774
80	10	8	29	7	720	774
100	9	8	56	8	693	774
120	9	8	73	11	673	774
140	9	7	86	17	655	774
160	10	6	93	22	643	774
180	10	6	108	26	624	774
200	10	3	121	35	605	774

Table A.8 WIM Site 05800002 Results

Span (ft)	Side-by-Side	Staggered	Following	Other	Single	All
20	5	4	0	0	355	364
40	4	4	3	0	353	364
60	4	4	4	0	352	364
80	4	4	8	2	346	364
100	4	3	18	3	336	364
120	4	3	23	6	328	364
140	4	3	27	9	321	364
160	4	3	31	12	314	364
180	4	3	40	12	305	364
200	4	3	48	12	297	364

Table A.9 WIM Site 26800000 Results

Span (ft)	Side-by-Side	Staggered	Following	Other	Single	All
20	0	2	0	0	193	195
40	0	2	0	0	193	195
60	0	2	0	0	193	195
80	0	2	0	0	193	195
100	0	2	0	0	193	195
120	0	2	0	0	193	195
140	0	2	1	0	192	195
160	0	2	1	0	192	195
180	0	2	2	0	191	195
200	0	2	2	0	191	195

Table A.10 WIM Site 82800000 Results

Span (ft)	Side-by-Side	Staggered	Following	Other	Single	All
20	9	4	0	2	298	313
40	8	4	0	3	298	313
60	8	4	0	3	298	313
80	7	3	3	4	296	313
100	7	3	7	4	292	313
120	6	2	9	5	291	313
140	5	3	8	6	291	313
160	5	3	10	6	289	313
180	5	2	11	6	289	313
200	5	2	12	6	288	313

Table A.11 WIM Site 8382 Results

Span (ft)	Side-by-Side	Staggered	Following	Other	Single	All
20	3	3	0	0	148	154
40	3	3	1	0	147	154
60	3	3	2	0	146	154
80	3	3	3	0	145	154
100	3	3	3	0	145	154
120	3	3	4	0	144	154
140	3	3	4	1	143	154
160	3	3	4	1	143	154
180	3	2	6	2	141	154
200	3	2	7	2	140	154

Table A.12 WIM Site 9121 Results

Span (ft)	Side-by-Side	Staggered	Following	Other	Single	All
20	9	13	0	0	323	345
40	9	12	0	1	323	345
60	9	12	0	1	323	345
80	9	11	7	3	315	345
100	8	11	9	4	313	345
120	8	10	10	4	313	345
140	6	10	9	6	314	345
160	6	9	16	5	309	345
180	5	9	21	6	304	345
200	5	9	23	8	300	345

Table A.13 WIM Site 96310000 Results

Span (ft)	Side-by-Side	Staggered	Following	Other	Single	All
20	0	0	0	0	59	59
40	0	0	0	0	59	59
60	0	0	0	0	59	59
80	0	0	0	0	59	59
100	0	0	0	0	59	59
120	0	0	1	0	58	59
140	0	0	1	0	58	59
160	0	0	1	0	58	59
180	0	0	1	0	58	59
200	0	0	1	0	58	59

Table A.14 WIM Site NBHCE (Year 2015, 69 Collection Days) Results

Span (ft)	Side-by-Side	Staggered	Following	Other	Single	All
20	0	4	0	0	28	32
40	0	4	0	0	28	32
60	0	4	0	0	28	32
80	0	4	0	0	28	32
100	0	4	0	0	28	32
120	0	3	0	1	28	32
140	0	3	1	1	27	32
160	0	3	1	1	27	32
180	0	3	1	1	27	32
200	0	3	1	1	27	32

Table A.15 WIM Site NBHCE (Year 2016, 207 Collection Days) Results

Span (ft)	Side-by-Side	Staggered	Following	Other	Single	All
20	4	12	0	0	139	155
40	4	12	0	0	139	155
60	4	11	1	1	138	155
80	3	11	5	2	134	155
100	3	11	5	2	134	155
120	3	11	7	2	132	155
140	3	10	8	3	131	155
160	3	10	8	3	131	155
180	3	10	9	3	130	155
200	3	10	12	3	127	155

Table A.16 WIM Site NBHCE (Year 2017, 332 Collection Days) Results

Span (ft)	Side-by-Side	Staggered	Following	Other	Single	All
20	4	14	0	0	138	156
40	5	15	0	0	136	156
60	5	15	1	0	135	156
80	5	15	2	0	134	156
100	5	15	3	1	132	156
120	5	15	4	1	131	156
140	5	14	6	2	129	156
160	5	14	7	2	128	156
180	5	13	8	3	127	156
200	5	13	9	3	126	156

APPENDIX B

BRIDGE DATABASE

The detailed data of the 131 steel-girder bridges from NCHRP Project 12-62 (Mertz, 2006) are documented in this appendix. The nominal values of resistance, dead-load effects and live-load effects per lane as well as both one-lane and two-lane distribution factors calculated for each of the bridges are also presented in this appendix.

Table B.1 - Data of Steel-Girder Bridges for Reliability Analysis (Mertz, 2006)

Bridge No.	Year Built	L (ft)	W (ft)	$W_{c\text{-}c}$ (ft)	W_{oh} (ft)	θ (degree)	N_b	S (ft)	d (in)	t_s (in)	e_g (in)	I (in^4)	A (in^2)	n
1	1940	20.0	23.0	22.0	1.08	0.0	5	5.00	18.0	6.50	11.5	801	14.7	7.0
2	1957	20.5	26.0	22.0	0.50	0.0	12	2.17	12.0	7.50	9.8	234	9.1	7.0
3	1953	27.0	29.5	24.0	2.75	0.0	5	5.75	21.0	7.25	14.1	1327	18.2	7.0
4	1926	28.0	22.0	19.0	0.25	0.0	9	2.58	15.0	6.50	11.3	516	11.2	7.0
5	1935	30.0	27.0	24.0	2.00	0.0	6	4.50	21.0	6.00	14.4	1327	18.2	7.0
6	1937	30.0	34.0	32.0	2.00	0.0	5	7.50	24.0	7.75	15.9	2364	24.7	7.0
7	1953	30.1	35.7	32.5	2.83	8.4	5	7.25	24.0	7.50	15.3	2987	29.4	7.0
8	1932	31.3	26.5	24.0	1.29	0.0	5	5.67	24.0	8.00	15.2	2096	22.4	7.0
9	1947	31.7	28.0	26.0	1.21	30.0	6	4.92	24.0	7.50	15.8	2364	24.7	7.0
10	1960	31.9	33.5	27.0	2.42	28.0	5	7.61	33.0	7.00	20.1	6699	38.3	7.0
11		34.5	47.7	45.0	1.33	29.0	10	5.00	23.7	7.00	15.4	1802	19.9	7.5
12	1928	34.8	22.5	20.0	0.50	0.0	5	5.25	26.0	8.75	17.4	3000	27.0	7.0
13	1928	36.0	22.5	20.0	0.50	0.0	5	5.25	26.0	8.75	17.4	3000	27.0	7.0
14	1927	37.2	22.5	20.0	0.33	0.0	5	5.25	26.0	8.75	16.4	2364	24.7	7.0
15	1956	38.8	31.0	28.0	1.83	0.0	5	6.58	30.0	7.50	23.7	4461	31.8	7.0
16	1953	38.9	35.7	32.5	2.83	8.4	5	7.25	30.0	7.50	18.8	5347	36.5	7.0
17	1941	39.0	28.5	24.0	2.50	0.0	5	5.75	27.0	6.75	16.8	3267	27.7	7.0
18	1955	39.1	53.5	36.0	2.25	2.1	8	6.83	30.0	7.00	18.4	4461	31.8	7.0
19	1938	40.0	28.3	26.3	0.00	30.0	13	2.29	18.0	10.00	11.3	890	16.2	7.0
20	1947	40.0	28.0	26.0	1.21	30.0	6	4.92	27.0	7.50	17.2	3267	27.7	7.0
21	1937	40.0	34.0	32.0	2.00	0.0	5	7.50	24.0	7.75	15.9	2364	24.7	7.0
22	1956	41.3	31.0	28.0	1.83	0.0	5	6.58	30.0	7.50	20.3	6699	38.3	7.0
23	1957	41.3	47.8	36.0	2.00	7.2	6	8.79	33.0	7.25	21.8	7721	42.3	7.0
24	1966	43.0	30.7	28.0	1.00	11.6	10	3.00	30.0	10.00	20.1	8826	55.9	7.0

Bridge No.	Year Built	L (ft)	W (ft)	$W_{c\text{-}c}$ (ft)	W_{oh} (ft)	θ (degree)	N_b	S (ft)	d (in)	t_s (in)	e_g (in)	I (in^4)	A (in^2)	n
25	1935	43.0	30.3	27.0	0.33	0.0	7	4.83	27.0	7.00	17.0	3267	30.0	7.0
26	1985	43.0	28.0	28.0	2.75	0.0	4	7.50	30.0	8.00	18.8	3989	29.1	7.0
27	1935	44.0	26.3	24.0	1.21	30.0	6	4.92	27.0	7.50	17.3	3604	30.0	7.0
28	1965	44.0	42.6	39.0	1.42	13.5	6	7.97	15.0	7.50	17.3	3604	30.0	7.0
29	1955	44.0	40.0	40.0	2.00	25.0	5	8.87	33.0	7.50	20.4	7442	41.5	7.0
30	1945	44.5	80.0	50.0	0.00	8.3	13	6.58	24.0	7.00	15.9	5110	47.0	7.0
31	1940	45.0	25.0	22.0	1.50	20.0	5	5.25	27.0	6.50	16.8	3604	30.1	7.0
32	1964	45.0	34.3	24.0	3.17	24.6	4	9.00	36.0	7.75	21.8	9012	44.2	7.0
33	1935	45.7	26.3	24.0	1.21	30.0	6	4.92	27.0	7.50	17.2	3267	27.7	7.0
34	1959	46.0	35.2	30.0	4.25	9.8	4	8.83	36.0	7.50	21.8	9739	47.1	7.0
35	1959	48.0	55.2	49.8	2.83	10.3	7	8.25	36.0	9.00	22.5	9739	47.1	7.0
36	1959	48.0	43.2	37.8	2.83	10.3	7	8.25	36.0	9.00	22.4	9012	44.2	7.0
37	1955	48.8	71.0	60.0	2.67	16.4	8	9.50	36.0	7.50	26.4	10967	52.9	7.0
38	1966	49.0	30.7	28.0	1.00	11.6	10	3.00	30.0	10.00	20.1	8826	55.9	7.0
39	1938	50.0	24.3	22.0	1.58	0.0	5	5.17	33.0	6.50	20.6	6699	38.3	7.0
40	1950	50.0	34.5	30.0	2.58	0.0	5	7.00	33.0	6.00	19.6	6699	38.3	7.0
41	1955	50.0	33.5	28.0	3.38	30.0	5	7.50	45.0	6.50	21.5	12103	57.1	7.0
42	1950	50.0	35.0	30.0	1.17	0.0	5	7.92	33.0	7.50	22.6	8641	42.8	7.0
43	1940	51.0	33.2	30.0	0.33	0.0	7	5.25	30.0	6.50	18.2	4461	31.3	7.0
44	1957	51.3	33.7	28.0	3.83	0.0	5	6.50	39.0	6.50	20.3	5357	36.3	7.0
45	1957	51.3	57.7	52.0	2.83	0.0	9	6.50	39.0	7.00	20.3	5367	36.3	7.0
46		51.7	47.7	45.0	1.33	33.0	9	5.80	35.8	7.50	21.4	8903	43.7	7.5
47	---	51.9	70.0	50.0	0.67	6.4	12	5.55	36.0	7.50	21.8	10470	50.0	7.0
48	1968	52.0	72.0	68.5	1.25	20.1	9	8.56	36.0	8.00	21.9	9012	44.2	7.0
49		52.5	44.5	40.0	1.25	25.0	8	6.00	29.7	8.00	20.8	4931	35.0	7.5
50	1958	53.0	35.0	30.0	2.25	30.0	4	9.33	33.0	7.00	20.1	6699	38.3	7.0
51	1969	53.0	34.8	32.0	0.90	30.0	4	11.00	54.0	7.50	35.2	39977	58.0	7.0

Bridge No.	Year Built	L (ft)	W (ft)	$W_{c\text{-}c}$ (ft)	W_{oh} (ft)	θ (degree)	N_b	S (ft)	d (in)	t_s (in)	e_g (in)	I (in^4)	A (in^2)	n
52	1964	53.5	34.3	24.0	3.17	24.6	4	9.00	36.0	7.75	21.8	9012	44.2	7.0
53	1985	55.0	44.0	36.0	1.89	12.0	6	7.87	33.0	8.25	20.6	6699	33.3	7.0
54	1955	55.0	40.0	40.0	2.00	25.0	5	8.87	33.0	7.50	20.4	7442	41.5	7.0
55	1958	55.0	37.9	28.0	3.96	15.5	4	10.00	43.8	7.13	21.5	14988	67.7	7.0
56	1963	56.0	44.0	44.0	1.79	30.0	6	7.87	36.0	7.75	21.7	7796	39.7	7.0
57	1965	56.0	58.0	50.0	3.50	0.0	7	8.33	36.0	8.50	22.3	9739	47.1	7.0
58	1920	56.3	33.3	30.0	0.17	0.0	7	5.33	30.0	7.25	18.8	5753	38.8	7.0
59	1960	58.6	33.5	27.0	2.42	17.0	5	7.61	33.0	7.00	23.9	10949	56.5	7.0
60	1956	59.8	31.0	28.0	1.83	0.0	5	6.58	38.0	7.50	21.8	10470	50.0	7.0
61	1935	60.0	25.0	22.0	2.00	0.0	5	5.00	36.0	7.00	21.4	9012	44.2	7.0
62	1958	60.0	35.9	26.0	5.10	2.2	4	9.50	43.0	7.13	21.7	17234	76.6	7.0
63	1936	61.0	29.0	24.0	1.21	0.0	6	4.92	33.0	7.50	20.4	7442	41.5	7.0
64	1972	62.6	63.5	55.8	1.53	2.5	8	8.83	36.0	8.75	22.3	14988	57.7	7.0
65	1964	63.0	44.5	39.7	2.00	8.3	6	7.95	36.0	8.75	22.4	16092	72.0	7.0
66	——	64.0	30.0	26.5	1.58	2.5	4	8.83	36.0	8.75	22.3	14988	67.7	7.0
67	1969	64.0	34.8	32.0	0.30	30.0	4	11.00	54.0	7.50	35.2	39977	58.0	7.0
68	1950	65.0	34.5	30.0	2.58	0.0	5	7.00	36.0	6.00	20.9	9012	44.2	7.0
69	1953	65.5	29.5	24.0	2.75	0.0	5	5.75	21.0	7.25	20.2	6699	38.3	7.0
70	1972	65.6	59.5	55.8	1.53	2.5	8	8.83	36.0	8.75	22.5	12103	57.1	7.0
71	1965	66.3	58.0	50.0	3.50	0.0	7	8.33	36.0	8.50	22.3	9739	47.1	7.0
72	1961	67.0	34.0	30.0	3.75	20.0	4	8.83	35.0	7.00	21.7	11282	53.5	7.0
73	1951	67.0	34.0	30.0	3.75	20.0	4	8.83	35.0	7.00	21.6	11282	53.5	7.0
74	1958	67.0	35.0	30.0	2.25	30.0	4	9.33	33.0	7.00	20.1	6699	38.3	7.0
75	1954	68.0	26.3	21.0	3.33	0.0	4	6.66	45.0	6.75	21.3	14988	67.7	7.0
76	1955	68.0	34.0	30.0	2.54	0.0	5	7.00	36.0	6.00	20.9	9012	44.2	7.0
77	1977	70.0	42.7	39.0	1.92	0.0	6	7.50	36.0	8.50	22.0	7796	39.7	7.0
78	1963	70.0	44.0	44.0	1.79	30.0	6	7.87	36.0	7.75	21.7	7796	39.7	7.0

Bridge No.	Year Built	L (ft)	W (ft)	$W_{c\text{-}c}$ (ft)	W_{oh} (ft)	θ (degree)	N_b	S (ft)	d (in)	t_s (in)	e_g (in)	I (in^4)	A (in^2)	n
79	1962	71.7	57.0	50.0	2.00	10.6	7	8.57	36.0	7.00	26.2	17002	74.6	7.0
80	1968	72.0	72.0	68.5	1.25	20.1	9	8.56	36.0	8.00	22.1	10470	50.0	7.0
81	1961	73.0	34.0	30.0	3.75	20.0	4	8.83	35.0	7.00	21.7	11282	53.5	7.0
82	1965	74.5	58.0	50.0	3.50	0.0	7	8.33	36.0	8.50	22.2	14988	67.7	7.0
83	1963	75.0	29.0	24.0	2.00	0.0	5	6.00	33.2	5.75	19.4	11048	58.3	7.0
84	1956	75.0	37.5	28.0	2.00	0.0	5	8.25	36.0	6.00	25.6	16856	74.0	7.0
85	1958	75.0	33.3	28.0	4.66	0.0	3	12.00	100.0	7.75	47.1	215965	53.5	7.0
86	1955	75.3	43.9	37.0	2.17	0.0	6	7.75	60.0	6.63	35.3	17101	41.5	7.0
87	1957	75.7	47.8	36.0	2.00	7.2	6	8.79	36.0	7.25	25.7	20252	87.0	7.0
88	1961	77.0	34.0	30.0	3.75	20.0	4	8.83	35.0	7.00	21.7	11282	53.5	7.0
89		78.5	35.9	31.2	2.33	14.0	6	6.25	37.5	7.50	25.1	15483	68.6	7.5
90	1959	79.0	35.2	30.0	4.25	9.8	4	8.83	36.0	7.50	21.8	9739	47.1	7.0
91	1959	80.0	55.2	49.8	2.83	10.3	7	8.25	36.0	9.00	22.5	16092	72.0	7.0
92	1959	80.0	43.2	37.8	2.83	10.3	7	8.25	36.0	9.00	22.4	14988	67.7	7.0
93	1965	80.0	58.0	50.0	3.50	0.0	7	8.33	36.0	8.50	22.5	12103	57.1	7.0
94	1955	80.3	71.0	60.0	2.67	16.4	8	9.50	36.0	7.50	26.7	21353	92.7	7.0
95	1949	80.7	27.5	24.0	3.50	0.0	5	5.25	42.1	6.00	21.0	9739	47.1	7.0
96	1950	83.6	63.0	40.0	2.83	13.0	8	8.23	48.0	7.50	34.3	33754	52.5	7.0
97	1955	84.6	53.5	36.0	2.25	2.1	8	6.83	36.0	7.00	23.4	14988	67.7	7.0
98	1961	86.0	34.0	30.0	3.75	20.0	4	8.83	35.0	7.00	21.7	11282	53.5	7.0
99	1970	87.3	31.3	28.0	1.21	0.0	5	7.00	36.0	8.50	24.5	17871	77.7	7.0
100	1962	89.0	35.2	30.0	3.00	0.0	4	9.33	36.0	6.75	25.1	10629	42.8	7.0
101	1979	90.0	36.6	32.0	1.42	0.0	5	8.00	36.0	9.00	27.3	18554	80.5	7.0
102	1955	91.3	43.9	37.0	2.17	0.0	6	7.75	60.0	6.63	36.1	24195	52.8	7.0
103	1965	93.1	58.0	50.0	3.50	0.0	7	8.33	36.0	8.50	22.3	16092	73.0	7.0
104	1970	95.0	42.7	38.8	2.50	30.0	6	7.33	42.0	7.50	28.4	20700	57.4	7.0
105	1956	96.5	27.8	24.0	2.00	10.0	5	5.75	36.0	6.50	25.7	17780	78.1	7.0

Bridge No.	Year Built	L (ft)	W (ft)	$W_{c\text{-}c}$ (ft)	W_{oh} (ft)	θ (degree)	N_b	S (ft)	d (in)	t_s (in)	e_g (in)	I (in^4)	A (in^2)	n
106	1968	96.5	57.8	55.0	2.00	27.9	8	7.40	16.0	7.50	31.7	25933	69.8	7.0
107	1973	98.0	45.1	36.0	2.57	0.0	5	9.83	58.0	8.25	35.8	29122	53.5	7.0
108	1973	100.0	33.7	29.8	1.92	0.0	5	7.00	36.0	8.00	23.7	10460	49.0	7.0
109	1961	100.7	47.0	33.0	2.00	0.0	8	6.60	18.0	7.00	35.4	43005	81.3	7.0
110	1955	105.0	47.7	36.0	1.69	0.0	6	8.67	36.0	12.01	29.6	15587	69.1	7.0
111	1971	110.0	31.7	28.0	2.33	0.0	4	8.50	48.0	8.50	32.9	29835	69.2	7.0
112	1962	113.0	76.0	70.0	6.00	0.0	6	9.00	48.0	7.00	34.6	27429	61.2	7.0
113	1957	113.2	34.0	28.0	4.25	0.0	4	8.50	62.5	7.13	39.8	27833	61.5	7.0
114	1960	116.0	33.6	28.0	3.33	0.0	4	9.00	78.0	7.00	42.3	68862	82.5	7.0
115	1978	121.5	64.3	46.8	3.33	0.0	8	8.08	44.0	9.00	26.5	41824	109.3	7.0
116	1973	125.0	49.0	36.0	2.57	0.0	5	9.83	58.0	8.25	34.7	27508	51.5	7.0
117	1983	125.0	41.0	38.0	3.25	0.0	4	11.00	60.0	10.00	41.0	51463	32.6	7.0
118	1955	130.0	47.7	36.0	1.69	0.0	6	8.67	36.0	12.01	32.8	19181	86.6	7.0
119	1971	130.0	41.0	39.0	5.00	0.0	3	15.50	95.0	9.63	51.9	188585	130.0	7.0
120	1951	140.0	59.0	58.0	2.00	0.0	6	13.50	105.7	6.50	55.8	203546	109.3	7.0
121	1962	142.0	76.0	70.0	6.00	0.0	6	9.00	48.0	7.00	34.6	27429	61.2	7.0
122	1975	142.0	84.8	79.3	2.00	0.0	10	9.25	66.0	7.50	37.6	59869	72.9	7.0
123	2004	147.7	74.8	63.0	2.46	0.0	10	8.04	50.4	8.66	38.9	32816	80.3	7.0
124	1958	151.1	33.3	28.0	4.55	0.0	3	12.00	100.0	7.75	51.4	287125	155.0	7.0
125	1969	152.5	34.8	32.0	0.90	30.0	4	11.00	54.0	7.50	37.8	45716	64.5	7.0
126	1971	155.0	41.0	39.0	5.00	0.0	3	15.50	95.0	9.63	51.9	188585	130.0	7.0
127	1983	160.0	41.0	38.0	3.25	0.0	4	11.00	60.0	10.00	41.0	51463	32.6	7.0
128	1977	161.0	67.2	55.0	2.33	10.0	8	8.67	114.0	8.50	40.6	44936	76.9	7.0
129	1980	180.0	46.8	44.0	2.11	22.9	6	8.20	56.0	7.00	41.3	43570	73.5	7.0
130	1977	201.0	67.2	54.0	2.33	10.0	8	8.67	114.0	8.50	38.8	41776	71.5	7.0
131	1975	205.0	84.8	79.3	2.00	0.0	10	9.25	66.0	7.50	43.9	75951	89.4	7.0

L = span length

W = edge-to-edge width of bridge

$W_{c\text{-}c}$ = curb-to-curb width of bridge

W_{oh} = overhang width of bridge

θ = skew angle

N_b = number of girders

S = girder spacing

d = girder depth

t_s = slab thickness

e_g = center-of-gravity distance between girder and deck

I = girder moment of inertia

A = girder area

n = modular ratio between girder and deck

Table B.2 – Nominal Values of Resistance and Loads and Distribution Factors

Bridge No.	R (k-ft)	DC1 (k-ft)	DC2 (k-ft)	DW (k-ft)	LL_{SU4} (k-ft)	LL_{SU5} (k-ft)	LL_{SU6} (k-ft)	LL_{SU7} (k-ft)	DF_1	DF_2
1	564	5	39	3	160	168	176	176	0.51	0.60
2	321	3	24	2	165	174	183	183	0.31	0.34
3	867	10	91	7	233	256	278	286	0.51	0.63
4	410	6	36	3	247	268	292	302	0.31	0.36
5	788	12	68	7	274	293	321	335	0.43	0.52
6	1322	17	153	11	274	293	321	335	0.58	0.75
7	1484	19	136	11	275	294	322	336	0.57	0.73
8	998	17	131	9	290	309	339	355	0.49	0.61
9	1260	18	105	8	296	314	345	362	0.44	0.55
10	2425	26	145	13	299	317	349	366	0.58	0.75
11	976	17	119	10	334	352	385	408	0.44	0.55
12	1383	24	162	11	337	356	389	412	0.45	0.56
13	1381	26	174	11	354	375	411	433	0.45	0.56
14	1122	28	202	12	370	393	431	455	0.44	0.56
15	2680	33	201	16	391	417	458	486	0.50	0.65
16	2178	38	225	18	393	419	461	489	0.53	0.69
17	1464	29	161	14	395	421	463	491	0.46	0.59
18	1820	34	201	17	396	422	464	492	0.51	0.67
19	557	22	119	7	408	436	480	510	0.27	0.32
20	1491	31	164	13	408	436	480	510	0.42	0.53
21	1308	30	273	20	408	436	480	510	0.54	0.71
22	2680	40	207	18	425	455	502	534	0.49	0.64
23	3034	48	287	24	425	455	502	534	0.59	0.79
24	3627	67	144	9	448	482	532	568	0.31	0.37
25	1387	40	177	15	448	482	532	568	0.41	0.51
26	1872	40	324	23	448	482	532	568	0.53	0.70

Bridge No.	R (k-ft)	DC1 (k-ft)	DC2 (k-ft)	DW (k-ft)	LL_{SU4} (k-ft)	LL_{SU5} (k-ft)	LL_{SU6} (k-ft)	LL_{SU7} (k-ft)	DF_1	DF_2
27	1465	40	195	16	462	497	549	587	0.41	0.52
28	3295	8	101	22	462	497	549	587	0.55	0.73
29	2682	54	345	28	462	497	549	587	0.59	0.79
30	2420	59	232	21	469	505	558	597	0.48	0.63
31	1555	41	184	18	475	513	567	607	0.42	0.54
32	3247	62	384	30	475	513	567	607	0.59	0.79
33	1337	41	214	17	485	524	579	621	0.40	0.52
34	3154	67	374	31	489	528	584	626	0.58	0.78
35	3276	76	473	31	516	559	619	665	0.55	0.73
36	3057	73	478	31	516	559	619	665	0.55	0.73
37	4709	84	447	37	526	571	632	679	0.59	0.81
38	3576	87	187	12	529	574	636	684	0.30	0.37
39	2375	62	218	21	543	590	653	704	0.41	0.52
40	2260	62	271	29	543	590	653	704	0.49	0.65
41	2846	105	353	33	543	590	653	704	0.51	0.68
42	3270	67	371	32	543	590	653	704	0.53	0.71
43	1692	55	236	23	556	605	671	723	0.41	0.53
44	1754	80	360	30	559	609	675	728	0.46	0.61
45	1761	81	392	30	559	609	675	728	0.46	0.61
46	2750	77	304	26	565	616	682	736	0.43	0.56
47	3512	87	290	25	568	619	686	740	0.42	0.55
48	3208	83	505	38	570	621	688	742	0.55	0.74
49	2308	68	368	27	576	628	697	752	0.44	0.58
50	2362	73	494	43	583	636	705	762	0.57	0.79
51	8384	83	488	48	583	636	705	762	0.64	0.89
52	3183	87	542	42	590	644	714	771	0.56	0.77
53	2427	65	507	39	610	667	740	800	0.51	0.69
54	2614	85	539	44	610	667	740	800	0.55	0.75
55	3559	148	616	52	610	667	740	800	0.59	0.82

Bridge No.	R (k-ft)	DC1 (k-ft)	DC2 (k-ft)	DW (k-ft)	LL_{SU4} (k-ft)	LL_{SU5} (k-ft)	LL_{SU6} (k-ft)	LL_{SU7} (k-ft)	DF_1	DF_2
56	2774	88	529	41	623	682	757	820	0.51	0.69
57	3455	102	607	43	623	682	757	820	0.53	0.72
58	1974	81	323	28	627	686	762	825	0.40	0.53
59	4480	119	452	42	658	722	802	870	0.49	0.67
60	3006	122	479	40	675	741	824	894	0.45	0.60
61	2451	103	326	30	677	744	827	897	0.38	0.50
62	4075	193	677	59	677	744	827	897	0.56	0.78
63	2481	101	357	30	691	759	844	917	0.38	0.49
64	4547	136	733	56	712	784	871	947	0.53	0.73
65	5255	184	711	52	718	790	879	955	0.50	0.68
66	4946	182	826	60	731	806	896	975	0.53	0.73
67	8217	121	711	69	731	806	896	975	0.61	0.86
68	2663	120	455	49	745	821	913	994	0.46	0.62
69	3802	50	251	35	752	830	923	1005	0.40	0.54
70	4189	167	895	63	752	830	923	1005	0.52	0.73
71	3402	143	849	60	762	840	935	1018	0.50	0.70
72	3538	153	705	65	772	852	948	1033	0.52	0.73
73	3515	153	705	65	772	852	948	1033	0.52	0.73
74	2308	117	789	68	772	852	948	1033	0.54	0.76
75	3203	218	576	54	785	868	966	1052	0.44	0.59
76	2655	131	498	53	785	868	966	1052	0.45	0.61
77	2779	140	880	61	812	898	1000	1091	0.47	0.64
78	2721	137	827	64	812	898	1000	1091	0.48	0.66
79	6408	232	752	71	835	925	1030	1124	0.50	0.70
80	3562	175	950	73	839	929	1035	1130	0.50	0.70
81	3517	181	837	77	853	945	1052	1149	0.51	0.71
82	4838	243	1017	76	873	968	1078	1178	0.49	0.68
83	3532	195	469	56	880	976	1087	1188	0.40	0.54
84	6129	246	666	75	880	976	1087	1188	0.49	0.68

Bridge No.	R (k-ft)	DC1 (k-ft)	DC2 (k-ft)	DW (k-ft)	LL_{SU4} (k-ft)	LL_{SU5} (k-ft)	LL_{SU6} (k-ft)	LL_{SU7} (k-ft)	DF_1	DF_2
85	12808	123	919	99	880	976	1087	1188	0.61	0.89
86	3906	182	875	74	883	980	1091	1193	0.47	0.65
87	7204	299	885	82	889	986	1099	1201	0.50	0.71
88	3503	202	932	85	907	1007	1122	1227	0.50	0.71
89	3966	271	742	64	927	1030	1148	1256	0.41	0.55
90	2996	198	1103	91	934	1038	1156	1265	0.50	0.70
91	4780	300	1234	87	947	1053	1174	1285	0.48	0.67
92	4472	285	1243	87	947	1053	1174	1285	0.48	0.67
93	4114	247	1211	88	947	1053	1174	1285	0.48	0.67
94	8096	360	1115	99	950	1057	1178	1290	0.52	0.74
95	2277	211	562	59	956	1063	1185	1298	0.36	0.49
96	7107	166	825	86	996	1109	1236	1354	0.47	0.66
97	4691	300	853	81	1009	1124	1253	1373	0.42	0.58
98	3443	252	1162	107	1028	1146	1278	1401	0.49	0.69
99	6253	370	1139	88	1045	1166	1301	1426	0.42	0.59
100	3544	200	1189	117	1068	1192	1330	1459	0.50	0.72
101	7681	407	1458	105	1082	1208	1347	1478	0.45	0.64
102	5080	314	1202	108	1099	1227	1369	1503	0.44	0.63
103	5027	409	1586	120	1124	1256	1402	1539	0.46	0.66
104	5763	290	1132	105	1149	1285	1434	1575	0.43	0.60
105	6045	426	829	88	1170	1309	1461	1605	0.37	0.50
106	42934	1500	3965	49	1170	1309	1461	1605	0.43	0.60
107	6123	331	1994	152	1190	1331	1486	1633	0.50	0.73
108	3652	326	1479	115	1217	1362	1521	1672	0.41	0.57
109	95354	3233	6351	201	1227	1374	1534	1686	0.39	0.55
110	6657	516	3070	155	1284	1440	1608	1769	0.46	0.66
111	7797	494	2084	165	1352	1517	1695	1866	0.45	0.65
112	7042	431	1811	180	1392	1564	1747	1924	0.46	0.67
113	6400	607	2326	185	1395	1566	1750	1927	0.44	0.64

Bridge No.	R (k-ft)	DC1 (k-ft)	DC2 (k-ft)	DW (k-ft)	LL_{SU4} (k-ft)	LL_{SU5} (k-ft)	LL_{SU6} (k-ft)	LL_{SU7} (k-ft)	DF_1	DF_2
114	8879	716	2190	202	1433	1610	1799	1982	0.46	0.67
115	9262	919	2496	193	1507	1695	1894	2089	0.42	0.61
116	5598	523	3273	248	1554	1749	1955	2157	0.47	0.70
117	6778	188	2812	254	1554	1749	1955	2157	0.51	0.76
118	9865	883	4262	232	1622	1827	2042	2253	0.43	0.64
119	20544	1341	6198	424	1622	1827	2042	2253	0.62	0.97
120	17203	1228	4016	427	1757	1982	2216	2447	0.56	0.86
121	7037	681	2860	285	1784	2013	2250	2486	0.43	0.64
122	8957	828	3212	298	1784	2013	2250	2486	0.44	0.66
123	10878	1073	3735	282	1860	2100	2349	2595	0.40	0.59
124	23132	1910	4715	437	1907	2154	2409	2663	0.51	0.78
125	9548	732	3900	391	1925	2175	2433	2689	0.48	0.73
126	20502	1907	8811	603	1959	2214	2476	2738	0.59	0.94
127	6759	308	4607	417	2027	2292	2563	2835	0.47	0.73
128	4826	1948	7098	420	2040	2307	2581	2854	0.41	0.61
129	10924	1290	4128	417	2296	2601	2911	3222	0.39	0.58
130	4078	2745	10785	647	2580	2927	3275	3629	0.39	0.59
131	13026	2055	6530	615	2634	2989	3345	3706	0.40	0.62

R = resistance

DC1 = factory-made components

DC2 = cast-in-place components

DW = asphalt surface

LL_{SU4} = simple span moment per lane created by AASHTO SU4

LL_{SU5} = simple span moment per lane created by AASHTO SU5

LL_{SU6} = simple span moment per lane created by AASHTO SU6

LL_{SU7} = simple span moment per lane created by AASHTO SU7

DF_1 = one-lane distribution factor

DF_2 = two-lane distribution factor