MOUNTAIN-PLAINS CONSORTIUM

MPC 15-294 | T. Kasperick and K. Ksaibati

Calibration of the Mechanistic-Empirical Pavement Design Guide for Local Paved Roads in Wyoming

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December 2015

Acknowledgements

This report has been prepared with funds provided by the United States Department of Transportation to the Mountain Plains Consortium (MPC). The MPC member universities include North Dakota State University, Colorado State University, University of Wyoming, and Utah State University.

ABSTRACT

Since release of the MEPDG in 2004, many national and state agencies have been working toward implementation of the new pavement design guide through calibration and validation. In order to aide Wyoming's Department of Transportation in its push toward total implementation, this study developed a set of traffic distributions and calibration coefficients for use within the MEPDG on designs of local paved roads that experience heavy truck traffic associated with the energy industry. A sensitivity analysis was also performed during this study to determine the effect of varying layer thicknesses on the prediction capabilities of the MEPDG. Findings of this report can be implemented on local paved roads that experience heavy truck traffic associated with the oil and gas industry.

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1. INTRODUCTION

1.1 Background

Since its development and eventual release in 2004, the Mechanistic-Empirical Pavement Design Guide (MEPDG) has been considered the future of pavement design. This new methodology, which was the product of National Cooperative Highway Research Program (NCHRP) Project 1-37A, combines mechanistic and empirical approaches to pavement design analysis while providing a prediction for accumulated damages to a pavement structure over time. This approach varies from the AAHSTO Design Guide, in any of its editions, in that mechanistic models are used to determine the structural response of pavement materials to repeated loadings and climate. This response is then combined with empirical relationships to determine the predicted distresses and smoothness. The AASHTO Design Guide, however, is solely based on empirical relationships that were developed during the AASHO Road Test in the early 1960s and has been considered outdated for some time.

In order for the maximum benefits to be attained through use of the MEPDG, in its most current edition called DARWIN-ME, implementation plans need to be established within each state agency or department of transportation. These implementation plans lay out the framework for performing necessary steps toward complete implementation on all levels of roadway design. One of the steps toward implementation includes calibration of the prediction models used in the DARWIN-ME.

These models were developed for global or national use based on Long Term Pavement Performance (LTPP) sites throughout the United States. Due to the extreme variations in traffic, weather, and construction methods that are seen in different regions of the U.S., it is recommended that the global calibration coefficients that are incorporated into the prediction models be altered to meet local or regional conditions. This is done in an effort to reduce the bias and standard error between predicted distresses and smoothness from the DARWIN-ME and observed distresses and smoothness on existing roadways. If calibration efforts are successful, the pavement design generated with the use of the DARWIN-ME program can be more cost effective and site specific.

1.2 Problem Statement

The Wyoming Department of Transportation (WYDOT) has recently begun efforts to implement the DARWIN-ME for use on its interstate and highway systems. However, local paved roads have not yet been considered in Wyoming. These roads are very important because of the increase in traffic associated with the oil and gas industry that they are experiencing currently and likely will experience in the future. Traffic, mainly heavy trucks, is much different than that which can be considered in the AASHTO Design Guide. The axle load spectra incorporated into the DARWIN-ME should improve pavement design for the traffic loads resulting from this industry.

Oil- and gas-related traffic has wreaked havoc on similar local paved roads in areas with extreme industrial activity, such as North Dakota. In order to account for current and future increases in oil and gas activity, Wyoming is looking to use the DARWIN-ME for pavement design as it can account for the very heavy and unique traffic associated with drilling activities. However, since the DARWIN-ME is currently only calibrated on a national level using LTPP sites across the country, oil and gas traffic has not been explicitly considered. In order to ensure that the use of the DARWIN-ME will be sufficient for the oil and gas industry, local calibration incorporating industry traffic and local climate conditions needs to occur.

1.3 Objectives

This study aimed at developing traffic characteristic inputs and local calibration coefficients for use within the DARWIN-ME program when designing local paved roads that experience heavy truck traffic associated with the oil and gas industry. In order to do this, traffic characteristics that have been observed throughout the state of Wyoming will be analyzed in order to develop a set of data that is indicative of the type of loadings that an industry service road can expect to see.

Once these traffic characteristics are developed, calibrating the DARWIN-ME to produce distresses and smoothness values similar to those being seen on local paved roads in Wyoming is necessary. During this study, four counties in Wyoming that have seen and are expected to see heavy oil and gas impacts were considered. Converse, Goshen, Platte, and Laramie counties were the areas of interest and a map detailing where these are located can be seen in Figure 1.1.

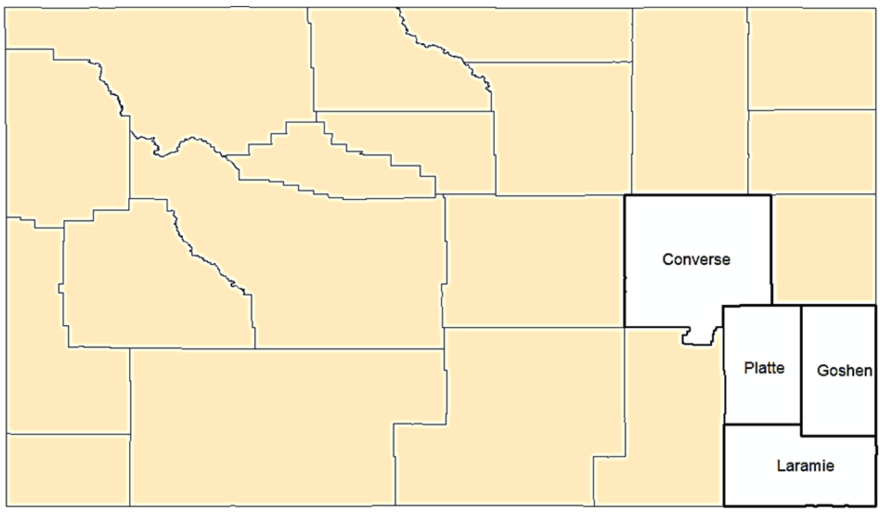

Figure 1.1 Location of Converse, Goshen, Platte, and Laramie Counties in Wyoming (Stroud, 2012)

This study considered local paved roads located within these four counties and intends to provide a set of local calibration coefficients and traffic characteristics that will aid in the design of new and rehabilitated roadways. The findings of this study will then be made available to local agencies in an effort to expedite the total implementation process in Wyoming and to assist in the mitigation of the oil and gas industry impact on local paved roads.

1.4 Report Organization

This report is broken up into six chapters and proceeds in a fashion as to describe the background and previous research conducted on the DARWIN-ME before detailing the methodologies and analysis performed. Section 1 of this report provides an overview of the background of the study and describes why local calibration of the DARWIN-ME is necessary on local paved roads to mitigate the impact of the oil and gas industry. The problem statement and objectives of the study are also presented.

Section 2 details the development of the DARWIN-ME while providing reasoning for why it is considered the future of pavement design. The general design process used in the DARWIN-ME as well as implementation and calibration efforts that have already taken place are presented.

Section 3 of this report describes the general methodologies that were used during this study. Methodologies used during the data collection of road conditions, traffic distributions, and input information are presented along with the methodologies used for calibration and performing the sensitivity analysis.

Section 4 provides where and how data used in this report were collected. The use of Pathway Services Inc., weigh-in-motion stations, traffic counters, and meetings with county road and bridge superintendents are detailed along with the data that were attained in each.

Section 5 presents the analysis that was performed using the data that were presented in Section 4. This analysis includes the development of traffic distributions, calibration procedures, and the sensitivity analysis performed during this report.

Section 6 details the findings of this report and provides recommendations for future research. Deliverables that were found during this study are also provided for use by local agencies.

2. LITERATURE REVIEW

2.1 Introduction

This section is intended to present the reader with a review of previous literature and studies that pertain to the Mechanistic-Empirical Pavement Design Guide (MEPDG). In this literature review, the background, design methodology, possible benefits, implementation, and calibration strategies are described to make the reader aware of issues related to this study.

2.2 MEPDG Development

The design of a pavement structure is a complicated task that incorporates everything from traffic loading to temperature extremes and moisture in a region. Traffic loading is an always changing characteristic of the road and ranges from heavy semi-trucks with multiple trailers and axles to motorcycles. Combine these various dynamic loadings with extreme heat or cold and dry to saturated materials and the analysis of how a pavement will perform becomes extremely difficult. To assist in this daunting task, the American Association of State Highway and Transportation Officials (AASHTO) and others have typically used empirical methods such as the 1993 AASHTO Design of Pavement Structures (Schwartz & R.L., 2007).

This methodology was developed in the mid to late 1950s during the AASHO road test. During this test, a seven-mile stretch of half concrete and half asphalt two-lane pavement was constructed in Ottawa, Illinois. From these seven miles, 836 test sections were developed to test wide ranges of surface pavement, base, and subbase thicknesses. The test sections were then exposed to heavy vehicles, and from the observed pavement responses to the loadings, relationships for pavement structural designs were developed. The AASHO road test provided the first step toward analyzing and evaluating the effect of moving vehicles on a pavement structure and was the basis from which empirical design guides were built (Weingroff, 2011).

Although the AASHO road test provided much needed analysis of the effect of dynamic loadings on a pavement structure, the test was performed over 50 years ago and much has changed over that time. Construction techniques and methods, knowledge of material properties, size and weights of vehicles, and expanded climatic data have all evolved since the original test and therefore are not taken into account when using design methodologies based off the AASHO road test. Because of this, a new method for designing pavement structures was called for by AAHSTO in 1996 and subsequently prompted National Cooperative Highway Research Program (NCHRP) to begin NCHRP 1-37A (Baus & Stires, 2010). This project sought a new method for designing pavements that incorporated mechanistic analysis to the empirical equations already in use. Because of this, the pavement design guide that was developed has become known as the mechanistic-empirical pavement design guide (MEPDG).

This new methodology, which was developed under NCHRP Project 1-37A (*Development of the 2002 AASHTO Guide for Design of New and Rehabilitated Pavement Structure: Phase II*), includes a mechanistic-empirical approach to pavement design that incorporates both empirical equations as well as mechanistic models. The previously used empirical approach is based off of observed performance and does not consider theoretical behavior, whereas a mechanistic-empirical approach ties together theoretical behavior of pavement with observed performance (Burnham & Pirkl, 1997). Because limitations of both solely empirical methods and solely mechanistic methods are evident, combining the two allows for expected performance of the pavement to be realized.

The MEPDG, in its most current form known as DARWIN-ME, utilizes this mechanistic-empirical approach in computing incremental damage to a pavement structure over time (Baus & Stires, 2010). DARWIN-ME, which the MEPDG will be referred to as here on out, is based on software generated pavement responses that include stresses, strains, and deflections. These responses are computed using detailed inputs attained from data, including traffic loading, material properties, and environmental data (Baus & Stires, 2010). Figure 2.1 depicts the procedural methodology that the DARWIN-ME is based off of.

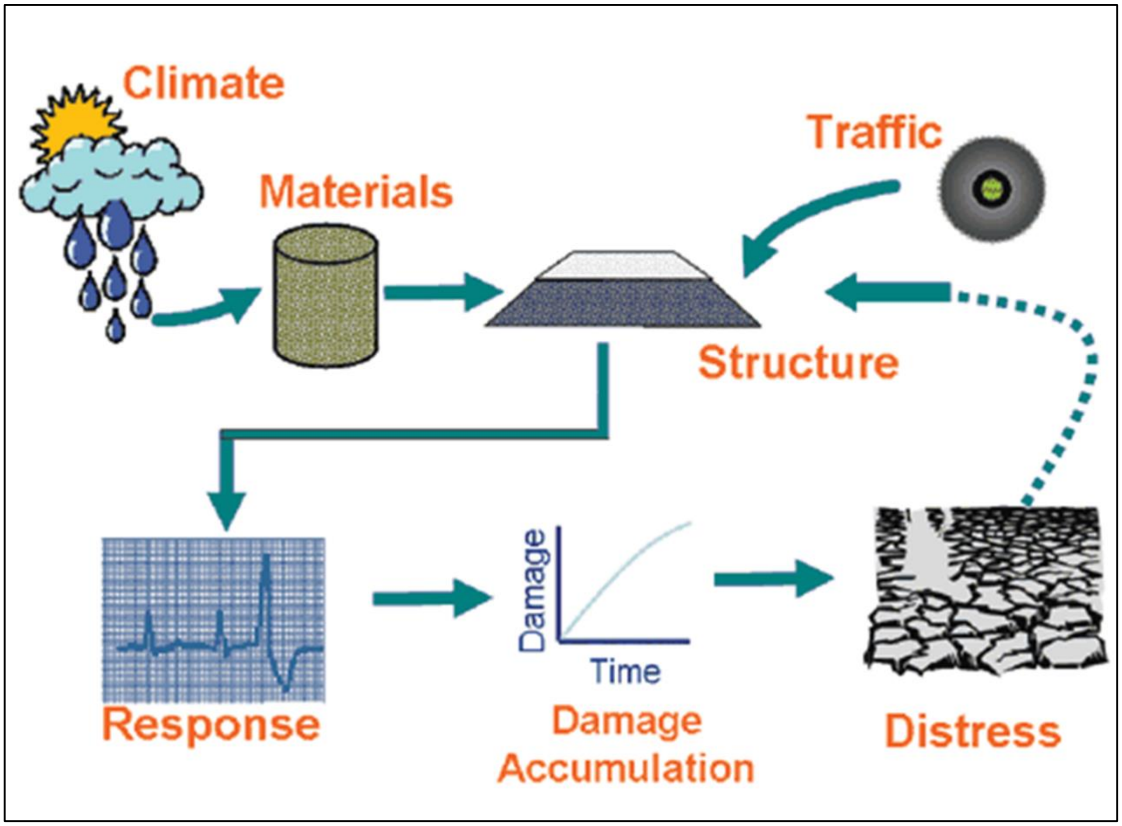

Figure 2.1 DARWIN-ME Design Flow Chart (FHWA, 2008)

2.3 Limitations of the AASHTO Design Guide

The pursuit of developing a new pavement design guide that incorporated a mechanistic approach was rooted in the realization of limitations that were being experienced with the available design procedures, most notably the AASHTO Pavement Design Guides. Although empirical design approaches are simple to apply and based on actual real-world data, their principle disadvantage lies in the validity of the empirical relationships and the ability for those relationships to account for new materials, construction procedures, and traffic characteristics (Christopher, Shwartz, & Boudreau, 2006). The deficiencies highlighted below limit the use of the AASHTO Design Guide as the nation's primary pavement design procedure.

- **Traffic:** Since the AASHO Road Test in the 1960s, heavy truck traffic levels have increased significantly. Interstate pavements were designed for 5–10 million equivalent single-axle loads (ESALs) in the 1960s. Today, the same classification of pavements are experiencing on the upwards of 50 – 200 million ESALs through their design life. This discrepancy makes it unrealistic that the AASHTO Design Guide can be used reliably to design roadways at this level of traffic given it was based off the 1960 values. Extrapolation from the data limits of the AASHO Road test are required when using the AASHTO Design Guide, which leads to either under-designed or over-designed roadways, and is very economically inefficient. To demonstrate this point, Figure 2.2 show the limits of the AASHO Road Test and how varied predictions of traffic levels can lead to vastly different pavement thicknesses (Christopher, Shwartz, & Boudreau, 2006).

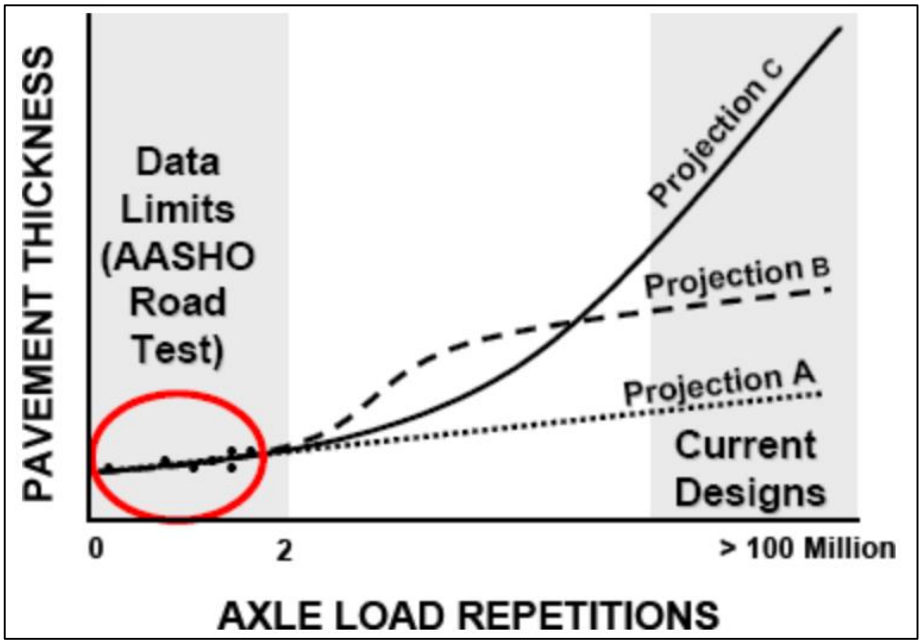

Figure 2.2 Extrapolation of Traffic Levels from AASHO Road Test (Christopher, Shwartz, & Boudreau, 2006)

Along with traffic loading limitations in the AASHTO Design Guide, characteristics of the actual vehicles have also changed since the 1960s. Truck suspensions, axle configurations, and tire types and pressures have all changed and the AAHSTO Design Guide is based off the older, lower characteristics (i.e., tire pressure of 80 psi versus 115 psi today) and is deficient for today's higher values (Christopher, Shwartz, & Boudreau, 2006).

- **Rehabilitation:** Because the AAHSTO road test was performed on newly constructed pavement that was built exclusively for the test, pavement rehabilitation was not considered. As the AASHTO Design Guide progressed, rehabilitation design recommendations were made, but they were completely empirical and limited under heavy truck traffic. Since rehabilitation accounts for a majority of toady's highway designs, it is vital to improve on the AASHTO Design Guide's rehabilitation capabilities (Christopher, Shwartz, & Boudreau, 2006).

- **Climatic Conditions:** The AASHO road test was conducted at one geographic location, Ottawa, Illinois, which limits the abilities of the AASHTO Design Guide to account for varying climatic differences in other regions of the country. Currently with the AASHTO Design Guide, climatic conditions can be considered in a very approximate matter, but direst consideration of site-specific climate effects, as done in the DARWIN-ME, leads to improved pavement performance and design reliability (Christopher, Shwartz, & Boudreau, 2006).

- **Subgrade Types:** Only one type of subgrade was used at the AASHTO road Test (AASHTO A-6/A-7-6) and because of this, many stronger materials that are used across the nation were not considered. Subgrade support has a major effect on the performance of pavement and can only be approximated in the AASHTO Design Guide (Christopher, Shwartz, & Boudreau, 2006).

- **Surfacing Materials:** Because of limited options in the 1960s, a single asphalt concrete and single Portland cement concrete mixture were used at the AASHTO road test. This differs from the varying grades of asphalt as well as high strength PCC being used today. However, the benefits of current material capabilities cannot be fully realized or accounted for using the AASHTO Design Guide (Christopher, Shwartz, & Boudreau, 2006).

- **Base Materials:** Only two unbound dense granular base and subbase materials were used for the flexible and rigid pavement sections of the AASHTO road test and only limited testing of stabilized bases was used for flexible pavement design. This least amount of materials does not account for the use of various other base or subbase materials present throughout the country or for stabilization methods that are typically used for heavy traffic loadings (Christopher, Shwartz, & Boudreau, 2006).

- **Construction and Drainage:** Pavement design, materials, and construction methods have all been outdated since the AASHTO road test. Subdrainage was not considered in the road test but has become common in today's roadways (Christopher, Shwartz, & Boudreau, 2006).

- **Design Life:** The AASHTO road test was conducted over a two-year span, which did not allow the long-term effects of climate and material aging to be considered. Given that roads are typically designed for 20 to 50 years, consideration of the cyclic effect on materials is necessary to improve the AASHTO Design Guides reliability at design life.

- **Performance Deficiencies:** The AASHTO Design Guide relates pavement serviceability to the thickness of the pavement surface layers. Because of this, distresses such as rutting, thermal cracking, and faulting in PCC pavement that are not related to pavement surface thickness cannot be remedied using the AASHTO Design Guide (Christopher, Shwartz, & Boudreau, 2006).

- **Reliability:** The 1986 AASHTO Guide included procedures for evaluating the reliability of the design, but these procedures have never been fully validated (Christopher, Shwartz, & Boudreau, 2006).

Because of the limitations experienced with the AASHTO Design Guide, an alternative method for design of pavement structures was necessary. The new pavement design method, the DARWIN-ME, provides users the ability to mitigate the limitations previously listed in this report.

2.4 Advantages of DARWIN-ME

The DARWIN-ME program offers numerous potential advantages over the AASHTO Pavement Design Guide because it is much more in-depth and allows designers to account for changes that have occurred since the AASHTO road test in the late 1950s. Aside from utilizing theoretical responses of the pavement and its layers, the DARWIN-ME can also be used as a prediction tool to allow designers to determine what type of performance can be expected from a given design. In response to the limitations presented about the AASHTO Design Guide in Section 2.3, the following advantages of the DARWIN-ME can be seen below:

- **Traffic:** As opposed to being based off of low-amounts of ESALs (5 to 10 million) as with the AASHTO Design Guide, the DARWIN-ME calculates the response of a pavement structure based on the axle load spectra. The axle load spectra differs from ESALs in that it considers traffic loading in terms of the number of load applications of various axle configurations (single, tandem, tridem, and quad) within a given weight classification range (FHWA Class 4-13). The load applications are used to calculate the axle load distribution factors. Traffic growth, seasonal traffic variations, and hourly traffic variations can all be considered in the DAWRIN-ME, as well as which allows the designer to forecast potential increases in traffic and its effect on the pavement design.

- **Rehabilitation:** Unlike the AASHTO Design Guide, DARWIN-ME provides for designs in new construction, rehabilitation, or reconstructed pavements for both asphalt and concrete (Timm, Turochy, & Davis, 2010). With these capabilities, designers using the DARWIN-ME can now determine effective and reliable designs for rehabilitation and reconstruction, a major feat considering a majority of projects fall in these categories rather than new construction.

- **Climate Conditions:** The DARWIN-ME has over 851 weather stations that are embedded into the program to allow the user to identify which climatic environment the project will be exposed to (Dzotepe G. A., 2010). The user can select a single weather station where the project is located, or extrapolate from various weather stations if the project is not located exactly where a weather station is. This is different from the AASHTO Design Guide where the empirical equations used in design were based off of a single weather station in Ottawa, Illinois, and where limited environmental inputs are considered.

- **Subgrade Types:** Because the DARWIN-ME is based on mechanistic equations as well as empirical, theoretical relationships between material properties and the loads applied to them can be used. This means that a multitude of different material types and classifications can be considered in design and the varying response to loadings can be analyzed. The DARWIN-ME allows for use of materials with both the AASHTO and Unified Soil Classification System (USCS) classifications and has nationally calibrated values for material properties that can be used when no laboratory testing can be performed.

- **Surfacing Materials:** Instead of being based off of a single asphalt type and concrete pavement mixture, the DARWIN-ME is able to consider current methods for grading asphalt binders, such as Superpave, as well as high strength concrete. This allows the designer to account for varying levels of strength and support rather than being based off of potentially weaker materials that were used in the AASHO road test.

- **Base Materials:** Much like the subgrade materials, more base and subbase materials are available for use within the DARWIN-ME. There are materials that have nationally calibrated properties embedded into the program that are ready for use, or project specific materials and properties can be input into the program for design considerations. The DARWIN-ME also allows designers to consider chemically stabilized base and subbases, capabilities that were previously unreliable or non-existent with the AASHTO Design Guide.

- **Construction and Drainage:** The DARWIN-ME program allows users to consider the effects of water on the aggregate base layers and subgrade soils. It is recommended by the DARWIN-ME to not allow water to accumulate within the pavement structure as it can have adverse effects on not only the structure below the pavement, but also can lead to stripping of the HMA layer. In order to account for water within the pavement structure, the DARWIN-ME allows users to address this issue via the materials and construction specifications and/or inclusion of subsurface drainage features in the design strategy (AASHTO, 2008). The DARWIN-ME is also based off of current construction procedures unlike the AASHTO Design Guide, which was based off of construction methods used in the late 1950s during the AASHO road test.

- **Design Life:** Because the design life being considered by the DARWIN-ME can be altered according to the user's preference or specifications, the cyclic effects of environment and repeated loadings on the pavement structure can be considered. This is a main aspect of the DARWIN-ME's ability to compute distresses over time and aid in the determination of when rehabilitation efforts are needed.

- **Performance:** The DARWIN-ME considers the effect of repeated loadings and environmental conditions over time. These effects include IRI, rutting, thermal cracking, and fatigue cracking in asphalt cement pavements; and IRI, faulting, and cracking for concrete pavements. The DARWIN-ME also considers strength of subgrade and base layers as well as repeated traffic loadings over the design life so these performance criteria can be better analyzed.

- **Reliability:** One area of concern regarding the AASHTO Design Guide was the reliability of the pavement designs that it produced. This concern is addressed with the DARWIN-ME. Reliability of the design is a performance criterion that indicates the chance of the pavement failing before its terminal service life. Reliability may need to be higher for projects with higher associated risks, whereas a low-volume roadway would need smaller reliability levels. The users can change the reliability level to fit their needs and thus provide a more feasible design.

The DARWIN-ME has addressed the limitations of the AASHTO Design guide by incorporating mechanistic models into the empirical analysis while providing a mechanistic-empirical approach to pavement design. It has also implemented the performance prediction of transverse cracking, faulting, and smoothness for jointed plain concrete pavements (JPCP), while adding more climatic inputs for use in design. DARWIN-ME better characterizes traffic loading inputs, has more sophisticated structural modeling capabilities, and has the ability to model real-world changes in material properties (Coree, 2005). This last improvement over the AASHTO Design Guide allows users to analyze how varying layer thicknesses, materials used, and quality of those materials affect the predicted performance of a designed roadway. Because of this, the DARWIN-ME provides its users an iterative approach to pavement design where characteristics can be altered in order to achieve the most economic and practical design for the project (Li & Cramer, 2012). The AASHTO Design Guide provides layer thicknesses given various inputs. The DARWIN-ME considers layer thicknesses along with material properties, environmental conditions, and traffic loadings to provide predicted distresses so decisions can be made regarding design suitability. By doing this, pavement designers are afforded the ability to determine if a design is practical for their project, or if altercations to the design need to take place in order to reach the performance criteria set out.

2.5 Cost Benefits of DARWIN-ME vs. AASHTO Design Guide

Due to the DARWIN-ME's improved design capabilities over the AASHTO Design Guide, considerable cost benefits can be expected from using the new mechanistic-empirical guide. These benefits are due to the more reliable and efficient designs that are produced for new, rehabilitated, or reconstructed pavements. Because DARWIN-ME provides an optimized pavement structure through enhanced characterization of traffic data and pavement material properties, cost savings typically come from reduced thicknesses of asphalt and concrete pavements as well as optimized joint spacing for concrete pavements (Nantung, 2010).

Aside from savings on initial construction or project designs, DARWIN-ME also provides users the capability to plan for maintenance activities on given roadways. Because the DARWIN-ME's output provides incremental damage over time to the roadway, the point where distresses in the pavement reach serviceability limits can also be predicted. This can allow for maintenance strategies to be determined and also for the reduction of over-designed pavements. That is, if an agency using the DARWIN-ME plans to apply maintenance strategies before the design life of the pavement is reached, distresses surpassing the serviceability limit before the design life is met can be mitigated through planned maintenance.

Cost benefits of using the DARWIN-ME have been quantified through comparing pavement designs for a same project using both the DARWIN-ME as well as the AASHTO Design Guide. This method for determining the economic benefits of the DARWIN-ME has been used by the Indiana Department of Transportation in its efforts toward implementation. In this analysis, cost savings were estimated by analyzing the difference in pavement thicknesses when considering designs made with the AASHTO Design Guide and those made with the DARWIN-ME, and calculating the expected savings using average contract unit prices for pavements in Indiana. Using this methodology, 23 pavement sections were analyzed with a total estimated contract savings of $9,729,000 (Nantung, 2010). The breakdown of these savings along with experienced savings on five of the 23 projects can be seen in Table 2.1.

Table 2.1 Indiana DOT Contract Savings

Road	Letting Date	AASHTO 1993 Thickness, Joint Spacing	MEPDG Thickness, Joint Spacing	Estimated Contract Savings	Actual Contract Savings
I-465 (mainline)	11/19/2008	16", 18' JPCP	14", 18' JPCP	$1,587,000	$1,000,000
I-465 ramps (10th St.)	11/19/2008	12.5", 18' JPCP	11", 18' JPCP		
I-80 (mainline)	11/19/2008	16", 18' JPCP	14", 18' JPCP	$881,000	$775,170
I-80 (ramp)	11/19/2008	12", 18' JPCP	10.5", 18' JPCP		
SR 14	3/8/2008	15" HMA	13.5" HMA	$333,000	$155,440
US 231	11/8/2008	15.5" HMA	13" HMA	$557,000	$673,796
SR 62	11/8/2008	16" HMA	13" HMA	$403,000	$420,548
US 24	3/11/2009	12.5" JPCP	10.5" JPCP	$720,000	
SR 32	2/11/2009	15.5" HMA	13.5" HMA	$283,000	
SR 66	2/11/2009	13.5" HMA	13" HMA	$90,000	
US 31	2/11/2009	15.5" HMA	14" HMA	$287,000	
SR 641	3/11/2009	15.5" HMA	13" HMA	$292,000	
SR 3	3/11/2009	14" HMA	13.5" HMA	$103,000	
SR 23	4/8/2009	18" HMA	13.5" HMA	$430,000	
I-465	9/10/2009	16", 15' JPCP	14", 18' JPCP	$432,000	
I-70 @ I-465 & ramps	9/10/2009	16", 15' JPCP	14", 18' JPCP	$665,000	
I-465	9/10/2009	16", 15' JPCP	14", 18' JPCP	$391,000	
AE @ I-465 & ramps	9/10/2009	18" HMA	14.5" HMA	$598,000	
I-465	1/13/2010	16", 15' JPCP	14", 18' JPCP	$494,000	
I-74 @ I-465 &ramps	1/13/2010	14.5", 15' JPCP	12.5", 18' JPCP	$234,000	
SR 37 @I-465	3/3/2010	13.5", 15' JPCP	12", 16' JPCP	$90,000	
SR Segment 3, Phase C	TBA	14" HMA	12.5" HMA	$484,000	
US 24 Phase 2	2/10/2010	15" HMA	13" HMA	$375,000	
Total Cost Savings				**$9,729,000**	

Savings such as those seen by the Indiana DOT can be realized throughout the nation with the use of the DARWIN-ME. This cost efficiency will and has allowed those using DARWIN-ME for the design of pavement structures to allocate more funding for additional projects, rather than potentially wasting money on less than optimal pavement designs.

2.6 DARWIN-ME General Overview

2.6.1 Design Process

Design and analysis of DARWIN-ME projects include steps that can be broken down into three distinct processes: inputs, analysis, and strategy selection (Saeed, 2004). These three steps in the design and analysis procedure provide the user a guideline for proper application of the DARWIN-ME. The overall design process includes providing the DARWIN-ME with inputs regarding the roadway materials and pavement structure, expected traffic loadings, and climate characteristics of the project location.

Project inputs are then used in developing a trial design strategy where the pavement response models are used to determine accumulated damage over time and predicted distresses. Upon completion of the initial trial design, the predicted smoothness and distresses are compared with the performance criteria that was specified for the project. This performance criteria consists of minimum reliability levels as well as distress and smoothness limits that, if surpassed, indicate that the trial design strategy was insufficient to meet the project's needs. Depending on if the trial design strategy meets the performance criteria laid out for the project, the strategy is then modified if the performance criteria is not met or accepted as a viable alternative if the performance criteria is met. Once a viable alternative has been selected, other analysis can be performed on the design to determine if it is feasible or not with respect to the unique project, such as life cycle cost analysis and constructability issues. A schematic detailing the DARWIN-ME design process can be seen in Figure 2.3.

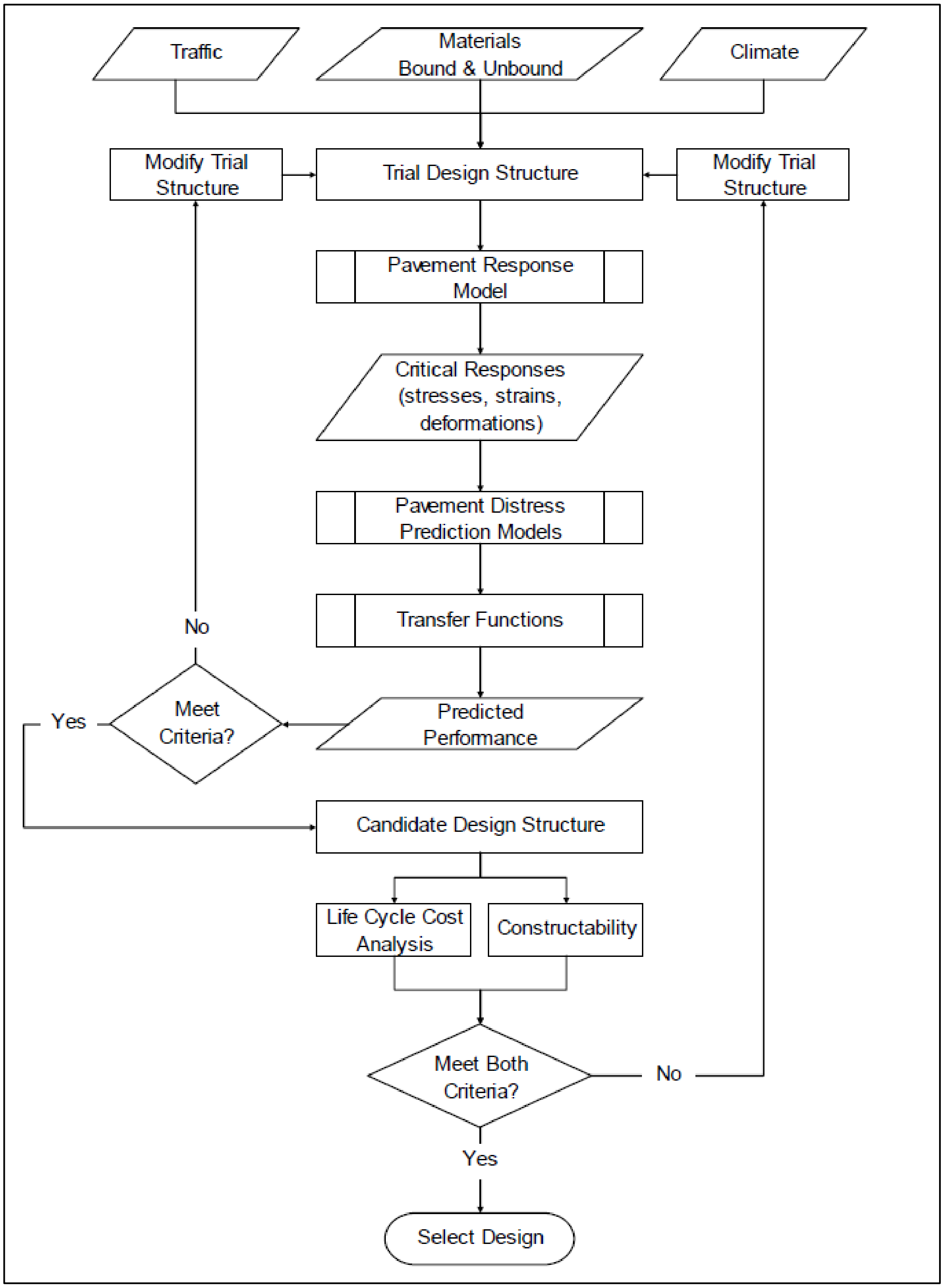

Figure 2.3 DARWIN-ME Design Process (Kim, Jadoun, Hou, & Muthadi, 2011)

The DARWIN-ME design process that was highlighted in Figure 2.3 can be implemented for use for three different pavement types, including asphalt pavement, jointed plain concrete pavement (JPCP), and continuously reinforced concrete pavement (CRCP). These design capabilities aid in the development of an optimized pavement design for a structure, allowing users to compare viable alternatives with different pavement surface types as well as varying material thicknesses.

2.6.2 Design Capabilities

The DARWIN-ME is capable of 17 pavement design situations that incorporate new concrete and asphalt pavements along with various types of asphalt and concrete overlays and restoration (Clark, 2010). New pavement, overlay, and restoration include various options regarding the pavement type being selected for use and previous pavement materials used. To demonstrate this point, the design and pavement types can be seen in Table 2.2.

Table 2.2 DARWIN-ME Design Types

New Pavement	Overlay	Restoration
Flexible Pavement	AC over AC	JPCP Restoration
JPCP	AC over JPCP	
CRCP	AC over CRCP	
	AC over JPCP (fractured)	
	AC over CRCP (fractured)	
	Bonded PCC / JPCP	
	Bonded PCC / CRCP	
	JPCP over CRCP (Unbound)	
	JPCP over JPCP (Unbound)	
	CRCP over CRCP (Unbound)	
	CRCP over JPCP (Unbound)	
	JPCP over AC	
	CRCP over AC	

Once a design type and strategy have been selected and necessary information, such as the trial structure, have been entered into the DARWIN-ME, the software analyzes the pavement's performance for the given design life. Through this analysis, significant pavement distresses are calculated by the software's structural response model and transfer functions (Baus & Stires, 2010). The structural response model operates with mechanistic models that calculate the pavement responses to given traffic loading and climatic environment. The pavement responses, such as pavement and base material degradation, are then converted using the embedded empirical transfer functions to pavement distresses that are accumulated over time. It is these pavement distresses that are generated in the DARWIN-ME output and used for analysis of the trial design.

When completing a pavement design in the DARWIN-ME, there is an input scheme that includes hierarchical input levels that categorizes the designer's knowledge of the input parameter. In this hierarchical system, there are three levels of inputs that can be used: Level 1, Level 2, and Level 3; with Level 1 representing the greatest knowledge of the input and Level 3 having the least amount of knowledge. A description of the degree of knowledge included in each input level can be seen below.

- **Input Level 1**: The input parameter is project- or site-specific and is usually determined by direct measurement.

- **Input Level 2**: The input parameter is calculated through correlations or other regression equations from other known site-specific data. This input level can also include regional values that are not site-specific.

- **Input Level 3**: The input parameter is based off of global or regional default values and is considered as the “best estimate” without any testing or data collection.

Because each of the input levels have varying degrees of testing and data collection associated with them, a decision must be made by the DARWIN-ME user to determine which input level is necessary for their design. Typically, Input Level 1 requires the most amount of time and money to develop inputs, but provides the most reliable results. Input Level 3 is far easier to attain and requires minimal effort in determining inputs, but produces less reliable or site-specific results.

2.6.3 Additional Features

Although DARWIN-ME is an iterative process where trial designs are changed in order to develop a final design that meets specified performance criteria, there are embedded capabilities that assist in this process. These features include an option for design layer thickness optimization and sensitivity analysis.

The optimization tool within the DARWIN-ME allows users to identify which layer of the pavement structure is of specific interest, and to provide a minimum and maximum thickness. These minimum and maximum thicknesses are then analyzed given vehicle loading characteristics, and climatic information and an optimal thickness is provided by DARWIN-ME. Although this process aids in the determination of proper layer thicknesses, there are some limitations associated with the optimization tool.

These limitations are concerned with DARWIN-ME’s inability to consider varying materials as well as multiple layers when optimizing layer thicknesses. Only one layer is allowed to be optimized at a time during a given trial, and when optimizing that layer the software is unable to consider multiple materials. Because of this, the layer is not truly optimized as the resulting layer thickness is calculated solely off of one material type and does not consider changes in the thickness of other layers within the structure.

However, the sensitivity analysis tool embedded into the software allows users to analyze how varying inputs alter the predicted performance indicators for a trial design. The properties that are included in sensitivity analyses for flexible pavements within DARWIN-ME include:

- Two-way average annual daily truck traffic (AADTT)
- Layer thickness
- Asphalt binder content (%) and air voids (%)
- Base, subbase, and subgrade unbound modulus

For each property described above, the user can determine ranges of values that should be included in the sensitivity analysis and also the number of increments that should be used when analyzing the range. The user then creates and runs the sensitivity project.

When a sensitivity analysis is run with the DARWIN-ME, instead of attaining an output that describes predicted performance indicators for one trial design, an output that contains performance indicators when considering the minimum and maximum values for selected properties is also provided. This output allows users to identify how varying AADTT, layer thicknesses, asphalt binder content and air voids, and unbound moduli can alter the predicted performance indicators.

2.7 DARWIN-ME Input

Inputs into an asphalt cement pavement design in the DARWIN-ME can be broken down into three main categories: traffic, climate, and asphalt cement layer properties. Each of these categories has a plethora of sub-categories within them and enables the user to develop a tailored design for their project. Because there are so many inputs, the person using the program can alter any number of design inputs in order attain the desired predicted distresses and reliability. The main screen when beginning an asphalt cement trial design in the DARWIN-ME can be seen in Figure 2.4.

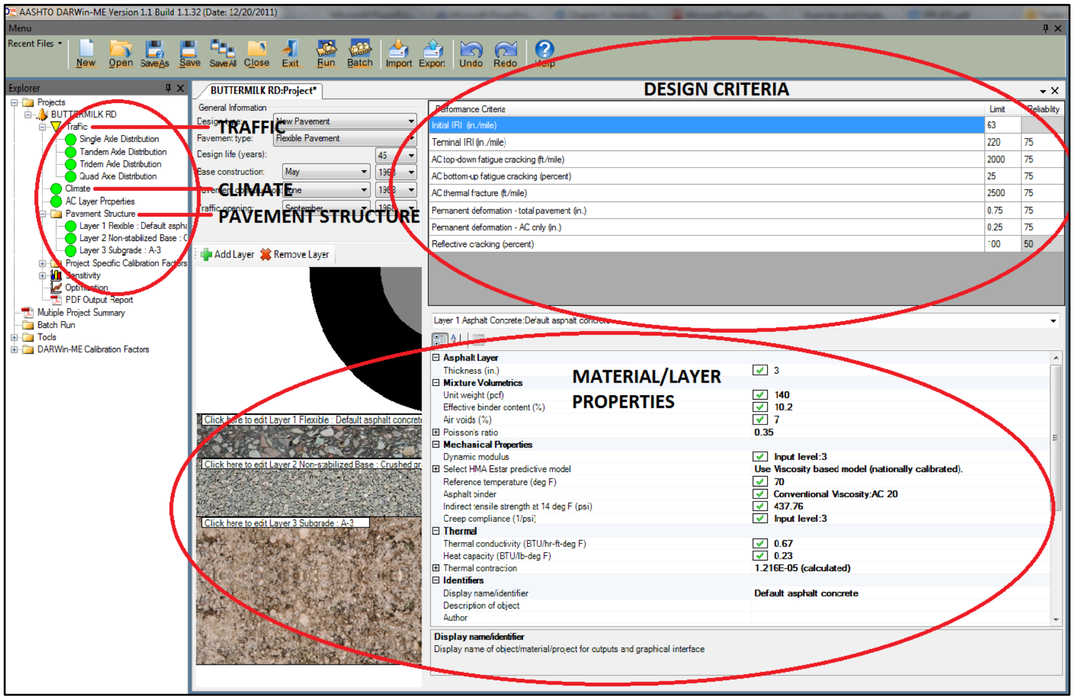

Figure 2.4 DARWIN-ME Main Screen

As can be seen on the left side of Figure 2.4, there are main tabs for traffic, climate, and pavement structure. These three categories of inputs are described further in the following sections.

2.7.1 Environmental/Climatic Data

The performance of a pavement structure is significantly affected by the climate and surrounding area that it is constructed, especially in areas where there is extreme seasonal variations and excessive precipitation. Temperature, precipitation, and frost depth can drastically affect pavement performance, which is why the DARWIN-ME requires these inputs to be locally calibrated (Dzotepe G.A., 2010). Local calibration of climatic inputs is achieved through a modeling tool that is programmed into the DARWIN-ME software called the Enhanced Integrated Climate Model (EIMC). The EIMC was initially developed by the Federal Highway Administration (FHWA) and is capable of modeling coupled heat and moisture flow to predict how a pavement structure will perform in the weather that it will be exposed to during its design life (NCHRP, Calibration and Validation of the Enhanced Integrated Climatic Model for Pavement Design, 2008).

Climate data that are used by the DARWIN-ME through the EIMC are available from weather stations throughout the United States. These weather stations are typically located at airfields and number around 851 (Dzotepe G. A., 2010). If the project site is not located where an embedded station is, the DARWIN-ME user only needs to know the latitude and longitude of the project site and the software within the DARWIN-ME will select the six closest weather stations. From here, a virtual weather station can be created by interpolating the climate characteristics of the surrounding weather stations, which will better represent the expected hourly temperature, precipitation, wind speed, relative humidity, and cloud cover. In states where climate varies widely depending on location, it is recommended that the state highway agencies split the area into climate zones that have similar characteristics. If there are insufficient weather stations for a project in the DARWIN-ME, weather stations can be created manually by using the Integrated Climatic Model (ICM) externally from the DARWIN-ME (AASHTO, 2008). An additional input considered in the climate and environmental input stage is the water table depth. This is an important factor for roadway design because of the negative effects that swelling soils, frost susceptible soils, and water flow can have on a pavement structure (AASHTO, 2008). Water table depth as well as infiltration can be accounted for in pavement design using DARWIN-ME through sub drainage considerations.

In Wyoming, there are 16 weather stations that are embedded into the program. Through previous research, WYT^2/LTAP, five additional weather stations with complete weather data were identified for inclusion into the MEPDG for use within Wyoming. These weather stations were obtained through the Water Resource and Data System at the University of Wyoming and used along with the 16 embedded weather stations to compare the variability of predicted distresses using actual and virtual climate information. Wyoming weather stations that are embedded into the DARWIN-ME can be seen in Figure 2.5 and the five additional weather stations, including Cody, Pinedale, Yellowstone Lake, Jackson Hole, and Torrington, can be seen in Figure 2.6.

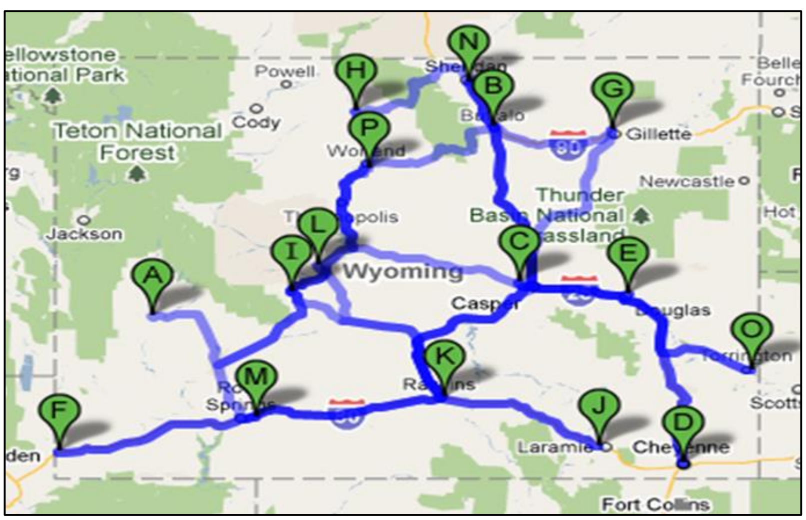

Figure 2.5 Weather Stations Embedded in the DARWIN-ME (Dzotepe G. A., 2010)

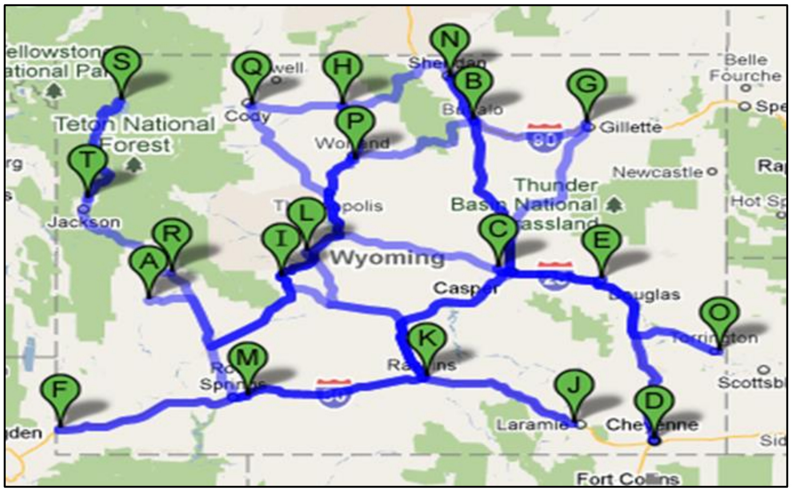

Figure 2.6 Weather Stations Including Additional Sites (Dzotepe G. A., 2010)

It was determined by Dzotepe that there was minimal variability of performance parameters between actual and virtual weather stations for all distresses other than transverse cracking. Because of this, it is evident that transverse cracking is more sensitive to weather data than other predicted distresses. The use of climatic data from similar elevations returned predicted distresses that were closer to measured values than selecting climatic data from the closest stations to the project site. Dzotepe recommended that the five newly identified weather stations be added to the DARWIN-ME for use within Wyoming, and that when interpolations of climatic data for a project is necessary, they should be done using climate stations with elevations similar to those of the project site (Dzotepe G. A., 2010). However, during the Applied Research Associate's (ARA) calibration efforts on Wyoming interstates and state highways, it was determined that only three of the recommended five additional weather stations included enough weather data to be included for use with the MEPDG.

2.7.2 Traffic Inputs

Unlike the AASHTO Design Guide that uses ESAL information for determining a design, the DARWIN-ME was developed using axle load spectra, which incorporates a multitude of traffic characteristics that a pavement structure expects to encounter. These traffic characteristics, mainly considering truck traffic, are a key element in the structural design and analysis of pavement structures (AASHTO, 2008). Full axle-load spectra combined with site-specific traffic inputs provide the DARWIN-ME with enough data for a mechanistic design of both new and rehabilitated pavement.

Traffic inputs that are required to complete analysis in the DARWIN-ME include: truck volume and highway parameters, monthly traffic volume adjustment factors, vehicle classification distribution (FHWA Class 4 – 13), hourly traffic volume adjustment factors, axle load distribution factors, truck growth factors, number of axles per truck, lateral traffic wander, and the configuration of axles. These inputs are typically split up into three different categories; roadway specific inputs, inputs extracted from weigh in motion (WIM) data, and truck traffic inputs not included in the WIM data. The breakdown of what category each input falls into can be seen in Table 2.3.

Table 2.3 Traffic Characterizations for the DARWIN-ME

Site Specific Traffic Inputs	• Initial Two Way Average Annual Daily Truck Traffic (AADTT) • Percent Trucks in Design Lane • Percent Trucks in Design Direction • Operational Speed • Truck Traffic Growth
WIM Traffic Data	• Axle Load Distribution • Normalized Truck Volume Distribution • Axle Load Configurations • Monthly Distribution Factors • Hourly Distribution Factors
Other Inputs	• Dual Tire Spacing • Tire Pressure • Lateral Wander of Axle Loads

Inputs that are included in the axle load spectra are typically determined through the use of WIM stations located near the project site. There are currently nine WIM stations located in Wyoming. These WIM stations were used by ARA to develop axle load spectra that is specific to Wyoming. The traffic characteristics that were developed by ARA include axle load distributions, vehicle class distributions, monthly adjustment factors (MAF), and hourly truck distributions. Distributions were developed for various roadway classifications including primary and secondary highways as well as inclusions for various traffic types. These traffic types included distributions where various vehicle classifications were prominent in an effort to provide WYDOT with a quick vehicle class distribution depending on the type of traffic encountered.

Due to the heavy influence that truck traffic has on pavement deterioration and damage, it is a vital step in the design of a roadway to determine the levels of traffic that the pavement can expect to see during its design life (Stone, et al., 2011). In order for the accumulated loadings from truck traffic to be realized in design, projected traffic volumes need to be calculated using expected growth rates.

The DARWIN-ME software package provides for this step in design to be completed through the use of three different functions when describing truck traffic growth rate. No traffic growth, linear traffic growth, or compounded traffic growth can be selected for each vehicle classification (4-13), and a unique growth rate can be applied to each vehicle classification as well. The functions that are used in the DARWIN-ME for computing and forecasting truck traffic over time can be seen in Table 2.4.

Table 2.4 Traffic Growth Functions and Models

FUNCTION	MODEL
No Growth	$AADTT_{FY} = 1.0 * AADTT_{BY}$
Linear Growth	$AADTT_{FY} = AADTT_{BY} + AADTT_{REF} * GR * t$
Compound Growth	$AADTT_{FY} = AADTT_{BY} * (1 + GR)^{t}$

In Table 2.4, $AADTT_{FY}$, $AADTT_{BY}$, and $AADTT_{REF}$ are the annual average daily truck traffic during the future year, base year, and reference year, respectively. GR is the percent growth rate and is the forecast time period (Stone, et al., 2011).

Although the growth functions embedded into the DARWIN-ME provide for traffic volume growth, users are unable to consider varying growth in traffic such as that experienced with the oil and gas industry. Varying growth rates can be caused by multiple issues, most of which can be grouped into two designations: roadway characteristics and socioeconomic characteristics. These factors have been previously analyzed and a methodology for accounting for varying growth rates in pavement design has been established. The methodology, which was developed during NCHRP Project 1-39, is as follows (Stone, et al., 2011):

1. *Distinguish two groups of vehicle classes: single unit vehicles (Class 4-7) and combination trucks (Class 8-13).* By distinguishing between the two groups of vehicle classes, those vehicles typically used to serve the local community (Class 4-7) can be separated from those used in regional and national markets (Class 8-13). This removes any aspect of the socioeconomic variability of traffic growth.

2. *Identify all Level 1A sites for which estimates of AADTT have been developed for at least four years and that are believed to have historic rates of growth in the volume of heavy vehicles similar to those at the project site.* A Level 1A site is one at which continuous data from an automatic vehicle classifier (AVC) are available for periods of at least one week for a minimum of 12 consecutive months

3. *Choose one or more Level 1A sites from step 2 to associate with the project site.*

4. *Use regression to estimate either linear growth rates or exponential growth rates for each site chosen in step 3.* Judgment on the expected growth rate, whether it is expected to rise steadily or significantly, can lead to the selection of either linear or exponential growth.

5. *Average the growth rates obtained in step 4 for each vehicle classification (Class 4-13) at each level 1A site selected.*

6. *Judgmentally adjust the growth rates on the basis of a review of national and regional macroeconomic and local site-specific factors.* The factors can include land use, industrial development, highway classification, mines, or other developments.

The last step in this methodology may be the most important as it is where the analyst can consider future development of activities, such as oil and gas drilling, that will have an impact on growth rates. This aspect of determining traffic volume growth rates has been previously analyzed, and in a study done by Lu, Zang, and Harvey (2007), it was shown that activities such as oil and gas drilling can be accounted for through multiple linear regression modeling.

Lu, Zang, and Harvey developed multiple linear regression models for each vehicle classification given averaged growth rates from WIM stations. The vehicle growth rates were the response variables in the models and roadway/socioeconomic characteristics were considered as explanatory variables. Because this methodology allows the analyst to incorporate road characteristics and socioeconomic factors (such as oil and gas traffic) into the determination of vehicle class growth rates, it accounts for the variability in growth rates (Lu, Zhang, & Harvey, 2007). The growth rates calculated from this procedure can then be used as inputs for the DARWIN-ME either as linear or compounded growth functions.

2.7.3 Material and Structure Inputs

For the analysis of the structural response of a flexible pavement design, the Jacob Uzan Layered Elastic Analysis (JULEA) is used. JULEA is a structural, mechanistic model that incorporates fundamental engineering principles to calculate critical pavement responses that are predicted with the design being analyzed. There is also a stress dependent finite element program within the DARWIN-ME that is intended to be used when Level 1 inputs are available and for research purposes (AASHTO, 2008).

Like climate and traffic inputs, material property inputs for the MEPDG greatly outnumber those required by the AASHTO Design Guide. Inputs used for the AASHTO Design Guide include structural layer coefficients, layer drainage coefficients, and subgrade resilient moduli, but have been deemed to be insufficient to provide an idea of how the materials will perform in place after construction. Because the DARWIN-ME is mechanistic, it can predict how a selected material will perform given the conditions that it will experience through its design life.

Inputs that are required in the DARWIN-ME but not in the AASHTO Design Guide include characteristics for each layer of the structure such as Hot-Mix Asphalt (HMA) materials, chemically stabilized materials, unbound base, sub-base, subgrade materials, and bedrock the pavement structure may be on top of. Typical material characterizations for flexible pavement design consist of the following:

- Binder: G^* and δ (Measures of Asphalt Binder Stiffness)
- HMA Materials: Dynamic Modulus (E^*)
- Unbound Base and Subgrade Layers: R-Value or Resilient Modulus (M_R), PI, Gradation, Poisson's Ratio

These material inputs can be found through a variety of different methods. The DARWIN-ME has preloaded properties for selected materials (Input Level 3); however, these properties can also be altered if there are material characteristics specific to the project (Input Level 1 and 2). DARWIN-ME default properties appear when a classification of material is selected from options in the software and are considered typical values that are experienced when using that selected type of material. In order to attain material properties to use instead of the preloaded classification values, lab testing or results from previous tests need to be used.

Currently, through ARA's calibration efforts, there are typical values for material characteristics of Wyoming state highways that are available for use. However, these are just typical values and methods for developing project specific inputs were presented to WYDOT. Specifically, these methods lay out the procedure for determining the resilient modulus of unbound materials (base/subgrade).

2.8 Determination of Resilient Modulus

Depending on input level (1, 2, or 3), there are varying applications for obtaining the resilient moduli and other material characteristic inputs. The accuracy of input data used also varies and is characterized by the design level. Methods for obtaining inputs depending on input level are described in this section.

2.8.1 Input Level 1

For level 1 pavement design, it is recommended by the DARWIN-ME that resilient moduli be determined through laboratory testing with cyclic load triaxial tests. There are two standard test procedures that the testing should be performed in accordance with: the NCHRP 1-28A report "Harmonized Test Methods for Laboratory Determination of Resilient Modulus for Flexible Pavement Design" or the AASHTO test standard T307 (Baladi, Thottermpudi, & Dawson, 2011). These test procedures describe the preparation, testing, and computations related to each test. Materials being tested must be subjected to stress conditions that represent the range of stresses that are likely to be experienced by the unbound base and subgrade materials when subjected to moving wheel loads. Stress states encountered by varying layers in the pavement structure could differ significantly, so they must be based upon the depth at which the layers will preside. The DARWIN-ME includes the generalized NCHRP 1-28A MR constitutive model shown below (Baladi, Thottermpudi, & Dawson, 2011).

$$MR = k_1 \left(\frac{\theta}{p_a}\right)^{k_2} \left(\frac{\tau_{oct}}{p_a}\right)^{k_3}$$

Where:

MR = Resilient Modulus, psi
Θ = Bulk Stress (psi) = $\sigma_1 + \sigma_2 + \sigma_3$
σ_1 = Major Principle Stress (axial stress, psi)
σ_2 = Intermediate Principal Lateral Stress (psi)
σ_3 = Minor Principal Lateral Stress (psi), in a triaxial test environment, the values of σ_2 and σ_3 are the same and equal to the confining pressure
τ_{oct} = Octahedral Shear Stress (psi)
p_a = Atmospheric Pressure (psi)
k_1, k_2, k_3 = Regression Coefficients

This procedure can be used for the design of new, reconstructed, or major rehabilitated pavements. For new construction, the sample materials can be sampled and tested; whereas for reconstruction and rehabilitation, the procedures differ. Reconstruction test specimens can be collected through destructive testing such as coring or drilling, while rehabilitation of existing pavements requires non-destructive sampling such as falling weight deflectometer (FWD) and backcalculation of layer moduli (Baladi, Thottermpudi, & Dawson, 2011).

2.8.2 Input Level 2

Developed correlations that relate soil and unbound granular material index properties and strength to resilient moduli are used for DARWIN-ME design level 2. These correlations can either be direct or indirect, with indirect correlations being based on two step correlations relating a known material characteristic to the California Bearing Ratio (CBR) and then the CBR to the resilient modulus. Correlation equations and models that are recommended for use with the DARWIN-ME can be seen in Table 2.5 (Baladi, Thottermpudi, & Dawson, 2011).

Table 2.5 DARWIN-ME Correlation Equations for Input Level 2 (Baladi, Thottermpudi, & Dawson, 2011)

Strength/Index Properties	Equation	Comments	Standard Test
CBR	$M_R = 2555\ (CBR)^{0.64}$ M_R in psi	CBR = California Bearing Ratio (%)	AASHTO T193. "The California Bearing Ratio"
R-Value	$M_R = 1155 + 555\ R$ M_R in psi	R = R-Value	AASHTO T190. "Resistance R-Value and Expansion Pressure of Compacted Soils"
AAHSTO Layer Coefficient	$M_R =$ M_R in psi	a_2 = AASHTO layer coefficient for base layer	AASHTO Guide for the Design of Pavement Structures, 1993
PI and Gradation	CBR	PI = Plasticity Index P_{200} = Percent Passing the No. 200 sieve size	AASHTO T27. "Sieve Analysis of Coarse and Fine Aggregates" AASHTO T90. "Determining the Plastic Limit and Plasticity Index of Soils"
DCP	CBR =	CBR = California Bearing Ratio (%) DCP = Dynamic Cone Penetration Index, mm/blow	ASTM D 6951. "Standard Test Method for Use of the Dynamic Cone Penetrometer in Shallow Pavement Applications"

Although this procedure was recommended by Baladi during the Applied Research Associates' calibration efforts for Wyoming state highways, they determined that FWD testing and backcalculations were necessary for level 2 inputs that are used for the design of pavement rehabilitation.

2.8.3 Input Level 3

For design input level 3, the DARWIN-ME recommends use of the calibrated typical resilient modulus values embedded into the program. These values are based on national averages of resilient modulus adjusted to account for the effect of shallow bedrock and other in-situ conditions that influence pavement condition strength. Data for the calibration of these values were obtained through long-term pavement performance (LTPP) test sites and were tested at optimum moisture content. The DARWIN-ME has resilient modulus values for subgrade, base, and sub-base materials embedded into the program. These values should be used with caution as they are merely typical values that are calibrated on the national level. Table 2.6 displays the typical resilient modulus values that are embedded into the DARWIN-ME (Baladi, Thottermpudi, & Dawson, 2011).

Table 2.6 DARWIN-ME Default Resilient Modulus Values
(Baladi, Thottermpudi, & Dawson, 2011)

Classification System	Material Classification	MR Range (psi)	Typical MR (psi)
AASHTO	A-1-a	38,500 - 42,000	40,000
	A-1-b	35,500 - 40,000	38,000
	A-2-4	28,000 - 37,500	32,000
	A-2-5	24,000 - 33,000	28,000
	A-2-6	21,500 - 31,000	26,000
	A-2-7	21,500 - 28,000	24,000
	A-3	24,500 - 35,500	29,000
	A-4	21,500 - 29,000	24,000
	A-5	17,000 - 25,500	20,000
	A-6	13,500 - 24,000	17,000
	A-7-5	8,000 - 17,500	12,000
	A-7-6	5,000 - 13,500	8,000
USCS	CH	5,000 - 13,500	8,000
	MH	8,000 - 17,500	11,500
	CL	13,500 - 24,000	17,000
	ML	17,000 - 25,500	20,000
	SW	28,000 - 37,500	32,000
	SP	24,000 - 33,000	28,000
	SW-SC	21,500 - 31,000	25,500
	SW-SM	24,000 - 33,000	28,000
	SP-SC	21,500 - 31,000	25,500
	SP-SM	24,000 - 33,000	28,000
	SC	21,500 - 28,000	24,000
	SM	28,000 - 37,500	32,000
	GW	39,500 - 42,000	41,000
	GP	35,500 - 40,000	38,000
	GW-GC	28,000 - 40,000	34,500
	GW-GM	35,500 - 40,500	38,500
	GP-GC	28,000 - 39,000	34,000
	GP-GM	31,000 - 40,000	36,000
	GC	24,000 - 37,500	31,000
	GM	33,000 - 42,000	38,500

These values have been determined to be suitable for use as level 3 inputs with new pavements, reconstructed pavements, as well as major rehabilitated pavements.

2.9 FWD Testing and Backcalculation

In order to attain layer moduli that can be used in design with the DARWIN-ME, non-destructive testing (NDT) and backcalculation using data obtained through this testing are commonly used. Non-destructive testing is the practice of using deflection basin data that are generated from applying a load to an in-place pavement structure in order to quantify the response. There are varying methods used for NDT, including static deflection measurements, steady-state vibration, and impulse loading. The falling weight deflectometer (FWD) is considered one of the most commonly used methods and is classified as impulse loading NDT. FWD testing is believed to provide realistic deflection basin parameters that can be used as an input into a mechanistic pavement model (Appea, 2003).

FWD testing is performed by dropping a load of known magnitude, between 5 kN and 245 kN, from a given height to a spring-buffer system that transfers the load to a pavement section. This load, which simulates those exerted by vehicles, then causes deflections in the pavement structure, including the supporting materials, and the deflections are measured using sensors that are mounted radially from the center of the load plate. The deflection response is an important indicator of structural capacity, material properties such as layer moduli, and subsequent pavement performance (LAW-PCS, 2000). Layer moduli that is calculated through FWD testing is determined at a specific loading condition and environmental state at the time of testing (Appea, 2003). State of the environment, such as temperature, is a factor that can influence the deflection response of pavement and so should be accounted for in FWD data analysis using temperature corrections. Temperature plays such a large role in determination of layer moduli through FWD testing because pavement deflections vary with temperature due to increases in strength of materials with frigid temperatures and decreases in strength with warming and thawing. Other factors that must also be accounted for include pavement discontinuities and variability in the pavement structure (LAW-PCS, 2000).

Backcalculation procedures are typically used to determine layer moduli given FWD deflection data. This process consists of various analytic techniques including iteration, database searching, closed-form solutions, and simultaneous equations (Appea, 2003). The iteration approach consists of adjusting layer moduli until computed and observed deflection basins concur; and the database searching process entails comparing measured deflections to known deflections that are associated with certain moduli.

The practice of FWD testing and backcalculation of moduli is typically used for determining the structural capacity of a roadway and also for rehabilitation design. This project solely looked at new pavement design; however, because the road sections being analyzed are near the end of their design life or serviceability rating, this procedure would be very useful in the design of overlays using DARWIN-ME.

2.10 Design Criteria of the DARWIN-ME

2.10.1 Performance Indicators

Performance indicators that are predicted by the MEPDG differ for hot mix asphalt (HMA) pavements and joint plain concrete (JPCP) pavements. For HMA pavements, the performance indicators include the international roughness index (IRI), longitudinal cracking, transverse cracking, alligator cracking, and rutting in the HMA layer as well as total rutting. For JPCP pavements, the performance indicators include IRI, transverse cracking, and mean joint faulting. Since this study looked solely at flexible pavements, the performance indicators associated with HMA pavements as described by the DARWIN-ME are detailed in this section.

- INTERNATIONAL ROUGHNESS INDEX (IRI)

  IRI is the parameter used by the DARWIN-ME to quantify the smoothness of ride of a pavement structure. This is an important parameter as functional adequacy of a pavement is determined by smoothness, and rough roads lead to user discomfort as well as higher vehicle operating costs (NCHRP, NCHRP Report 1-37A: Guide for Mechanistic-Empirical Design of New and Rehabilitated Structures, 2004). IRI is derived from the simulation of “quarter-car” traveling along the longitudinal profile of the roadway and is calculated from the longitudinal profiles in each wheel path. The DARWIN-ME predicts IRI through empirical functions of pavement distresses, site factors that include the foundation’s shrink/swell and frost heave, and the initial IRI after construction. IRI is calculated by the DARWIN-ME in inches per mile (NCHRP, Calibration and Validation of the Enhanced Integrated Climatic Model for Pavement Design, 2008).

- LONGITUDINAL CRACKING

  Longitudinal cracking is defined as a fatigue or load-related crack that forms parallel to the centerline of the roadway within the wheel path. Longitudinal cracks initially form at the surface of the HMA layer as short longitudinal cracks that eventually connect with one another with increased truck loadings. Raveling or cracking may often be present along the crack; however, this is not to be confused with alligator cracking. The MEPDG measures longitudinal cracking in total feet per mile (NCHRP, NCHRP Report 1-37A: Guide for Mechanistic-Empirical Design of New and Rehabilitated Structures, 2004).

- TRANSVERSE CRACKING

  Transverse cracking, also known as thermal cracking, is a result of low temperatures and thermal. Occurrence of transverse cracking can be seen when non-load related cracks form perpendicular to the traveled way of the road and are generally maintained to the HMA layer. These cracks form as a result of asphalt hardening over time, consistent cold weather conditions, or seasonal and daily temperature differences (Dzotepe G. A., 2010). The DARWIN-ME calculates transverse cracking in feet per mile (NCHRP, NCHRP Report 1-37A: Guide for Mechanistic-Empirical Design of New and Rehabilitated Structures, 2004).

- ALLIGATOR CRACKING

  Alligator cracking is a type of fatigue or load related cracking that forms interconnected cracks. This type of cracking begins below the HMA surface as a result of failure of base and subgrade layers. Alligator cracking tends to appear in a characteristic “chicken wire” or “alligator” pattern and starts out as small longitudinal or transverse cracks that connect with continued loadings. The MEPDG calculates alligator cracking as a percent of total lane area (NCHRP, NCHRP Report 1-37A: Guide for Mechanistic-Empirical Design of New and Rehabilitated Structures, 2004).

- RUTTING

  Rutting is the plastic or permanent vertical deformation of pavement layers due to repeated loadings. Rut depth is a measure of maximum vertical difference in elevation of the pavement structures cross section. The MEPDG calculates rutting for both the HMA layer as well as total rutting through the pavement structure. The unit of measurement for rutting is in inches (NCHRP, NCHRP Report 1-37A: Guide for Mechanistic-Empirical Design of New and Rehabilitated Structures, 2004).

The performance indicators previously described were analyzed during this study by comparing predicted values for each that were generated from the DARWIN-ME to observed values that were determined through road conditioning.

2.10.2 Road Conditioning

In order to analyze the performance criteria described in the previous section on existing roadways, pavement condition surveys are used by many state agencies to evaluate pavement performance on a network-wide basis. These pavement condition surveys can be utilized in providing valuable information for pavement performance analysis, which then can be applied to forecasting pavement performance, anticipating maintenance and rehabilitation needs, establishing maintenance and rehabilitation priorities, and allocating funding (Timm & McQueen, 2004).

Manual and automated pavement condition surveys represent two methods for conducting such assessments. Manual pavement condition surveys include walking surveys, windshield surveys, and a combination of both where a well-trained and experienced rater judges the roadway's condition based off of his/her observations (Timm & McQueen, 2004). Although this procedure provides precise data about the condition of the pavement, given the raters are competent, it is extremely time consuming and subjective. However, due to recent technological advances over the last decades, automated pavement condition surveys have become industry standard.

Automated pavement condition surveys are conducted through the utilization of a technologically complex vehicle that has the capabilities of collecting data for the roadway's surface distresses, rutting, and IRI. These performance criteria are measured by the vehicle, which is typically equipped with a downward-facing camera that is aimed at the road surface, a rutbar or laser transverse profiler, and a device to measure the vehicle's height above the roadway (Timm & McQueen, 2004). These devices collect data pertaining to surface distresses, rutting, and IRI, respectively, in real time and can be linked to each point on the roadway through the use of GPS locating.

Wyoming's Department of Transportation (WYDOT) annually evaluates approximately 7,400 miles of state maintained roadways through the use of automated pavement condition surveys provided by Pathway Services Incorporated. Pathway Services Incorporated employs an automated pavement condition survey vehicle that is equipped with full frame progressive scan cameras for surface imaging, one accelerometer and one laser height sensor in each wheel path for calculating IRI, and a 1028-point laser-based transverse profiler for calculating rutting (Pathway Services Inc., 2010). For this study, through coordination with WYDOT, Pathway Services Inc. completed automated pavement condition surveys for local paved roads in Converse, Platte, Goshen, and Laramie counties, and the data from these efforts were used in determining current pavement distresses.

2.10.3 Reliability

Performance criteria that are selected for a trial design using the DARWIN-ME includes determining reliability levels for each distress type and smoothness. The reliability levels are consistent and uniform for all pavement design types, which include flexible asphalt pavement and concrete pavement. This design reliability (R) is defined as the probability (P) that the predicted distress will be less than the critical level over the design period (AASHTO, 2008). In functional terminology, reliability is as follows:

$$R = P[Distress\ over\ Design\ Period < Critical\ Distress\ Level], for\ Distresses$$

$$R = P[IRI\ over\ Design\ Period < Critical\ IRI\ Level], for\ Smoothness$$

Reliability is most easily described as the percentage of projects that will show fewer distresses or smoothness than predicted by the DARWIN-ME. That is, for instance, if 100 projects were designed and constructed using the DARWIN-ME, 90 would experience distresses and smoothness less than predicted for a reliability level of 90. An example of how reliability is calculated can be seen in Figure 2.7.

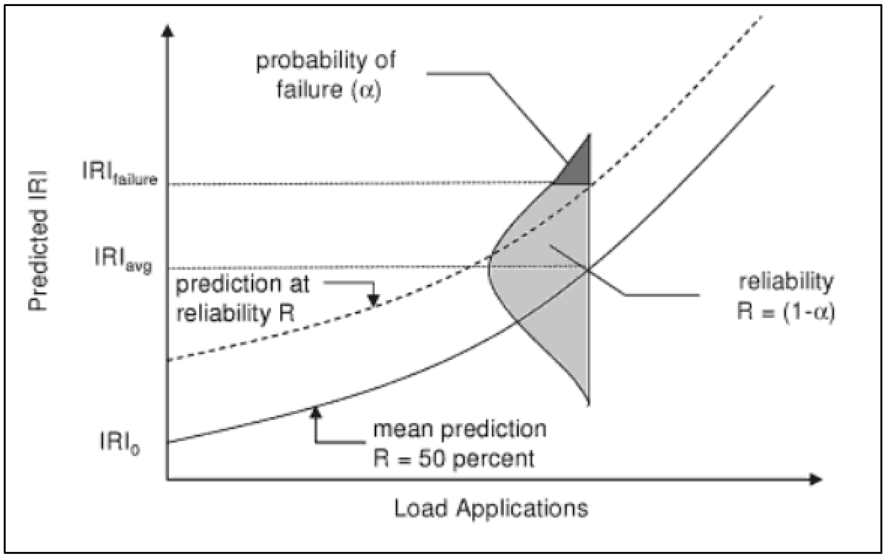

Figure 2.7 Design Reliability Concept for IRI (AASHTO, 2008)

As can be seen in Figure 2.7, reliability is the probability of success for predictions made by the DARWIN-ME at the selected design level. Reliability levels for use in pavement design can be determined through analysis of the importance of the roadway and also by agency standards. Highly traveled roadways likely require levels of reliability higher than those with minimal traffic or importance to the public's travel; therefore, functional classification can be used as a guideline for reliability level selection. Each state agency will likely have varying recommended reliability levels, but those recommended by AASHTO for use in the DARWIN-ME can be seen by functional classification in Table 2.7.

Table 2.7 DARWIN-ME Recommended Levels of Reliability (AASHTO, 2008)

Functional Classification	Level of Reliability	
	Urban	Rural
Interstate/Freeways	95	95
Principal Arterials	90	85
Collectors	80	75
Local	75	70

These levels of reliability can be compared to the levels of reliability used by the Wyoming Department of Transportation in Table 2.8.

Table 2.8 WYDOT Recommended Levels of Reliability

Functional Classification	Traffic Levels	Reliability (%) Rigid	Reliability (%) Flexible
Interstate	All Traffic Levels	95	95
Primary	> 550 trucks/day per direction	85	85
	≤ 550 trucks/day per direction	80	80
Secondary and Miscellaneous	All Traffic Levels	75	75

As can be seen from comparing Table 2.7 and Table 2.8, WYDOT's standards for reliability are similar to those recommended by AASHTO for use in design of pavement structures, although there are no designations for urban or rural and rigid or flexible pavements in WYDOT's values and AASHTO's values, respectively. For this study, reliability levels provided by WYDOT were used.

2.11 Implementation Efforts

Since the MEPDG became available in 2004, state agencies and those within the private sector have been placing extreme amounts of effort towards achieving full implementation of the pavement design guide. During a national survey conducted in 2007, the 50 state agencies plus the Dominican Republic and Puerto Rico were asked if they were currently using or planned to use the MEDPG (Crawford, 2009). Two states, Oregon and Missouri, responded that they were already using the program; the other responses can be seen in Figure 2.8.

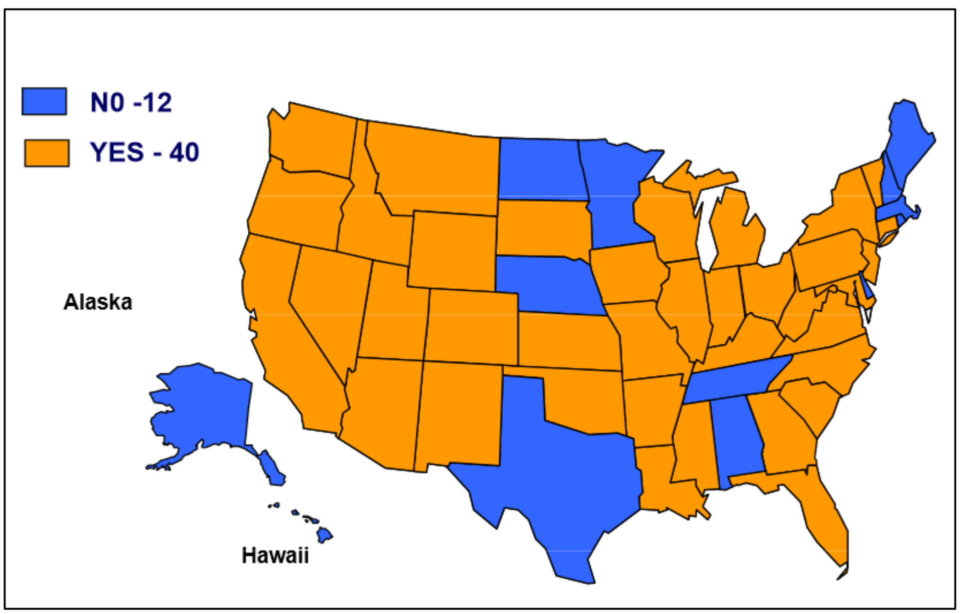

Figure 2.8 State Agency Survey for DARWIN-ME Use (Crawford, 2009)

From 2004 to the present there have been numerous study efforts to refine the original MEPDG and allow for a streamlined transition from the AASHTO Design Guide. These efforts have been aimed at mitigating challenges that were reported by state agencies as obstacles for implementation of the DARWIN-ME. Such challenges that were reported as large hindrances include data collection, training staff, material characterizations, local calibration procedures, and revising specifications to meet

DARWIN-ME criteria (Crawford, 2009). These hindrances have been addressed both on the national level as well as the regional level.

2.11.1 National

In order to take full advantage of the capabilities that the DARWIN-ME presents to users, a substantial commitment of resources is necessary in the implementation procedure. Since the MEPDG was released, some states have fully committed to immediate implementation activities such as testing programs for determination of input data and establishment of calibration test sections. However, some states have not yet committed, and to aid in their and other states' implementation efforts, the Federal Highway Administration created a Design Guide Implementation Team (DGIT) to inform, educate, and assist all interested agencies on the new design guide (Baus & Stires, 2010). The DGIT worked in conjunction with the Lead States Group, which contained representatives from state highway agencies that had early interest in DARWIN-ME implementation, to promote growth of the DARWIN-ME and implementation plans of other states (Baus & Stires, 2010).

When looking at various states implementation strategies and degrees of success, there is a multitude of different methods or strategies that are put to use. Several investigations, however, cite local calibration of the MEPDG/DARWIN-ME to be a top priority. In addition, observations that have been made through various states implementation efforts can be seen as follows (Baus & Stires, 2010):

- Some states utilize Long Term Pavement Performance (LTPP) data to calibrate the MEPDG while others use field/laboratory testing on specific pavement sections.
- The longitudinal cracking model has been cited as being inadequate and/or unreliable.
- The axle load spectra used with the DARWIN-ME is an improvement over equivalent single axle loads (ESAL) considered with the AASHTO Design Guide.
- Sensitivity analyses have indicated inputs that have significant importance in the design of flexible asphalt pavements as well as concrete pavements.

These observations, along with a nationwide push for DARWIN-ME implementation, has led to a significant amount of research and ongoing projects. These projects look to correct deficiencies within the prediction models and well as address issues that have been identified through implementation efforts. Current and previous studies associated with version 2.0 of DARWIN-ME can be seen below (Dzotepe & Ksaibati, 2010).

- NCHRP 9-30A – Calibration of Rutting Models for HMA Structural and Mix Design
- NCHRP 9-41 – Reflection Cracking of HMA Overlays
- NCHRP 9-42 – Top-Down Cracking of HMA
- NCHRP 9-38, 9-44, 9-44A – Application of the Endurance Limit for HMA mixes

Along with these projects, NCHRP Project 1-40 looked to review the DARWIN-ME and make recommendations for changes. All of these projects and/or studies were performed in order to advance the capabilities and reliability of the MEPDG and allow for streamlined implementation nationwide.

2.11.2 Regional

In 2009, a North-West States MEPDG User Group Meeting was held at Oregon State University to discuss participating states implementation plans and issues that they had found relating to the MEPDG. The North-West States User Group includes eight states including Wyoming, Montana, North Dakota, South Dakota, Oregon, Washington, Idaho, and Alaska. Of these states, Washington, Oregon, South Dakota, and Wyoming presented plans for implementation at the meeting, which will be discussed below.

Washington DOT: Through Washington Department of Transportation's implementation efforts, they have strived to prepare data for calibration-validation in the areas of traffic, material properties, and pavement performance. WSDOT has selected both concrete and flexible pavement sections to be used in the calibration procedure. During WSDOT's step towards implementation, these major findings were determined.

- The MEPDG is an advanced tool for pavement design and evaluation
- Calibration is required prior to implementation
- The distress models for new flexible pavement have been calibrated to WSDOT conditions
- Calibration, along with implementation, is a continual process
- Local agencies need to balance the input data accuracy and costs (Level 1, 2, or 3 Inputs)

Also, WSDOT has created future works, which included developing a user guide, preparing sample files for typical designs, and training pavement designers on the use of the DARWIN-ME (Dzotepe & Ksaibati, 2010).

Oregon DOT. The Oregon Department of Transportation has been working closely with Oregon State University (OSU) in its movement toward full implementation. OSU has completed and is still completing research studies pertaining to backcalculation software, AC Dynamic Modulus, Axle Load Spectra, HMA density, and various pavement mixtures. ODOT looks to use the DARWIN-ME on design of interstate sections, and until full implementation, will use the DARWIN-ME and AASHTO Design Guide in conjunction with each other (Dzotepe & Ksaibati, 2010).

South Dakota Department of Transportation. Beginning in 2005, the South Dakota Department of Transportation began implementation efforts for the MEPDG through research project SD2005-01. This project had five main goals, which were to conduct a sensitivity analysis, recommend input levels, determine resource requirements, identify calibration requirements, and to develop an implementation plan. The implementation plan developed during this research called for the development of an implementation team, now called the SDDOT Transportation Implementation Group, as well as the development of a communication plan and MEPDG training schedule. These tasks have all been completed by SDDOT. Current research being completed for SDDOT in order to expedite the implementation process includes reviews and appraisals of South Dakota soils, materials, climate, and traffic (Dzotepe & Ksaibati, 2010). The implementation schedule laid out by SDDOT can be seen in Table 2.9.

Table 2.9 South Dakota Implementation Plan (Dzotepe & Ksaibati, 2010)

Short-Term (1-3 years)	• Review inputs' significance using MEPDG Version 1.0 • Assess training needs and begin training • Begin database compilation using non-project specific data • Review recommendations for model calibration
Mid-Term (2-4 years)	• Conduct preliminary calibration of models • Acquire new equipment as needs define • Train personnel in new testing requirements • Begin using MEPDG alongside existing pavement design procedure • Develop MEPDG documentation and guidelines • Calibrate and validate models • Determine any further data collection needs
Long-Term (> 4 years)	• Move towards full implementation of MEPDG • Develop a design catalog for standard designs

By projecting this implementation plan out from the date of development, SDDOT should be in the "Mid-Term" stage of its implementation efforts.

Wyoming Department of Transportation. The Wyoming Department of Transportation developed a plan for implementation of the MEPDG in 2006 that primarily focused on the materials side of the program. However, this plan was found to be too aggressive at the time and WYDOT has since then created new implementation goals. To meet these goals, WYDOT has enlisted the help of the Applied Research Associates (ARA) due to their familiarity with implementation and calibration of the MEPDG/DARWIN-ME in surrounding states. To this point, ARA has assisted in WYDOT's efforts to calibrate and validate the DARWIN-ME program for primary and secondary state highways as well as provided training to WYDOT personnel on the use of the DARWIN-ME. It has been determined that WYDOT faces considerable challenges with climate data, traffic inputs, and material inputs. These challenges typically exist because of lack of data or insufficient number of sites for weather stations, Weigh-in-Motion stations, or diverse pavement sections. WYDOT, in conjunction with ARA, have worked at mitigating these challenges and have become very close to implementing the DARWIN-ME for use on state maintained interstates and highways.

2.12 Calibration Efforts

As discussed in the previous section, local calibration of the DARWIN-ME is a vital step toward total implementation of the program. The DARWIN-ME program was developed for national use through the modeling of pavement sections that are included in the Long-Term Pavement Performance (LTPP) database. The LTPP database was used to obtain a representative sample of roadways that had the highest level of input data available for calibration of the DARWIN-ME through NCHRP Project 1-40D (AASHTO, 2010). Through this project, global calibration coefficients were developed for use with the DARWIN-ME; however, it is still recommended that local calibration steps are taken to ensure the accuracy of performance prediction models embedded into the program is optimized.

Local calibration of the DARWIN-ME has been deemed necessary for total implementation due to the dependency of the DARWIN-ME design and analysis procedure on the pavement distress prediction models. Since the embedded prediction models have calibration coefficients that were developed off of global representations of roadway distresses and smoothness, state agencies can alter these calibration coefficients to account for more unique characteristics that pertain to their regional or local roadways. For instance, the state of Wyoming has a limited number of LTPP pavement sections, which means that during global calibration of the DARWIN-ME, Wyoming likely did not have as much influence on the final calibration coefficients as other states likely did. A map of LTPP pavement sections in Wyoming can be seen in Figure 2.9.

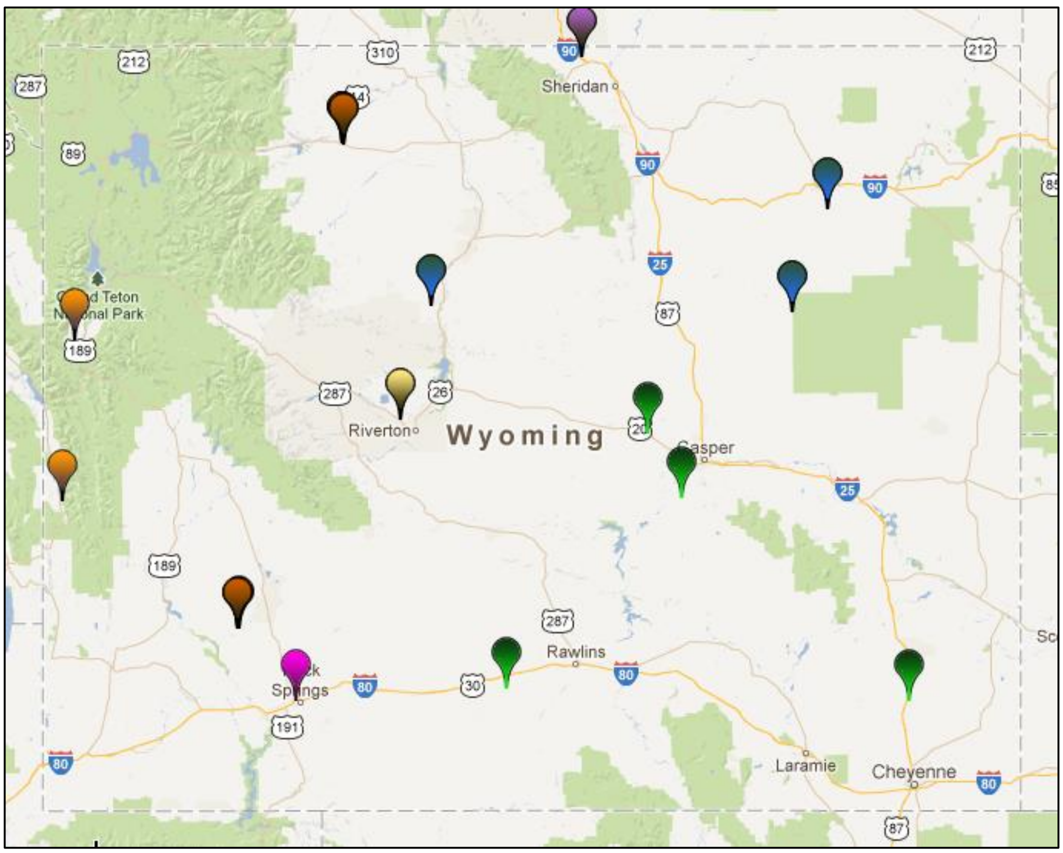

Figure 2.9 Wyoming LTPP Pavement Sections (LTTP, 2013)

To achieve greater accuracy and confidence in pavement designs with the DARWIN-ME, calibration on the local level is necessary to account for variation in the policies on pavement preservation and maintenance, construction and material specifications, and materials from state to state (AASHTO, 2010). Calibration is defined as the process through which bias (or residual error), and the standard error of the estimate (S_e) are both minimized (Kim, Jadoun, Hou, & Muthadi, 2011). This bias and standard error are produced when predicted distresses that are developed with the DARWIN-ME differ from those that are observed in the corresponding pavement section. To determine if calibration procedures are necessary, model verification needs to take place. Model verification is the process of determining if prediction models accurately simulate real-world performance (Kim, Jadoun, Hou, & Muthadi, 2011). Model verification is successful if predicted performance indicators are determined to be reasonably close to observed values. If model verification is not successful, calibration procedures are necessary.

NCHRP Project 1-40B laid out the calibration procedure for use with the MEPDG/DARWIN-ME. The procedure can be seen in a step by step methodology listed below (AASHTO, 2010):

1. Select hierarchical input level for each input parameter
2. Develop local experimental plan and sampling template
3. Estimate sample size for specific distress prediction models
4. Select roadway segments
5. Extract and evaluate distress and project data
6. Conduct field and forensic investigations
7. Assess local bias: Validation of global calibration values to local conditions, policies, and materials
8. Eliminate local bias of distress and IRI prediction models
9. Assess the standard error of the estimate
10. Reduce standard error of the estimate
11. Interpretation of results, deciding on adequacy of calibration parameters

This procedure has been recommended by AASHTO as it lays out a repeatable methodology for determining calibration coefficients for use with the DARWIN-ME program.

Previous studies have been performed in efforts to calibrate model coefficients for use in different state agencies and applications. Rutting and Alligator cracking prediction models were calibrated for the North Carolina Department of Transportation by Kim, Jadoun, Hou, and Muthadi in 2008. Longitudinal cracking and alligator cracking prediction models were calibrated for use in Michigan, Ohio, and Wisconsin by Kang and Adams in 2007, and many other calibration efforts have been made as well. In each study, to calibrate the DARWIN-ME for local conditions, the goal of reducing bias and related error of the prediction models is achieved through alteration of the calibration coefficients.

Calibration has been a main aspect of the implementation of the DARWIN-ME program in Wyoming. WYDOT has been very active in working with the ARA to attain a set of calibration coefficients that are unique to Wyoming primary and secondary roadways. In September 2012, a set of preliminary calibration coefficients were presented to WYDOT by the ARA for use on new and rehabilitated flexible pavements. This set of calibration coefficients can be seen in Table 2.10.

Table 2.10 ARA Calibration Coefficient Comparison

Model Name / Coefficient	Default Coefficients	ARA Coefficients
AC Cracking, C1 Bottom	1	0.4951
AC Cracking, C2 Bottom	1	1.469
AC Rutting, BR1	1	1.0896
IRI Flexible C1	40	20.53
IRI Flexible C2	0.4	0.4094
IRI Flexible C3	0.008	0.00179
Granular Subgrade Rutting BS1	1	0.9475
Fine Subgrade Rutting BS1	1	0.6897
Thermal Fracture Level 1K	1.5	7.5
Thermal Fracture Level 3K	1.5	7.5

The set of calibration coefficients that the ARA came up with were targeted for use on state maintained primary and secondary roadways. These calibration coefficients were developed using LTPP sites within Wyoming and from neighboring states. For the design of local paved roads (i.e., county paved roads), the calibration coefficients that the ARA developed may not be sufficient.

2.13 Summary

The information presented in this section provides a review of literature pertaining to development, characteristics, implementation, and calibration of the Mechanistic-Empirical Pavement Design Guide (MEPDG), most currently known as the DARWIN-ME. This background information and presentation of previous works allow the readers to familiarize themselves with the relatively new pavement design methodology as well as develop an understanding of the scope of this project. With the knowledge gained through this literature review, proper analysis and understanding of the calibration of local paved roads in Wyoming is possible.

As demonstrated in the literature review, calibration procedures will be used to develop a calibrated DARWIN-ME program for use on local paved roads that experience heavy truck traffic associated with the oil and gas industry. This scope of work has previously been considered for interstate and state highways in Wyoming; however, calibration procedures have not yet taken place on local paved roads.

3. METHODOLGY

3.1 Introduction

This section summarizes of the methodologies used during this study. Sections are written in a chronological order to demonstrate the sequential processes that were used and how each step led into the other.

3.2 Road Conditioning

In order to determine the existing distresses and smoothness (IRI) on local road sections in Converse, Platte, Goshen, and Laramie counties, Pathway Services Inc. was enlisted to provide automated pavement condition surveys on each county paved road. Through these pavement surveys, distresses including alligator cracking, longitudinal cracking, transverse cracking, and rutting were all measured, as well as IRI. The methodology for computing these distresses was based on current WYDOT practices used in their pavement management systems. WYDOT also works with Pathway Services Inc. to obtain pavement condition data on all state maintained highways. The methodologies used in this study were performed in the exact manner of WYDOT's methodologies for state highways in order to provide an accurate and consistent result. The general process for determining roadway conditions, which included IRI, rutting, alligator cracking, transverse cracking, and longitudinal cracking, can be seen in Figure 3.1.

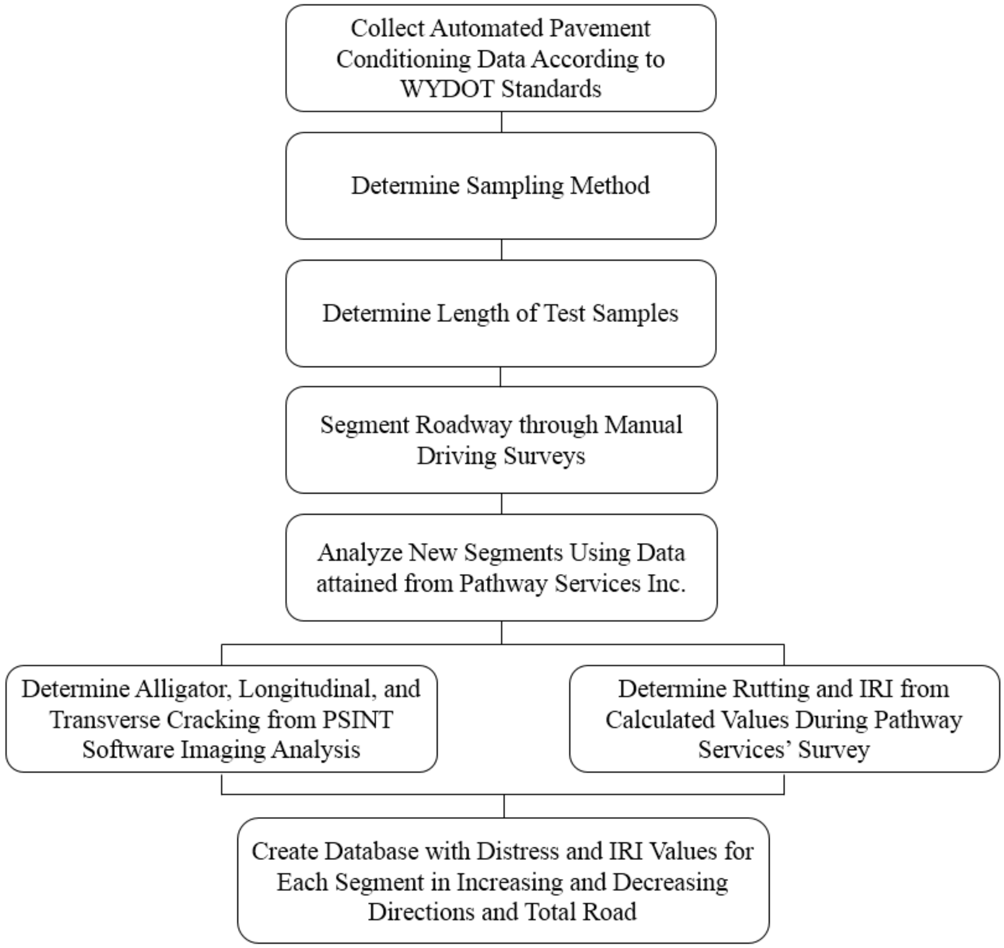

Figure 3.1 Pavement Conditioning Flow Chart

As can be seen in the final step of the flowchart in Figure 3.1, after pavement conditioning analysis has been completed, a detailed Excel spreadsheet, including each of the county paved road segments being analyzed, was developed. Pavement conditioning methodologies are covered in more detail later in this report in Chapter 4.

3.3 Input Value Determination

In order to develop pavement trial designs using the DARWIN-ME, input values for traffic, pavement structure, material properties, and climate needed to be determined. Ideally, on a new or rehabilitated project, these inputs are specific to the design. However, for this study, regional traffic characteristics were developed through the utilization of data from WYDOT's Weigh-In-Motion (WIM) stations as well as traffic counters. There are nine WIM stations currently in Wyoming, with four of those located on the interstate systems and five on U.S. and state highways. In order to determine if there was a significant difference between traffic seen on the interstate and highway system, vehicle class distributions for each functional classification were compared and it was determined that the WIM stations located on U.S. and state highways would be more representative of what local paved roads would be seeing. From this point, axle load distributions, vehicle class distributions, and monthly adjustment factors (MAF) were developed for use in design and calibration. Local traffic volumes were determined through the placement of traffic counters on local paved roads that the county superintendents indicated were being or had been impacted by the energy industry. The data from these traffic counters were collected over a 72-hour period and from this, average daily traffic volumes (ADT and ADTT) were determined.

Combined with the traffic data developed for use as inputs during this study, structural makeup and material properties of the roads needed to be developed. After several meetings with the county road maintenance superintendents, general ideas of the pavement age, layer thicknesses, and material properties were determined. It was assumed that most of the local paved roads being analyzed were approaching 40 to 50 years old and were made up of 2" to 4" of asphalt pavement on top of 2" to 6" of crushed base material. These are wide ranges so average values were initially selected for use in calibration efforts. For material properties, asphalt grade AC-20 asphalt was commonly used as the asphalt binder during that time period on local paved roads, so this was designated as the binder grading. For asphalt pavement and crushed base, gradations and typical R-values used by WYDOT on secondary road systems were considered as the material properties. An A-3 subgrade material was assumed to be the in-place material beneath the assumed layer thicknesses for asphalt and base.

Climate conditions were determined through weather stations that are embedded into the DARWIN-ME program. There were embedded weather stations included in three of the four counties being looked at, so those weather stations were selected for the corresponding county roads and interpolations were made from surrounding weather stations for the roads in counties without weather stations.

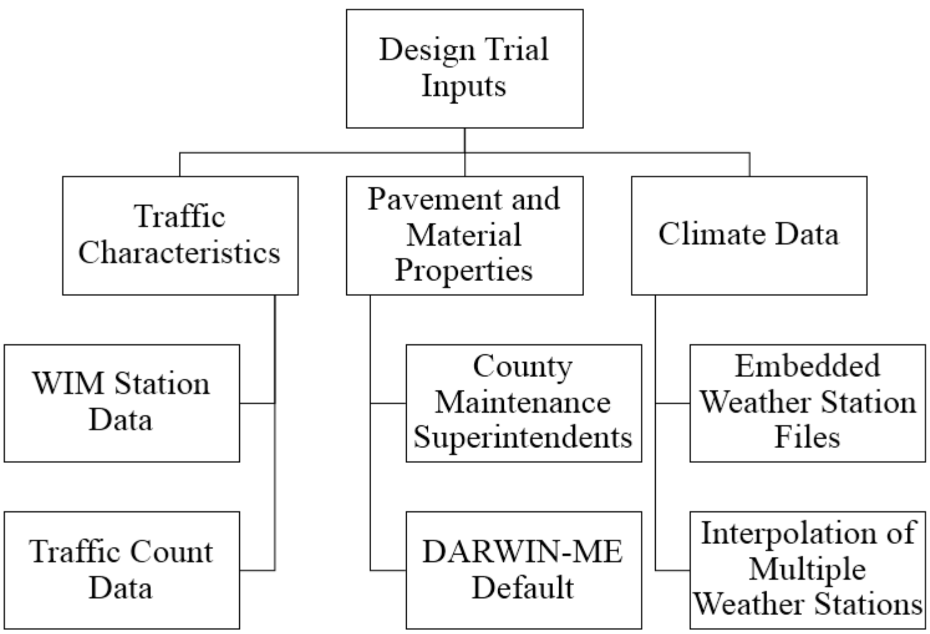

Figure 3.2 DARWIN-ME Input Values Origination Flow Chart

Figure 3.2 depicts the sources of origin for each of the categories of inputs: traffic, materials, and climate. Development of inputs from these sources of origin are detailed further later in this report.

3.4 Test Section Selection Process

In order to perform the most reliable calibration possible, it was determined that the test sections selected for use needed to display high amounts of distresses and IRI as well as experiencing high truck traffic volumes. These two criteria were developed as a way to ensure that the roads being selected for calibration measures were likely within the range of 40 to 50 years old as well as experiencing heavy truck traffic associated with the energy industry. In the process of selecting test sections, high levels of distresses were matched with roads that had high traffic volumes. The goal was to be able to achieve both of these selection criteria, and in most cases the criteria was met. However, some local paved roads exhibited high levels of distresses but moderate levels of truck traffic. Therefore, it was determined that even though there may not have been high levels of truck traffic, the roadway sections were still viable for use as the high amounts of distresses likely indicated older pavement that would fall into the design life range being looked at.

3.5 Design Process

The design process for generating predicted distresses for the test sections that were selected followed repeatable steps for each of the roadway sections. In this process, the traffic, material, and climate characteristics were determined and inputted for the given DARWIN-ME project. For calibration, as there was a level of uncertainty regarding age and structural makeup of the roadways, the main characteristics of each road that changed from design to design were the truck traffic volumes and climatic data.

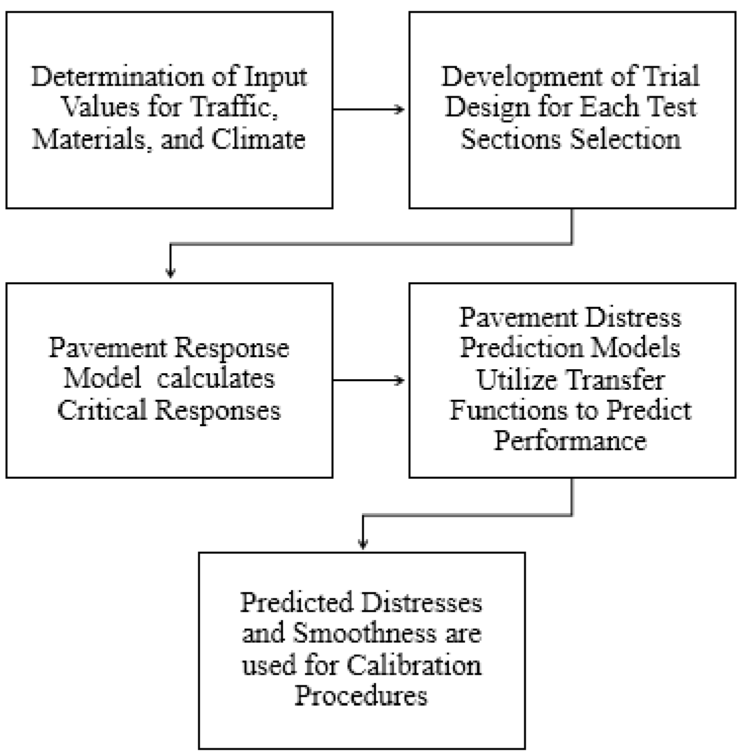

Figure 3.3 Design Process for Selected Test Sections

As can be seen in Figure 3.3, once the inputs for each selected test section were determined, the DARWIN-ME program was utilized to run each project. While running trial designs, pavement response models calculated critical responses of the material and pavement structure. This information within the DARWIN-ME was then applied to transfer functions within the pavement distress prediction models. After each project was done running in the DARWIN-ME, predicted distresses and smoothness were provided, which were then used for calibration of the pavement design software.

3.6 Calibration

The general methodology for calibration of the DARWIN-ME incorporates the additional methodologies that have been described previously. The methodologies for road conditioning, input value determination, pavement segment selection, and project design process are all included in the overall methodology for local calibration of the DARWIN-ME. This methodology has previously been laid out by the American Association of State Highway and Transportation Officials (AASHTO), but was somewhat revised to fit the goals of this project and available data information. Figure 3.4 displays the flow from one step to another in the DARWIN-ME local calibration process used in this report.

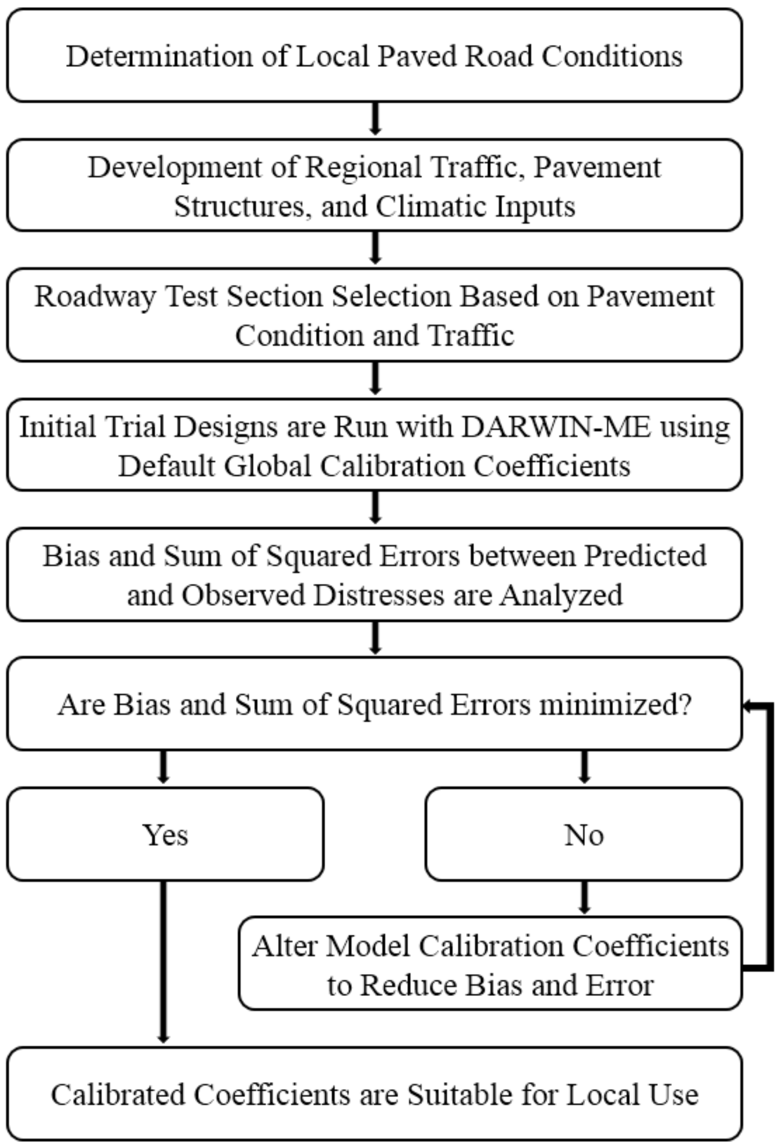

Figure 3.4 DARWIN-ME Local Calibration Flow Chart

As can be seen from Figure 3.4, the general methodology used for local calibration of the DARWIN-ME focuses on the reduction of bias and sum of squared errors between the observed distresses and smoothness gathered during road conditioning and the predicted distresses and smoothness from the DARWIN-ME. This methodology initially looked at the bias and sum of squared errors that were present between the observed and predicted distresses and smoothness using the global default calibration coefficients that are embedded into the DARWIN-ME. After these values were established as the baseline, the calibration coefficients were altered to reduce the sum of squared errors and bias as much as possible. Once both measures were minimized, the DARWIN-ME was considered to be calibrated to local conditions for southeast Wyoming county paved roads that experience heavy truck traffic associated with the energy industry.

3.7 Sensitivity Analysis

Due to assumptions regarding layer thicknesses made during the initial part of this study, the researchers determined that there was likely a level of uncertainty pertaining to the robustness of the calibration coefficients. In order to analyze this uncertainty as well as determine how making alternate assumptions would vary the results, a sensitivity analysis was performed in order to determine if the calibration coefficients developed with 3” of asphalt on top of 4” of base differed when the assumed layer thicknesses were changed.

To perform this analysis, a 2^2 factorial with center point analysis was completed. In this analysis, five different combinations of asphalt and base layer thicknesses were looked at. Because the ranges for the asphalt layer and the base layer were 2” to 4” and 2” to 6”, respectively, the combinations of layer thicknesses seen in Table 3.1 were analyzed.

Table 3.1 Sensitivity Analysis Asphalt and Base Combinations

Combination Number	Thickness, in. Aspahlt Layer	Base Layer
1	3	4
2	2	2
3	2	6
4	4	2
5	4	6

3.8 Summary

This section provides the methodologies that were utilized throughout the data collection and data analysis portion of this report. Methodologies for collecting road condition data and input values are provided along with the methodologies for selecting roadway test sections that were used in local calibration. The analysis methodologies include the DARWIN-ME design process used, calibration procedures, as well as the methodology used during the 2^2 factorial experiment.

4. DATA COLLECTION

4.1 Introduction

Section 4 of this report is meant to demonstrate the means of data collection that were used for this study. This section describes how data were collected as well as the methods used for interpreting these data and converting them into a format that was easily utilized. Analysis of these data and how they were used in this study is discussed in Section 5.

4.2 Road Conditioning

Pavement distresses and IRI were collected for this study with the assistance of Wyoming's Department of Transportation and Pathway Services Inc. WYDOT uses Pathway Services Inc. annually to collect automated pavement condition surveys for use in its pavement management system and to determine the current serviceability of state maintained roadways. Historically, the condition of a pavement section was depicted using the Pavement Serviceability Index (PSI), which was determined by a panel of technicians who manually drove the road and rated it on a scale of 1 to 5, with 1 being the worst and 5 being the best. This method was based solely from the technician's observations of the roadways smoothness of ride, rather than incorporating cracking, rutting, and IRI. In 1996, WYDOT began rating paved road sections using the Pavement Serviceability Rating (PSR), which incorporates IRI, rutting, and the Pavement Condition Index (PCI), which is a function of the surface distresses. Because PSR is the method for depicting the condition of a paved road for WYDOT, this is also the method for which pavement conditions were gathered for this study. This allows results from this study to be consistent with those that could be determined on the statewide level for Wyoming.

Pathway Services Inc. collected automated pavement condition surveys for each of the local paved roads within Converse, Platte, Goshen, and Laramie counties for this study. These surveys included surface imaging for a given road as well as IRI and rutting data. These data were collected using Pathway Services Inc. automated pavement condition survey vehicle, which is equipped with full frame progressive scan cameras for surface imaging, one accelerometer, and one laser height sensor in each wheel path for calculating IRI, and a 1028-point laser-based transverse profiler for calculating rutting. Data were continuously collected with this vehicle while driving the local paved roads at posted limits in both increasing and decreasing directions starting at mile marker 0. Because the data are continuous for the entire road, it was impractical to evaluate the entire length of the roadway as this would be extremely labor intensive and a waste time and money. Instead, a sampling process was developed for this study with the help of WYDOT personnel (Pearce, 2012).

For WYDOT's pavement conditioning, each road is broken up into segments that are of like conditions or construction ages so that, for instance, an older section in poor condition does not influence the condition rating of the entire road that may be in better condition. Once WYDOT divides a road into segments, it randomly selects 1,000' sections to represent the entire segment. For instance, a number of 1,000' sections, dependent on segment length, are selected in both the increasing and decreasing direction to be used for evaluation of the roadway condition. Similar methods were used to develop sections of each local paved road that would produce valid results without excessive sampling (Pearce, 2012).

Based on recommendations from WYDOT personnel, it was established that samples would be collected in 1,000' increments starting at each even mile post in the increasing direction and, conversely, each odd mile post in the decreasing direction. By doing this, a representative PCI value could be calculated for entire roadway by analyzing the samples located at various points in both the increasing and decreasing direction.

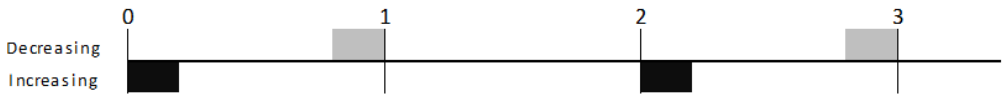

Figure 4.1 Theoretical Sampling Method (Pearce, 2012)

Figure 4.1 depicts this methodology for collecting random samples on a road with equal number of samples in both the increasing and decreasing direction. On county roads where this was not possible, as seen in Figure 4.2, it was determined that an additional 1,000’ sample would be used for PCI analysis. This additional sample would be located in the decreasing direction and begin at the last milepost.

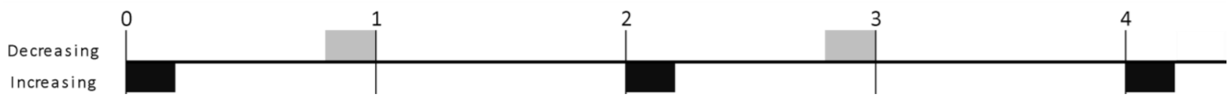

Figure 4.2 Unequal Sampling in Increasing and Decreasing Direction (Pearce, 2012)

Figure 4.3 Equal Sampling Including Additional Sample (Pearce, 2012)

By adding the 1,000’ sample to balance the quantity of samples in the increasing and decreasing direction, as seen in Figure 4.3, the data obtained through the automated pavement condition survey can be determined in both the increasing and decreasing direction and as the entire roadway. Without equal sampling in both the increasing and decreasing direction, proper weighting of the samples and consistency in locations across all roadways analyzed could not be attained. PCI of the entire roadway is calculated by averaging the PCI attained in the increasing direction and that attained in the decreasing direction.

Within this sampling method, there are some exceptions that are applied due to data collection “interruptions.” WYDOT personnel explained that sampling never crosses a cattle guard or a bridge deck. In these scenarios, if a cattle guard or bridge deck are present within a sample, the sample must either terminate before reaching the interruption or begin after. By terminating the sample before a cattle guard or bridge deck, the full 1,000’ increment may not be reached, producing some uncertainty if the sample is well represented. However, if the 1,000’ sample begins after the cattle guard or bridge deck a full sample is taken at a shifted location. In this scenario, it was determined that the technician’s judgment would determine which sample would be best to use (Pearce, 2012).

Once a sampling method had been developed, the software PSINT was used to record surface distresses, which included longitudinal cracking (sealed and unsealed), transverse cracking (sealed and unsealed), alligator cracking, blocking, bleeding, raveling, and patching. For this study, only the observed cracking was pertinent as these are the distresses used as performance criteria with the DARWIN-ME. In order to determine longitudinal, transverse, and alligator cracking density, the viewing technician stepped through each sample in 6’ long increments counting the length of each distress. Lane widths were assumed to be 12’, which is consistent with WYDOT’s assumptions. Observed distresses were recorded in PSINT through the use of “hotkeys” that represent a given amount of each distress within the 6’ x 12’ image being looked at. The number of times each hotkey is pressed indicates how prevalent each distress is in the image; and from that, distress density and PCI is calculated within the PSINT software after the entire 1,000’ sample has been viewed. An example of the PSINT software and surface imaging that is analyzed by the viewing technician can be seen in Figure 4.4.

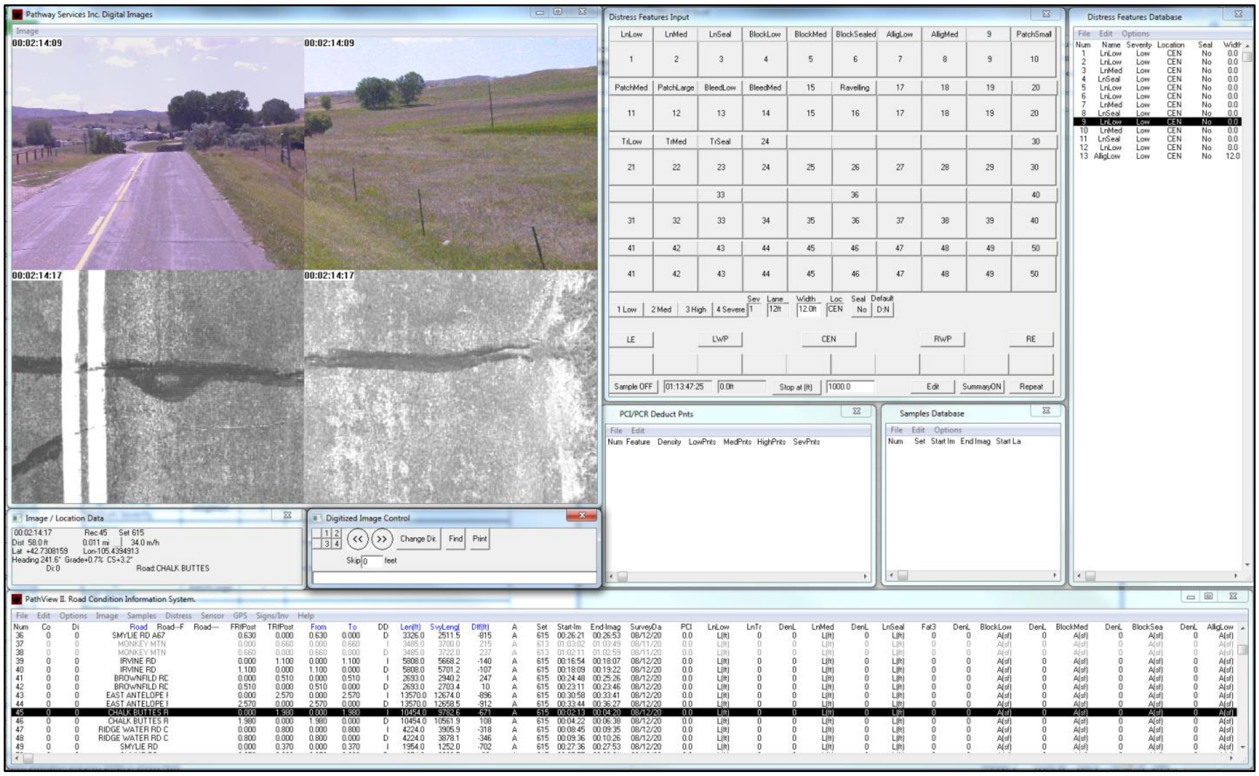

Figure 4.4 PSINT Software and Surface Image (Pearce, 2012)

Due to the subjectivity in calculating surface distresses and PCI through image observation, it was necessary to ensure that the viewing technician was well trained and could produce consistent results. In order to do this, a WYT^2/LTAP research assistant met with WYDOT personnel to receive proper training and to verify sample results. A WYDOT technician completed PCI analysis on several samples already completed by WYT^2/LTAP. The results determined in these separate analyses returned small error and after receiving input, the roadway samples were re-evaluated at the University of Wyoming and the remainder of county roads were evaluated. From the pavement conditioning with PSINT, alligator, longitudinal, and transverse cracking were all calculated. Units for longitudinal and transverse cracking were feet of cracking per 1,000' of roadway, and alligator cracking was calculated as percent (%) density of the total roadway.

IRI was measured and recorded continuously by the Pathway Services Inc. vehicle using an accelerometer and laser height profiler in each wheel path as well as in the center of the vehicle. The IRI data are gathered and stored in the onboard equipment, and upon completion of the road survey, can be extracted at varying amounts of detail, from every 100 feet to every mile. WYDOT extracts data at every one-tenth (1/10) of a mile, so for consistency purposes the same interval was used on the county roads in this study. WYDOT personnel assisted in the extraction of the raw IRI data into a compatible text file (.txt) where is was stored. Of the three measurements of IRI produced by the Pathway vehicle, the middle measurement ("IRI half car") is used in this study as opposed to the left and right quarter car IRI values, which are generally higher in values. This selection is consistent with WYDOT practices.

Pavement rutting is measured by determining the difference between the highest and lowest points of the pavement structure cross section. These cross sections are produced by a 1028-point laser-based transverse profiler that is equipped on the Pathway Services Inc. survey vehicle. Much like IRI, these data are recorded continuously as the vehicle drives the county road and can be extracted at varying length increments. WYDOT personnel helped in extracting rutting values into a compatible text file (.txt) at one-tenth (1/10) of a mile increments. Rutting is measured by the survey vehicle at three points: left rut, right rut, and center rut. For this study, the maximum value of the three was used for analysis (Pearce, 2012).

Because cracking, rutting, and IRI values were all measured using separate procedures, the data pertaining to each distress were combined into a single spreadsheet for use in this study. Each local paved road being considered with the observed distresses was included in this spreadsheet.

4.3 WIM Data

Weigh-in-motion (WIM) stations are a method for capturing and recording gross vehicle weights as well as axle weights for moving vehicles, typically trucks. There are nine WIM stations located across Wyoming, with four of those located on the interstate system and five located on U.S. and state highways. WYDOT has been using WIM stations since 2002 as a method for weight enforcement and attaining data regarding vehicle characteristics of its roadways. For this study, WIM data provided by WYDOT were analyzed to determine axle load distributions, vehicle class distributions, and monthly adjustment factors for use as regional inputs in the DARWIN-ME.

WYDOT has been collecting data from WIM stations since 2002 and made these data available to WYT^2/LTAP for use during this study. Because of varying installation dates and operational lapses, not all the nine stations had data going back to 2002, but as can be seen in Table 4.1, most stations being looked at had data from at least 2006.

Table 4.1 Available WIM Data from Wyoming

Station Identification	Location	Roadway	MP	Years with Data									
				2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
STN027	Muddy Gap South	US 287	39.3					X	X	X	X	X	X
STN028	Casper West	US 20/26	12.08					X	X	X	X	X	X
STN059	Cheyenne South	I25	0.97									X	X
STN156 or 156	Gillette South	WY59	103.12	X	X	X	X	X	X	X			
STN160 or 160	Little Bear	I25	19.45	X	X	X	X	X	X	X	X	X	X
STN172 or sw0172	Granger	US 30	98.2					X	X	X	X	X	X
STN173 or bh0173	Lovell south	WY 789	234.7	X	X	X	X	X	X	X	X	X	X
STN176 or la0176	Pine Bluffs	I80	399.35	X	X	X	X	X	X	X		X	X
STN177 or ui0177	Evanston West	I80	2.2	X	X	X	X	X	X	X	X	X	X

The data that were provided by WYDOT included classification files (.CLA) as well as weight files (.WGT) that were broken up into week-long observation periods. In order for analysis of these data to be completed, WYDOT also provided WYT^2/LTAP with the federal program VTRIS. This is an older program, and a potential replacement will be released in the future. VTRIS is used to convert the raw data in the classification and weight files into easier to interpret report summaries, which can be configured in order to provide the user with the pertinent information that is sought after. For instance, during this study, axle load distributions that considered the same weight ranges as the DARWIN-ME were sought after, so the parameters for VTRIS were set to match those used in the DARWIN-ME for each axle type. The axle loads were considered as follows:

- Single Axle: 3,000 lbs. to 41,000 lbs. in 1,000 lb. increments
- Tandem Axle: 6,000 lbs. to 82,000 lbs. in 2,000 lb. increments
- Tridem Axle: 12,000 lbs. to 102,000 lbs. in 3,000 lb. increments
- Quad Axle: 12,000 lbs. to 102,000 lbs. in 3,000 lb. increments

Along with the ability to set parameters of VTRIS to meet the user's needs, there are seven (7) different reports that can be generated as summaries. These summaries each provide various information regarding the WIM station. A description of what each summary provides can be seen below.

- W-1 Table: Weigh Station Characteristics – This table displays the characteristics of the WIM station, such as functional classification, number of lanes, weighing equipment used, and the year the station was established. This is all information contained in the station description records.
- W-2 Table: Summary of the Vehicles Counted and the Vehicles Weighed – Provides the FHWA vehicle classification, average daily count, and percentage distribution of total vehicles, average number weighed, and percentage distribution of vehicles weighed.
- W-3 Table: Average Weights of Empty, Loaded and all Trucks and Their Estimated Average Carried Load
- W-4 Table: Equivalency Factors – This table provides the number of single, tandem, tridem, and quad axles weighed which fall into particular weight ranges. It also provides ESAL information that corresponds to the recorded loadings.
- W-5 Table: Gross Vehicle Weights – Provides the entire vehicle weight within specified ranges for each vehicle classification.
- W-6 Table: Overweight Vehicle Report – Provides the number of vehicles exceeding load limits for single, tandem, tridem, and quad axles for each vehicle classification.
- W-7 Table: Distribution of Overweight Vehicles – Provides information regarding overweight vehicles and percentages of excess weight.

This information can be used in various ways depending on application needed. For this study, W-2 and W-4 tables were utilized. W-2 tables provided information that was utilized for calculation of vehicle class distributions as well as monthly adjustment factors. The W-4 table was utilized to develop the axle load distribution factors for use in the DARWIN-ME.

4.4 Traffic Counts

In order to calibrate the DARWIN-ME to local conditions on county roads, truck traffic volumes needed to be determined. Average daily truck traffic (ADTT) is an important design parameter when considering trial designs with the DARWIN-ME and can significantly influence predicted distresses. Because of this, traffic counters were placed on local paved roads that county road and bridge superintendents indicated were experiencing impacts from the energy industry. These traffic counts were conducted over a 72-hour period.

Data collected while these traffic counts were being conducted includes average daily traffic (ADT), percent trucks, and speed percentiles. For use in calibration, the ADTs on each road were multiplied by the percent trucks in order to calculate the ADTT. This process is represented by Equation 4-1 below:

Equation 4.1

$$ADTT = \%\, trucks * ADT$$

The ADTTs were calculated using this procedure for each roadway being analyzed, and the ADTTs were then used in calibration procedures as the design truck traffic volume. A table displaying the traffic count data that were collected for the 18 roadways used in this study can be seen in Table 4.2.

Table 4.2 Road Test Section Traffic Counter Data

Road Number	Road Name	ADT (vehicles/day)	ADTT (trucks/day)	Percent Trucks (%)	85th Percentile Speed (mph)
3	ALBIN / LAGRANGE	108	22	20.4	60.8
6	BLACK HILLS	114	36	31.6	64.5
222-1	CHALK BLUFF / "78" RD	168	72	42.9	68.5
19	OLD HWY BURNS W	198	26	13.1	63.4
21	OLD YELLOWSTONE RD.	36	6	16.7	58.8
40	CEMETERY/PINE BLUFFS S RD	170	14	8.8	71.3
154	DEER CREEK RD	88	9	10.2	57.2
178	BUTTERMILK RD	164	23	14	54.2
191-2	VAN TASSEL RD	115	11	9.6	66.7
188	SHEEP CREEK	171	14	8.2	55.2
157	WYNCOTE RD	152	16	10.5	52.6
223-1	BORDEAUX RD	85	15	17.6	58
139	PALMER CANYON	79	12	15.2	58.4
195	DEER CREEK RD	142	10	7	58.5
196	HIGHLAND LOOP RD	173	31	17.9	53
200	WALKER CREEK RD	154	27	18.2	60.6
201-2	55 RANCH RD	380	21	5.5	55.3
214	NATURAL BRIDGE RD	150	7	4.7	57.7

4.5 Design Inputs

In order for proper analysis using the DARWIN-ME to take place, detailed input information pertaining to the selected roadway segments needed to be collected. These inputs are what the empirical and mechanistic relationships within the DARWIN-ME program use to determine cumulative stresses and strains that the pavement will incur through its design life. The calculated stresses and strains were then translated into cumulative distresses and smoothness that were compared to observed values in order for the calibration process to take place. The methods for collecting these inputs are broken up into their respective categories below.

4.5.1 Materials

The DARWIN-ME program requires that detailed inputs for materials used in the pavement structure be determined for each trial design. For this study, because the local paved roads were already in place and have been for some time (estimated between 40 and 50 years), there was limited information regarding material types or properties available. To mitigate this, researchers spoke with personnel from the four counties' road and bridge departments in order to determine general pavement structure characteristics. From these conversations, it was determined that the roadways were typically constructed between 40 and 50 years ago using between 2" and 4" of asphalt pavement on top of 2" to 6" of crushed base material. These two layers were indicated to have been placed on natural subgrade.

As can be seen in Figure 4.5, the general assumptions given by the county road and bridge superintendents were averaged for the initial calibration. That is, 3" of asphalt pavement over 4" of crushed base and a semi-infinite layer of natural subgrade material (assumed to be an average strength material, A-3) were selected for use in the initial calibration. However, to account for these general assumptions, a sensitivity analysis was performed during this study to determine the effect that varying layer thicknesses would have on the final calibration coefficients determination. The full ranges for both asphalt pavement and crushed base were considered in this analysis.

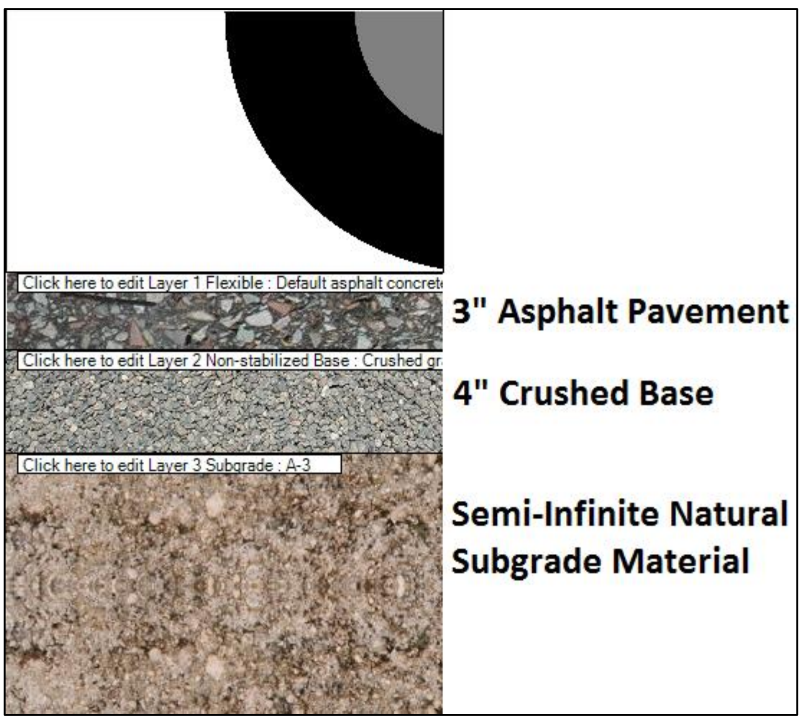

Figure 4.5 Trial Design for Average Pavement Cross Section

Once the layer thicknesses and material types had been selected, material properties of each layer needed to be determined. To do this, typical values for material strength, aggregate gradations, and mix properties were determined through examination of WYDOT's *AAHTO DARWIN-ME Pavement Design User's Guide* (ARA/WYDOT, 2012). This guide detailed various material properties for those used on state roadways. Values obtained from this source were determined to be similar to what would have been used to construct the local paved roads being looked at and thus were used for this study. In addition to the input parameters gathered from the *AAHTO DARWIN-ME Pavement Design User's Guide,* national default values embedded into DARWIN-ME were used for material properties. These are typical values that are seen nationwide for materials within a given material classification, such as the AASHTO Soil Classification system. Values that were used as inputs for the material's strength, gradation, mix properties, as well as the origin of the information can be seen in Table 4.3.

Table 4.3 DARWIN-ME Inputs for Calibration

Asphalt Pavement			Crushed Base Material (A-1-a)			Natural Subgrade Material (A-3)		
Material Property	**Property Value Used**	**Origin of Property Value**	**Material Property**	**Property Value Used**	**Origin of Property Value**	**Material Property**	**Property Value Used**	**Origin of Property Value**
Layer Thickness (in.)	3"	County Superintendents	Layer Thickness (in.)	4"	County Superintendents	Layer Thickness (in.)	Semi-Infinite	County Superintendents
Unit Weight (pcf)	140	WYDOT Manual	Poisson's Ratio	0.35	WYDOT Manual	Poisson's Ratio	0.35	DARWIN-ME Default Value
Effective Binder Content (%)	10.2	WYDOT Manual	Coefficient of Lateral Earth Pressure (k0)	0.5	WYDOT Manual	Coefficient of Lateral Earth Pressure (k0)	0.5	WYDOT Manual
Air Voids (%)	7	WYDOT Manual	Resilient Modulus (psi)	25000	DARWIN-ME Default Value	Resilient Modulus (psi)	16000	DARWIN-ME Default Value
Poisson's Ratio	0.35	WYDOT Manual	Liquid Limit (%)	6	DARWIN-ME Default Value	Liquid Limit (%)	11	DARWIN-ME Default Value
Aggregate Gradation			Plasticity Index (%)	1	DARWIN-ME Default Value	Plasticity Index (%)	0	DARWIN-ME Default Value
% Passing 3/4"	100	WYDOT Manual	Aggregate Gradation	Default Gradation	DARWIN-ME Default Value	Aggregate Gradation	Default Gradation	DARWIN-ME Default Value
% Passing 3/8"	81.4	WYDOT Manual	Compacted?	Yes	County Superintendents	Maximum Dry Unit Weight (pcf)	120	DARWIN-ME Default Value
% Passing No. 4	53.3	WYDOT Manual						
% Passing No. 200	5.1	WYDOT Manual						
Reference Temperature (F°)	70	DARWIN-ME Default Value						
Indirect Tensile Strength at 14 °F (psi)	437.76	DARWIN-ME Default Value						
Thermal Conductivity (BTU/hr-ft-°F)	0.67	DARWIN-ME Default Value						
Heat Capacity (BTU/lb-°F)	0.23	DARWIN-ME Default Value						

These properties were used as general assumptions of the in-place material characteristics and thus were considered to be Level 3 inputs in the hierarchical level approach of the DARWIN-ME. Also, asphalt grade AC-20 was considered to be the asphalt binder in place on these roadways as it was most commonly used in Wyoming during the roadways' construction period. Although this is the assumed asphalt binder grade for this study, future use of the DARWIN-ME for design and rehabilitation should consider penetration grading and Superpave performance grading as well.

In order to perform the sensitivity analysis on the pavement layers' thickness, material properties were left the same and thicknesses were the sole input that was changed. This allowed for determination of how varying layer thicknesses and the general assumptions made about the layer thicknesses would affect the overall results of this study.

4.5.2 Climate

Climatic information used within the DARWIN-ME program includes a multitude of different inputs that are generated after selecting a single weather station or combining multiple in the creation of a virtual weather station. This information incorporates average temperatures, annual precipitation, number of wet days, freezing index, and number of freeze/thaw cycles. In addition to this information, hourly climate data that are characteristic of the weather station is also used. Hourly climate data include temperature, wind speed, percent sunshine, precipitation, humidity, and water table depth each hour for the time period included with the weather station. Examples of the data that are embedded into the DARWIN-ME for each weather station can be seen in Figure 4.6 and Figure 4.7, which displays embedded information for Douglas, WY.

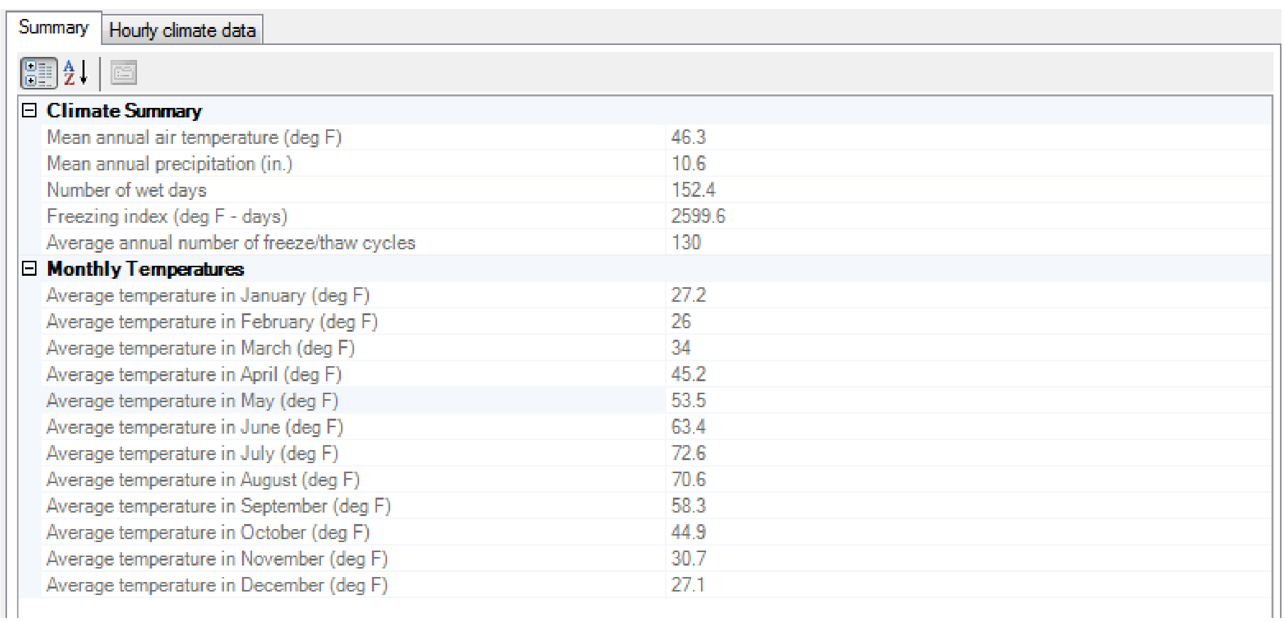

Figure 4.6 Douglas WY Climate Data Summary

Summary | Hourly climate data

July /1999 to February /2006 Verify Weather

Date/Hour	Temperature (deg F)	Wind Speed (mph)	Sunshine (%)	Precipitation (in.)	Humidity (%)	Water Table (ft)
7/1/1999 12:00:0...	51.1	0	25	0	96	10
7/1/1999 1:00:00 ...	50	6	25	0	96	10
7/1/1999 2:00:00 ...	50	5	0	0	96	10
7/1/1999 3:00:00 ...	46.9	3	100	0	100	10
7/1/1999 4:00:00 ...	46.9	4	100	0	97	10
7/1/1999 5:00:00 ...	51.1	5	100	0	89	10
7/1/1999 6:00:00 ...	55	4	100	0	83	10
7/1/1999 7:00:00 ...	59	3	100	0	69	10
7/1/1999 8:00:00 ...	61	4	100	0	63	10
7/1/1999 9:00:00 ...	64.9	9	100	0	52	10
7/1/1999 10:00:0...	66.9	10	100	0	53	10
7/1/1999 11:00:0...	70	9	100	0	53	10
7/1/1999 12:00:0...	72	4	100	0.01	46	10
7/1/1999 1:00:00 ...	73.9	7	100	0	45	10
7/1/1999 2:00:00 ...	75.9	9	100	0	43	10
7/1/1999 3:00:00 ...	77	8	100	0	40	10
7/1/1999 4:00:00 ...	78.1	9	100	0	39	10
7/1/1999 5:00:00 ...	77	8	100	0	44	10
7/1/1999 6:00:00 ...	72	6	100	0	61	10
7/1/1999 7:00:00 ...	66.9	10	100	0	71	10
7/1/1999 8:00:00 ...	66.9	7	100	0	68	10
7/1/1999 9:00:00 ...	59	4	100	0	90	10
7/1/1999 10:00:0...	57	0	100	0	93	10
7/1/1999 11:00:0...	55	4	100	0	96	10
7/2/1999 12:00:0...	54	16	100	0	90	10
7/2/1999 1:00:00 ...	53.1	16	25	0	89	10
7/2/1999 2:00:00 ...	53.1	15	0	0	89	10
7/2/1999 3:00:00 ...	53.1	13	0	0	89	10
7/2/1999 4:00:00	53.1	9	0	0	86	10

Figure 4.7 Douglas WY Hourly Climate Data

Climate data that were used for this project is embedded into the DARWIN-ME program, but the actual data in the program were obtained from weather stations located across the state. For this study, weather stations located in Cheyenne, Wyoming; Douglas, Wyoming; and Torrington, Wyoming were used. The locations of these weather stations can be seen on the map in Figure 4.8, indicated by the blue pins.

Figure 4.8 Weather Station Locations Used (Courtesy of Google)

These weather stations were used according to where a roadway being analyzed was located. For those local road segments located in Laramie County, the Cheyenne, WY, weather station was used. For those located in Converse County, the Douglas, WY, weather station was used; and for those located in Platte or Goshen counties, a virtual weather station including Torrington, WY, was used.

4.5.3 Traffic

As described earlier in 4.3 and 4.4, data were collected for traffic inputs using WIM stations located across the state of Wyoming and traffic counters located on impacted local paved roads. These data were then used to calculate axle load distributions, vehicle class distributions, monthly adjustment factors, and average daily truck traffic. Please see the previous sections for descriptions of the traffic data collection processes.

4.6 Summary

Section 4 of this report details the data collection process used during this report. This chapter provides information regarding data collection in a manner as to describe how one step in data collection led to the other, and finally to data analysis phase. Road conditioning data were collected by Pathway Services Inc., which provided WYDOT and researchers with road surface imaging, rutting profiles, and IRI values for all the paved county roads within the study area. These data were then used to determine distresses on existing roadways for comparison to predicted distresses from the DARWIN-ME.

WIM stations and traffic counters were the sources for traffic characteristics used in the DARWIN-ME during this study. From these sources, data were gathered that provided detailed information regarding truck traffic, axle loadings, and seasonal traffic variations.

Design inputs for the DARWIN-ME were collected during this study from multiple sources. Those sources include WIM stations and traffic counters, known WYDOT values, previous studies done within the state, county road and bridge superintendents, and default DARWIN-ME values. Input categories consist of traffic, climate, and pavement structure.

5. DATA ANALYSIS

5.1 Data Analysis Introduction

The data analysis that was conducted in this report provided insight into developing traffic characteristics and localized calibration coefficients for use within the DARWIN-ME on local paved roads which experience heavy truck traffic associated with the energy industry. This study analyzed data to determine axle load spectra, vehicle class distributions, monthly adjustment factors, and DARWIN-ME calibration coefficients for IRI, rutting, alligator cracking, and transverse cracking. Along with these developments, comparisons of designs using the AASHTO Design Guide and the DARWIN-ME were analyzed. In addition, a sensitivity analysis was performed to determine how robust the developed calibration coefficients were to varied assumptions regarding pavement layer thicknesses.

5.2 Traffic Characteristics

Before calibration of the DARWIN-ME program could take place for local county roads that experience heavy truck traffic, detailed traffic characteristics representative of those seen in the four counties being analyzed needed to be developed. These characteristics included axle load spectra, vehicle class distributions, monthly adjustment factors, and truck traffic volumes. For each set of inputs developed, analysis of either WIM station data or data collected from traffic counters placed on impacted county paved roads was completed. Analysis of the traffic characteristics that were developed is detailed in this section.

5.2.1 Vehicle Class Distributions

Vehicle class distributions are used to provide the percentage of vehicles that are within a given FHWA vehicle classification in relation to the total amount of vehicles recorded. Information from vehicle class distributions can be used to determine what type of traffic, whether it be large tractor trailers, such as vehicle class 9, or smaller passenger cars, such as vehicle class 2, is typically seen on a given roadway. Figure 5.1 demonstrates the various FHWA vehicle classifications that are typically considered in pavement design as well as those considered in this study and report.

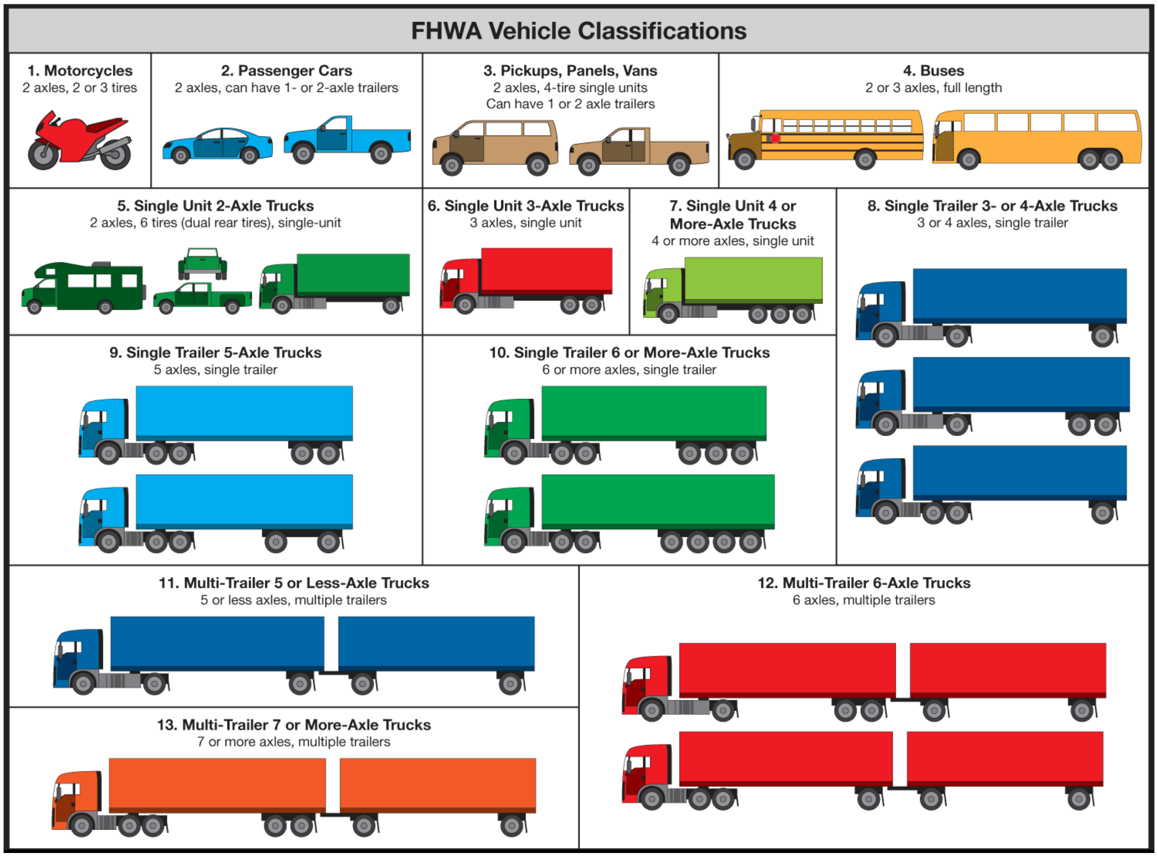

Figure 5.1 FHWA Vehicle Classification Description (Randall, 2012)

It has been shown through previous studies that large, heavy vehicles have more of an impact on the durability and serviceability of roadway than smaller, lighter vehicles. Because of this, the DARWIN-ME program focuses on truck traffic, which is considered FHWA vehicle class 4-13. By only considering truck traffic, the DARWIN-ME program focuses on those vehicles that will produce the highest amounts of stresses and strains to the pavement structure. Due to this reality, only vehicle classifications 4 through 13 were considered when developing traffic characteristics in this study.

Vehicle class distributions were initially looked at in this study to determine how traffic characteristics varied from WIM station to WIM station in Wyoming. Because there were four WIM stations located on the interstate system and five located on U.S. and state highways, the vehicle class distributions from these two functional classifications were compared with each other to see if there were any significant differences.

Data from the nine WIM stations from across Wyoming were reduced to provide the total number of vehicles recorded in a given time period, as well as the number of those vehicles which fell into each vehicle classification. This information was then separated for interstate and highway WIM stations and the vehicle class distributions were calculated. Vehicle class distributions can be best represented by Equation 5.1.

Equation 5.1

$$Vehicle\ Class\ Distribution = \frac{Vehicles\ within\ Classification\ of\ Interest}{Total\ Vehicles\ Recorded} * 100$$

This equation is used to determine the percentage of total vehicles that were recorded in a single vehicle classification. In practice, once this calculation has been completed for all of the specified vehicle classifications, the sum of all the vehicle class distributions needs to equal 100%. If this is not met, there may be an error regarding data collection or analysis.

Using Equation 5.1, vehicle class distributions were developed for both interstate and highway WIM station data. These were calculated separately so that they could be compared in order to determine if there was significant variation between vehicle class distributions on the interstate and highway systems. The vehicle class distributions that were calculated can be seen in Table 5.1.

Table 5.1 Vehicle Class Distributions for Interstate and Highway Systems

FHWA Vehicle Classification	State and U.S. Highway	Interstate	Difference
4	2.37	0.84	1.53
5	11.95	5.44	6.51
6	5.38	1.59	3.79
7	0.29	0.05	0.24
8	2.91	1.73	1.18
9	52.76	78.47	-25.71
10	8.26	2.74	5.52
11	0.22	2.32	-2.10
12	0.21	2.17	-1.96
13	15.66	4.66	11.00
Sum	100.00	100.00	

As can be seen from Table 5.1, there are considerable differences between the two sets of vehicle class distributions, with the largest coming in vehicle classification 9. In order to prove that these differences were in fact significant, a paired t-test was used to determine the statistical significance. This test is based off of a null-hyporeport that states the following:

$$H_0: Mean\ Difference\ Between\ Interstate\ and\ Highway\ Vehicle\ Class\ Distributions = 0$$

$$H_1: Mean\ Difference\ Between\ Interstate\ and\ Highway\ Vehicle\ Class\ Distributions \neq 0$$

To either accept or reject the null hyporeport (H_0), the paired t-test is conducted by finding the mean, standard deviation, and standard error of the difference between the two means. This information was then used to calculate the t-statistic and p-value for the set of data. This study tested the difference between interstate and highway vehicle class distributions using a 95% level of significance. That is, the results obtained from this analysis produce a 95% level of certainty that the results are correct. Because the 95% level of significance was chosen, the criteria for rejection or acceptance of the null hyporeport is as follows:

$$Reject\ H_0: \alpha = 0.05 > P - value$$

$$Accept\ H_0: \alpha = 0.05 < P - value$$

In order to conduct the paired t-test for the vehicle class distributions in this study, the computing program Minitab® was used. In this program, the statistical test "Paired T-Test and CI" was selected and which provided the 95% confidence interval, T-Value, and P-Value for the mean differences between interstate and highway vehicle class distributions. The output that was obtained through the use of Minitab for this statistical analysis can be seen in Table 5.2.

Table 5.2 Paired T-test Results

FHWA Vehicle Classification	State and U.S. Highway	Interstate	Difference	Standard Deviation	SE Mean	95% Confidence Interval		T-Value	P-Value
						Low	High		
4	2.37	0.84	1.53	0.77	0.32	**0.72**	**2.35**	4.86	**0.005**
5	11.95	5.44	6.51	2.33	0.95	**4.07**	**8.96**	6.84	**0.001**
6	5.38	1.59	3.79	1.30	0.53	**2.42**	**5.15**	7.11	**0.001**
7	0.29	0.05	0.24	0.12	0.05	**0.11**	**0.36**	4.66	**0.006**
8	2.91	1.73	1.18	0.48	0.20	**0.68**	**1.69**	6.01	**0.002**
9	52.76	78.47	-25.71	6.01	2.45	**-32.02**	**-19.40**	-10.47	**0.000**
10	8.26	2.74	5.52	0.80	0.33	**4.69**	**6.36**	17.01	**0.000**
11	0.22	2.32	-2.10	0.67	0.27	**-2.81**	**-1.40**	-7.69	**0.001**
12	0.21	2.17	-1.96	0.35	0.14	**-2.33**	**-1.59**	-13.62	**0.000**
13	15.66	4.66	11.00	1.70	0.69	**9.22**	**12.78**	15.90	**0.000**

As can be seen in Table 5.2, the p-values that were calculated when comparing the mean difference of interstate and highway vehicle class distributions were all smaller than the 0.05 level of significance. This indicates there was significant difference between the two sets of vehicle class distributions and shows that the null hyporeport, that the mean difference between the interstate and highway vehicle class distributions equals 0, is rejected in favor of the alternative that the mean difference does not equal 0. From this test, the 95% confidence intervals can also be looked at. As seen in Table 5.2, the confidence interval ranges never include 0, which means it is 95% certain that the mean difference will not include 0.

After the paired t-test had indicated there was significant differences between the interstate and highway system's vehicle class distributions, researchers were faced with selecting which set of distributions best represented local paved roads. Because local paved roads are typically two-lane roadways in rural regions, the vehicle class distributions generated from the U.S. and state highway systems were selected for use in the DARWIN-ME. U.S. and state highways were deemed to better represent local paved roads as they more closely resemble local paved roads and the type of traffic that is seen on local roads than the interstate system does. Figure 5.2 depicts the final vehicle class distributions selected for use in the DARWIN-ME calibration efforts in this study.

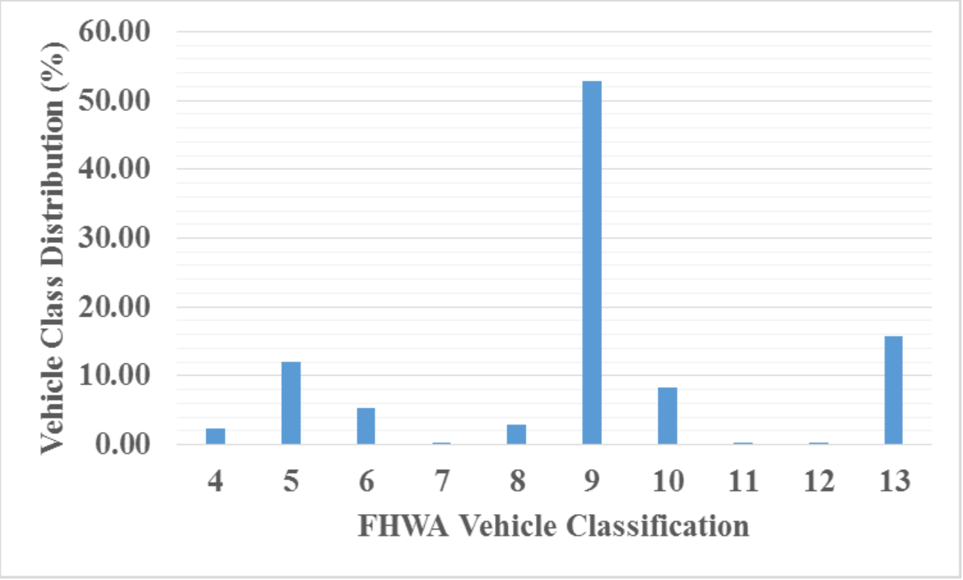

Figure 5.2 U.S. and State Highway Vehicle Class Distribution

As can be seen from Figure 5.2, FHWA vehicle classifications 5, 9, and 13 were noted to be most prevalent in the Wyoming U.S. and state highway system. The vehicle class distributions that were selected to be used as regional inputs into the DARWIN-ME can be seen in numeric form in Table 5.2.

Table 5.3 Regional Vehicle Class Distribution

Vehicle Class Distribution										
FHWA Vehicle Classification	4	5	6	7	8	9	10	11	12	13
Percent Distribution	2.37	11.95	5.38	0.29	2.91	52.76	8.26	0.22	0.21	15.66

5.2.2 Axle Load Spectra

Once the vehicle class distributions had been determined and the U.S. and state highway WIM data were deemed to best represent local paved roads, axle load spectra needed to be determined for use in the DARWIN-ME. These axle load spectra were developed for use in the calibration efforts in this study, but will also provide those using the DARWIN-ME for pavement design on local paved roads a representative set of values for this region. Axle load spectra differ from the ESAL method used in the AASHTO Design Guide in that it provides the percentage distribution of axles within a specified weight range for single, tandem, tridem, and quad axles. This percent distribution allows the DARWIN-ME program to determine exactly how much loading will be applied to the trial design and, in turn, how much stress and strain the pavement structure will be subjected to over its design life. Axle load distributions contain a massive amount of data, and would be difficult to compute for each trial design. Therefore, by developing a regional set of axle load inputs through this study, those using the DARWIN-ME program for design of local paved roads will be saved from having to compute these in the future.

Axle-load distributions were calculated during this study in the same manner that the DARWIN-ME requires for inputs. The same loading ranges for single, tandem, tridem, and quad axles were applied. The loading ranges are as follows:

- Single Axle: 3,000 lbs. to 41,000 lbs. in 1,000 lb. increments
- Tandem Axle: 6,000 lbs. to 82,000 lbs. in 2,000 lb. increments
- Tridem Axle: 12,000 lbs. to 102,000 lbs. in 3,000 lb. increments
- Quad Axle: 12,000 lbs. to 102,000 lbs. in 3,000 lb. increments

In order to obtain the WIM data from the five U.S. and state highway locations in these loading increments, the program VTRIS was used and the parameters for data extraction were set as indicated above. For each station, five years of data were analyzed, which met and exceeded the minimum sample size for estimation of the normalized axle-load distribution as given by AASHTO in the *Mechanistic-Empirical Pavement Design Guide: A Manual of Practice*. To calculate the axle-load distributions, each year of station data was broken up into month-by-month recordings. This was done to stay consistent with the DARWIN-ME, which requires load distributions for each classification (FHWA Class 4 through 13), in each month (January through December).

W-4 tables generated from VTRIS provided the total number of axles recorded, number of axles within each loading range, as well as number of vehicles measured. This information was also broken up into single, tandem, tridem, and quad axles, which was necessary for development of the axle load spectra for the DARWIN-ME. From these data, Equation 5-2 was used to determine the normalized axle load distribution.

Equation 5.2

$$\% \, Axles\ within\ Specified\ Load\ Range = \frac{\#\ of\ Axles\ within\ Specified\ Load\ Range}{Total\ \#\ of\ Axles\ Recorded} * 100$$

In order to utilize the five years of WIM data, each station was analyzed separately. The five years of data were divided into single years and each month of the five years was analyzed by itself. After the axle load-distributions were computed for each station, month, and axle type, not including quad axles as there were none recorded during the five-year span, the axle load distributions were averaged. In this procedure, a single set of axle load distributions was created for single, tandem, and tridem axles that incorporated monthly variation as well as variation across vehicle classifications. Examples of the axle load distributions developed for the month of January can be seen in Figure 5.3, Figure 5.4, and Figure 5.5.

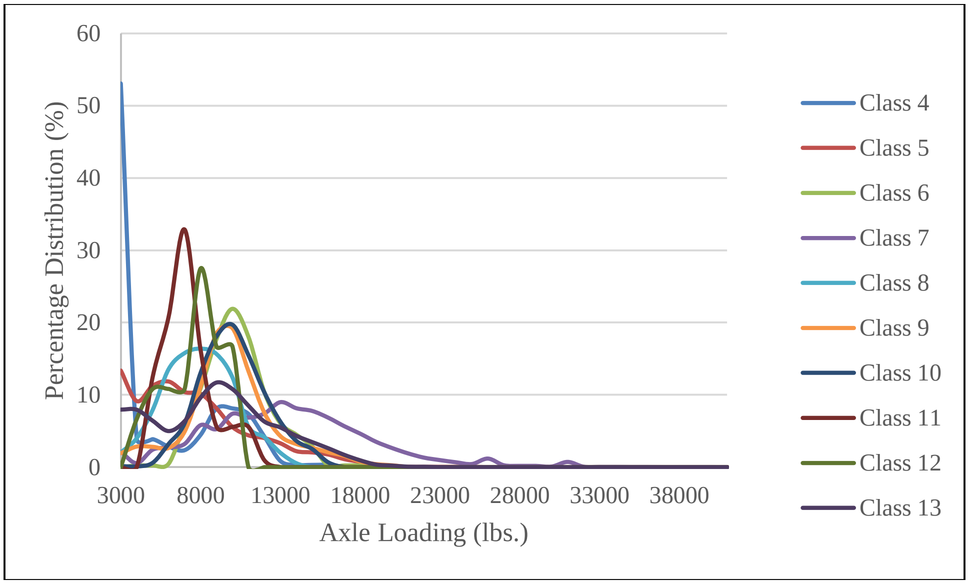

Figure 5.3 January Single Axle Load Distributions

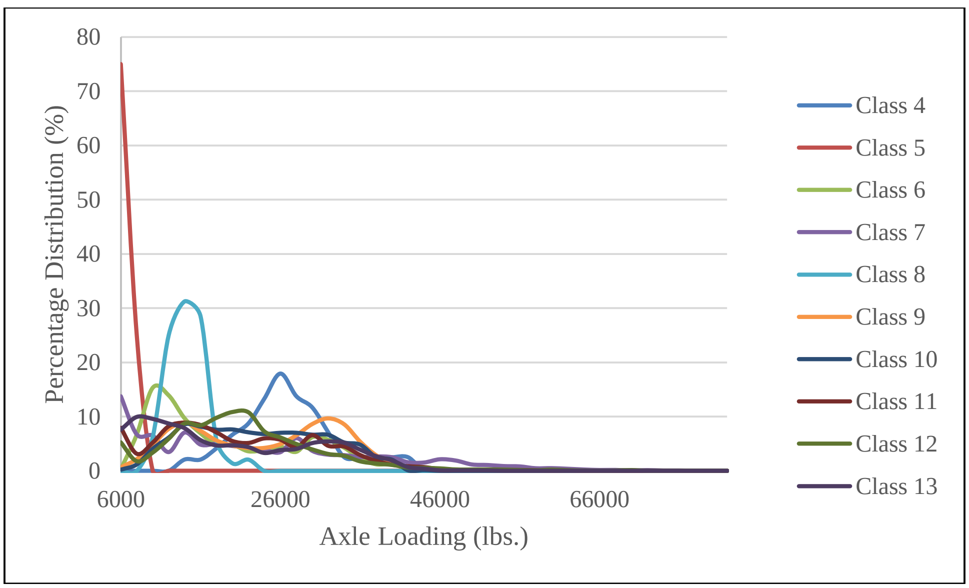

Figure 5.4 January Tandem Axle Load Distributions

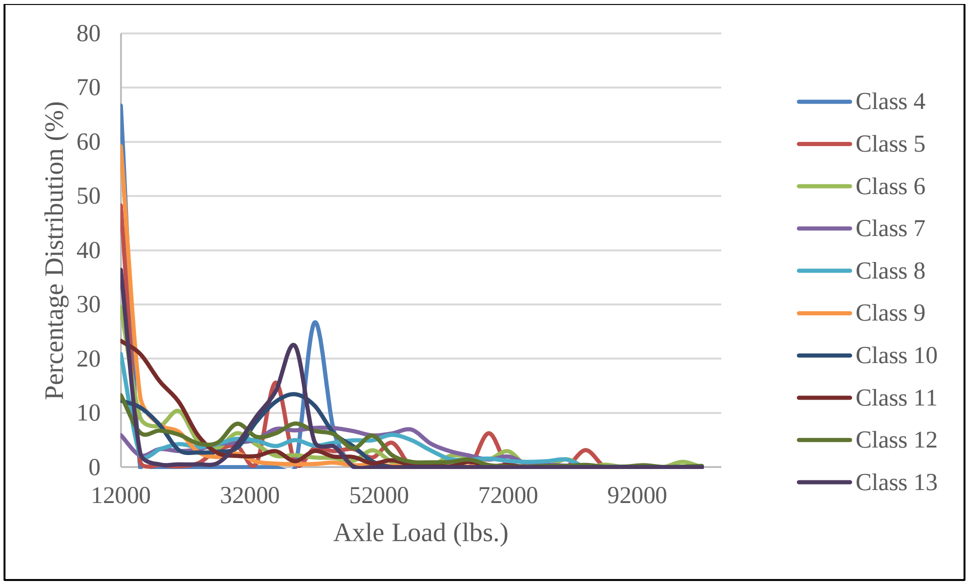

Figure 5.5 January Tridem Axle Load Distributions

No figures are displayed for January quad axle load distributions because there were no vehicles with quad axles recorded at any of the Wyoming highway WIM stations during the five-year period of analysis for this study. For quad axles load distributions, default axle load distributions were used; however, to account for no quad axles being recorded, the number of quad axles per truck was set to 0 in the DARWIN-ME for this study. In addition to no quad axles being recorded, there were multiple vehicle classifications that were not recorded at the highway WIM stations during the analysis period as well. These null recordings can be seen in Table 5.4.

Table 5.4 Class and Axle Type with No Axles Recorded

No Axles Being Recorded	
Class	**Axle Type**
Class 7	Single
Class 7	Tandem
Class 11	Tandem
Class 12	Tandem
Class 4	Tridem
Class 5	Tridem
Class 6	Tridem
Class 7	Tridem
Class 8	Tridem
Class 9	Tridem
Class 12	Tridem

Because no axles were recorded for the axle types and vehicle classifications listed in Table 5-4, DARWIN-ME default axle load distributions were used for those scenarios. This was accounted for by the vehicle class distributions, where, as can be seen from Table 5-3, there was a low percentage of those classes recorded.

The axle load distributions developed during this study contain a massive amount of data and thus cannot be presented in the body of this report. Appendix 1 includes full tables that display the axle load distributions and the corresponding graphs depicting the axle load distributions can be seen in Appendix 2.

5.2.3 Monthly Adjustment Factors

In order to account for seasonal variation of traffic, monthly adjustment factors are included as inputs to the DARWIN-ME program, and thus were developed for use during this study. It is important that these monthly distributions are included in the DARWIN-ME as varying truck traffic loadings during freeze/thaw cycles can have a major impact on the performance of a roadway. For instance, if there are significant amounts of truck traffic being applied to a pavement structure while ice lenses are thawing and the base and subgrade material are weakened, there will be a significant amount of stress and strain placed on the roadway, resulting in increased distresses.

Monthly adjustment factors were calculated for this study on a classification-by-classification basis as this is the method of entry in the DARWIN-ME. Data used for this study's analysis were collected from Wyoming highway WIM stations and as with the axle load distributions and vehicle class distributions, were examined over a five-year period (2007 to 2011). Since the W-4 reports had previously been generated for each month during axle load distribution analysis, they were used for this portion of the traffic characteristics analysis as well.

Monthly adjustment factors were used to distribute truck traffic observed throughout the year to months that see the highest amount of traffic. In order to calculate this, the total number of vehicles recorded for the entire year was determined (from which the average vehicles per month was calculated), as well as the number of vehicles that were recorded in each month. Once this information was known, Equation 5.3 could be used to calculate the monthly adjustment factors (MAF).

Equation 5.3

$$MAF = \frac{Average\ Monthly\ \#\ of\ Vehicles}{\#\ of\ Vehicles\ in\ a\ Given\ Month}$$

Equation 5.3 was used to calculate the monthly adjustment factors for each classification in each of the five years being analyzed. After this had been done, the distributions from each year were averaged together to produce a final set of monthly adjustment factors, which can be seen in Table 5.5.

Table 5.5 Monthly Adjustment Factors by Classification

Month	FHWA Vehicle Classification									
	4	5	6	7	8	9	10	11	12	13
January	1.05	1.15	1.05	1.04	1.20	1.04	1.05	1.07	1.07	0.96
February	0.96	1.11	1.02	0.97	1.17	0.99	1.04	1.07	0.89	0.97
March	0.99	1.12	0.99	1.04	1.11	0.94	1.02	1.07	0.89	0.98
April	0.92	1.01	0.94	0.97	0.95	0.93	0.98	0.98	1.07	0.98
May	0.95	0.96	1.02	1.21	1.02	0.96	0.99	0.90	1.19	1.00
June	0.79	0.78	0.88	0.85	0.81	0.95	0.93	0.90	0.97	0.92
July	0.73	0.75	0.89	1.12	0.74	0.95	0.96	0.98	0.89	0.88
August	0.99	0.86	0.99	0.97	0.81	0.94	0.98	0.78	0.89	0.93
September	1.04	0.88	0.96	0.97	0.88	0.96	0.93	1.07	0.97	0.97
October	1.27	1.08	1.01	0.81	1.11	1.03	0.95	1.18	1.07	1.13
November	1.34	1.29	1.12	1.12	1.21	1.12	0.98	1.07	1.33	1.15
December	1.39	1.42	1.22	1.12	1.44	1.27	1.24	1.07	0.97	1.24

As can be seen from Table 5.5, monthly adjustment factors are typically less than 1 during the summer months and greater than 1 during the winter months. This is most likely explained due to decreases in traffic during the winter months when roads are more difficult to travel on and increases in the summer when more traffic is typically seen. This trend in the monthly adjustment factors can also be seen in Figure 5.6.

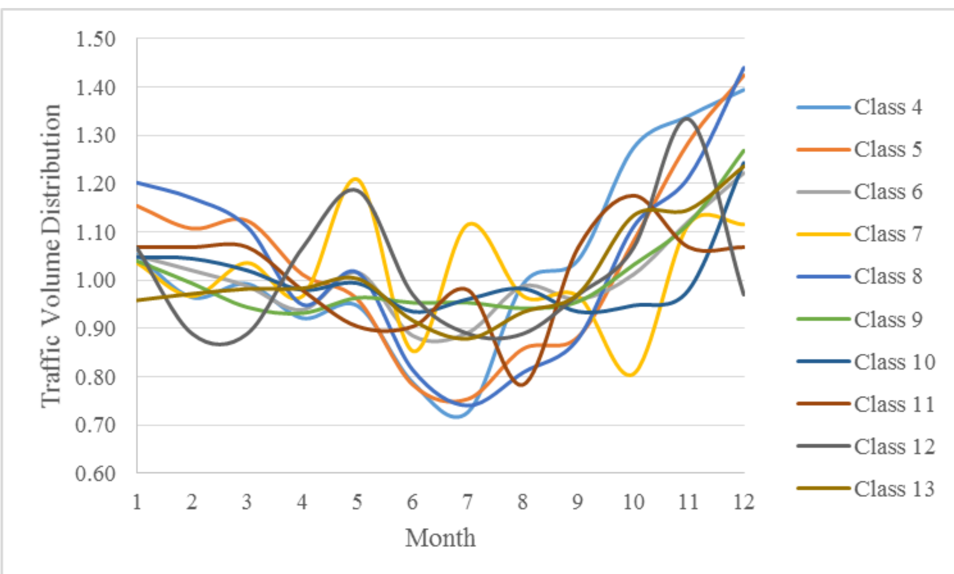

Figure 5.6 Monthly Adjustment Factors Variation

The distributions found during this study are typical of those found in this region, southeastern Wyoming. Fewer travelers take to the road during poor driving conditions of the winter months and increase to above average during the summer months. The monthly adjustment factors are less than one during months with high truck traffic to decrease the observed volume down to the average, and conversely with monthly adjustment factors larger than one during months with low truck traffic volumes.

5.2.4 Traffic Characteristics Summary

The DARWIN-ME programs requires a wide range of traffic inputs to be developed for each trial design tested. This study and report describes the methodology and results of determining regional traffic inputs for vehicle class distributions, axle load distributions, and monthly adjustment factors. Along with the traffic characteristics developed during this study, current truck traffic volumes were determined for each test section through the use of traffic counters.

Other traffic characteristics that were accepted as default values for this study were those that are typically standard nationwide and do not tend to vary depending on region. Such inputs are detailed in Table 5.6.

Table 5.6 Default Traffic Inputs Used

Input Type	Default Value Used	
Axle Configuration		
Average Axle Width	8.5	ft.
Dual Tire Spacing	12	in.
Tire Pressure	120	psi
Tandem Axle Spacing	51.6	in.
Tridem Axle Spacing	49.2	in.
Quad Axle Spacing	49.2	in.
Lateral Wander		
Mean Wheel Location	18	in.
Traffic Wander Std. Deviation	10	in.
Design Lane Width	12	ft.
Wheelbase		
Average Spacing of Short Axle	12	ft.
Average Spacing of Medium Axle	15	ft.
Average Spacing of Long Axle	18	ft.
% Trucks with Short Axle	33	%
% Trucks with Medium Axle	33	%
% Trucks with long Axle	34	%

The use of these default values coincide with the predominant input levels used for recalibration as laid out by AASHTO in the *Mechanistic-Empirical Pavement Design Guide: A Manual of Practice*. Because the inputs are default values, they were considered to be Level 3 inputs.

5.3 Local Calibration of DARWIN-ME

Local calibration of the DARWIN-ME program was performed during this study to provide local agencies with a means for designing paved roadways subjected to heavy truck traffic associated with the oil and gas energy industry. The first step in this process, as previously detailed, was developing a set of regional traffic distributions that were representative of the truck traffic seen in southeastern Wyoming, which is currently experiencing and expected to experience oil- and gas-related traffic. Once these traffic distributions had been developed, local calibration of the DARWIN-ME followed.

Analysis of local calibration for the DARWIN-ME was conducted in this study through the use of the procedure laid out by AASHTO in the *Guide for the Local Calibration of the Mechanistic-Empirical Pavement Design Guide*. By closely following this methodology, it was ensured that the local calibration done in this study can be repeated and is consistent with methodologies used by federal and state agencies.

The local calibration performed in this study was conducted using observed pavement conditions gathered through Pathway Services Inc. and roadway segmenting performed by research assistants. Pavement conditioning data were collected for Converse, Platte, Goshen, and Laramie counties' local paved roads prior to calibration efforts; however, the roadways had not yet been segmented to group like pavement conditions on the same roadway. This was completed during the summer of 2012 and produced pavement segments that had consistent distresses and smoothness, which could be analyzed during local calibration.

To begin the local calibration process, county paved road segments from the four counties being analyzed were put through a selection process to match high levels of distresses with high truck traffic volumes. This selection criteria was based on the assumptions that local paved roads were between 40 and 50 years old and that high amounts of truck traffic indicated oil and gas industry impact. By selecting local paved roads with high levels of distresses, it was ensured that each roadway was likely near the end of its design life (falling within the 40 to 50 years old assumption), as well as seeing the effects of the oil and gas industry. After applying this selection process to the sample population, 18 paved road segments were selected for local calibration. These road segments, their average daily truck traffic (ADTT), and distress values can be seen in Table 5.7.

Table 5.7 Test Segments Selected for Local Calibration

Road I.D. Number	Road Name	ADT (vehicles/day)	ADTT (trucks/day)	IRI (in./mile)	Rutting (in.)	Alligator Cracking (%)	Transverse Cracking (ft./mile)	Longitudinal Cracking (ft./mile)
3	ALBIN / LAGRANGE	108	22	161	0.295	13	1789.92	2925.12
6	BLACK HILLS	114	36	209.6	0.322	20	2708.64	4313.76
222-1	CHALK BLUFF / "78" RD	168	72	191.9	0.3	14	2449.92	1742.4
19	OLD HWY BURNS W	198	26	195.1	0.359	7	2381.28	4551.36
21	OLD YELLOWSTONE RD.	36	6	229.2	0.328	21	4498.56	1774.08
40	CEMETERY/PINE BLUFFS S RD	170	14	142	0.513	0	2122.56	1077.12
154	DEER CREEK RD	88	9	143.7	0.22	14	3273.6	3590.4
178	BUTTERMILK RD	164	23	229	0.206	0	3009.6	1198.56
191-2	VAN TASSEL RD	115	11	235.1	0.305	3	2122.56	1393.92
188	SHEEP CREEK	171	14	174.5	0.244	0	3717.12	2439.36
157	WYNCOTE RD	152	16	158.2	0.237	1	3659.04	1742.4
223-1	BORDEAUX RD	85	15	203.6	0.285	0	47.52	95.04
139	PALMER CANYON	79	12	140.5	0.275	4	686.4	1198.56
195	DEER CREEK RD	142	10	172.3	0.313	21	1008.48	834.24
196	HIGHLAND LOOP RD	173	31	234.7	0.362	36	1172.16	570.24
200	WALKER CREEK RD	154	27	195.4	0.271	17	971.52	976.8
201-2	55 RANCH RD	380	21	189.8	0.593	9	459.36	285.12
214	NATURAL BRIDGE RD	150	7	175.5	0.3	14	1235.52	876.48

The information presented in Table 5.7 was used as the observed values for IRI, longitudinal cracking, transverse cracking, alligator cracking, and rutting during local calibration. Once road segments had been selected for use in local calibration, the development of trial designs to use in the DARWIN-ME program was necessary.

The trial designs that were established for local calibration combined regional traffic distributions that were developed during this study, as well as general assumptions that were made after meetings with county road and bridge superintendents. The assumptions were made as follows:

- Road segments were constructed 40 to 50 years ago, with 45 years being accepted as the average.
- Typical asphalt pavement layer thicknesses range from 2” to 4” and use AC-20 as asphalt binder.
- Typical base layer thicknesses range from 2” to 6” of crushed base.
- Pavement layers sit on top of natural subgrade materials, likely AASHTO classification A-3 material.

From these assumptions, the trial design project information selected for use in the initial local calibration is detailed in Table 5.8.

Table 5.8 General Trial Design Project Information

Trial Design Project Information	
Design Type	New Pavement
Pavement Type	Flexible Pavement
Design Life (years)	45
Base Construction	May 1967
Pavement Construction	June 1967
Traffic Opening	September 1967
Asphalt Layer Thickness	3"
Base Layer Thickness	4"
Subgrade Layer Thickness	Semi-Infinite

By selecting "New Flexible Pavement" as the design and pavement type with a 45-year design life and construction year of 1968, the local calibration of the DARWIN-ME was conducted such that predicted distresses and smoothness would be presented as those seen in current times. In this manner, predicted distresses from the DARWIN-ME could be compared to observed distresses seen in 2012 and any bias or standard error could be analyzed. Design inputs for materials and traffic distributions (except truck traffic volumes) remained constant across all road segments being looked at, while climatic characteristics varied with where the segment was located. Material inputs for each trial design can be seen in Table 4.3 of this report. Locations of weather stations used in local calibration can be seen in Figure 4.8 of this report and detailed traffic distributions used in local calibration can be seen in Appendix 1.

Upon completing the trial designs for each of the 18 road segments being analyzed in this study, DARWIN-ME projects files (.dgpx) were developed for each roadway. To establish the bias and error associated with each project using DARWIN-ME default calibration coefficients, each of the 18 road segments were designed and analyzed in the DARWIN-ME. The resulting predicted distresses and IRI values compared to the observed values can be seen in Table 5.9.

Table 9. Observed Distresses vs. Default Predicted Distresses

Road Number	Road Name	ADTT	Observed Distresses					Predicted Distresses				
			IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking	IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
		(trucks/day)	(in./mile)	(in.)	(%)	(ft./mile)	(ft./mile)	(in./mile)	(in.)	(%)	(ft./mile)	(ft./mile)
3	ALBIN / LAGRANGE	22	161	0.30	13.00	1789.92	2925.12	199.11	0.39	1.14	1928.05	1359.86
6	BLACK HILLS	36	209.6	0.32	20.00	2708.64	4313.76	200.84	0.42	2.96	1928.05	1693.13
222-1	CHALK BLUFF / "78" RD	72	191.9	0.30	14.00	2449.92	1742.4	204.3	0.48	10.73	1928.05	2460.77
19	OLD HWY BURNS W	26	195.1	0.36	7.00	2381.28	4551.36	199.65	0.4	1.37	1928.05	1461.92
21	OLD YELLOWSTONE RD.	6	229.2	0.33	21.00	4498.56	1774.08	195.73	0.31	0.81	1928.05	751.49
40	CEMETERY/PINE BLUFFS S	14	142	0.51	0.00	2122.56	1077.12	197.79	0.36	0.93	1928.05	1119.36
154	DEER CREEK RD	9	143.7	0.22	14.00	3273.6	3590.4	202.97	0.35	0.86	2691.59	873.02
178	BUTTERMILK RD	23	229	0.21	0.00	3009.6	1198.56	205.91	0.42	1.23	2691.59	1327.94
191-2	VAN TASSEL RD	11	235.1	0.31	3.00	2122.56	1393.92	203.53	0.37	0.89	2691.59	960.87
188	SHEEP CREEK	14	174.5	0.24	0.00	3717.12	2439.36	204.25	0.38	0.94	2691.59	1071.49
157	WYNCOTE RD	16	158.2	0.24	1.00	3659.04	1742.4	204.67	0.39	0.98	2691.59	1136.11
223-1	BORDEAUX RD	15	203.6	0.29	0.00	47.52	95.04	197.7	0.36	0.95	1928.05	1154.3
139	PALMER CANYON	12	140.5	0.28	4.00	686.4	1198.56	197.38	0.35	0.9	1928.05	1045.6
195	DEER CREEK RD	10	172.3	0.31	21.00	1008.48	834.24	203.26	0.36	0.87	2691.59	917.88
196	HIGHLAND LOOP RD	31	234.7	0.36	36.00	1172.16	570.24	207.08	0.45	2.09	2691.59	1511.12
200	WALKER CREEK RD	27	195.4	0.27	17.00	971.52	976.8	206.52	0.43	1.53	2691.59	1422.92
201-2	55 RANCH RD	21	189.8	0.59	9.00	459.36	285.12	205.59	0.41	1.13	2691.59	1277.1
214	NATURAL BRIDGE RD	7	175.5	0.30	14.00	1235.52	876.48	202.31	0.34	0.83	2691.59	771.62

Once the predicted and observed distresses were obtained, Equation 5.4 and Equation 5.5 were used to determine if there was bias and what the associated sum of squared errors was.

Equation 5.4

$$Bias = \frac{\sum Difference\ between\ Predicted\ and\ Observed\ Distress}{Numberof\ Road\ Segments\ Being\ Analyzed\ (18)}$$

Equation 5.5

$$Sum\ of\ Squared\ Errors\ (SSE) = \sum_{i=1}^{18}(Predicted\ Distress_i - Observed\ Distress_i)^2$$

By analyzing the bias and the sum of squared errors between predicted and observed distresses, one is able to determine if the DARWIN-ME is typically over or under predicting distresses, as well as measure how well the predicted distresses fit the observed values. Bias and sum of squared errors results from the initial DARWIN-ME run with default calibration coefficients can be seen in Table 5.10.

Table 5.10 Average Difference and SSE - Default Calibration Coefficients

County	Road Number	Road name	IRI (in./mile)	Rutting (in.)	Alligator Cracking (%)	Transverse Cracking (ft./mile)	Longitudinal Cracking (ft./mile)
LARAMIE	3	ALBIN / LAGRANGE	38.11	0.095	-11.86	138.13	-1565.26
LARAMIE	6	BLACK HILLS	-8.76	0.098	-17.04	-780.59	-2620.63
LARAMIE	222-1	CHALK BLUFF / "78" RD	12.4	0.18	-3.27	-521.87	718.37
LARAMIE	19	OLD HWY BURNS W	4.55	0.041	-5.63	-453.23	-3089.44
LARAMIE	21	OLD YELLOWSTONE RD.	-33.47	-0.018	-20.19	-2570.51	-1022.59
LARAMIE	40	CEMETERY/PINE BLUFFS S RD	55.79	-0.153	0.93	-194.51	42.24
GOSHEN	154	DEER CREEK RD	59.27	0.13	-13.14	-582.01	-2717.38
GOSHEN	178	BUTTERMILK RD	-23.09	0.214	1.23	-318.01	129.38
GOSHEN	191-2	VAN TASSEL RD	-31.57	0.065	-2.11	569.03	-433.05
GOSHEN	188	SHEEP CREEK	29.75	0.136	0.94	-1025.53	-1367.87
GOSHEN	157	WYNCOTE RD	46.47	0.153	-0.02	-967.45	-606.29
PLATTE	223-1	BORDEAUX RD	-5.9	0.075	0.95	1880.53	1059.26
PLATTE	139	PALMER CANYON	56.88	0.075	-3.1	1241.65	-152.96
CONVERSE	195	DEER CREEK RD	30.96	0.047	-20.13	1683.11	83.64
CONVERSE	196	HIGHLAND LOOP RD	-27.62	0.088	-33.91	1519.43	940.88
CONVERSE	200	WALKER CREEK RD	11.12	0.159	-15.47	1720.07	446.12
CONVERSE	201-2	55 RANCH RD	15.79	-0.183	-7.87	2232.23	991.98
CONVERSE	214	NATURAL BRIDGE RD	26.81	0.04	-13.17	1456.07	-104.86
		Average Bias	**14.31**	**0.069**	**-9.05**	**279.25**	**-514.91**
		SSE	**20,106.89**	**0.27**	**3,101.74**	**30,784,100.62**	**33,484,713.74**

As can be seen from Table 5.10, there were significant amounts of bias when looking at the difference between predicted and observed distresses using default calibration coefficients in the DARWIN-ME. The sum of squared errors (SSE) were also extremely high. Because of these two observations, it was deemed necessary that the calibration coefficients would have to be altered to reduce the bias and SSE. In order to do this, the modeling equations used within the DARWIN-ME were analyzed to determine how altering each calibration coefficient would affect the predicted distresses.

Hot-mix asphalt (HMA), base, and subgrade rutting were the first equations to be analyzed. These equations were developed for use in the DARWIN-ME through field calibration on HMA mixtures and unbound materials. The equations used by the DARWIN-ME to determine total rutting and rutting only in the asphalt concrete are provided in Equation 5.6 and Equation 5.7 (AASHTO, 2008).

Equation 5.6

$$\Delta_{p(HMA)} = \varepsilon_{p(HMA)} h_{HMA} = \beta_{1r} k_z \varepsilon_{r(HMA)} 10^{k_{2r}\beta_{2r}} T^{k_{3r}\beta_{3r}}$$

where:

$\Delta_{p(HMA)}$ = Accumulated permanent or plastic vertical deformation in the HMA layer/sub layer, in.,
$\varepsilon_{p(HMA)}$ = Accumulated permanent or plastic axial strain in the HMA layer/sub layer, in./in.,
h_{HMA} = Thickness of HMA layer/sublayer, in.,
$\varepsilon_{r(HMA)}$ = Resilient or elastic strain calculated by the structural response model at mid-depth of each HMA sublayer, in./in.,
$\beta_{1r}, \beta_{2r}, \beta_{3r}$, = Local or mixture field calibration constants; for the global calibration, these constants were all set to 1.0,
k_z = Depth Confinement factor,
$k_{1r,2r,3r}$ = Global field calibration parameters (from the NCHRP 1-40D recalibration),
T = Mix or pavement temperature, °F,

$\Delta_{p(HMA)}$ provides the amount of rutting within the asphalt pavement layer. To determine the amount of rutting, or permanent vertical deformation, in the support layers, Equation 5.7 is used (AASHTO, 2008).

Equation 5.7

$$\Delta_{p(soil)} = \beta_{s1} k_{s1} \varepsilon_v h_{soil} \left(\frac{\varepsilon_0}{\varepsilon_r}\right) e^{-\left(\frac{\rho}{n}\right)^{\beta}}$$

where:

$\Delta_{p(soil)}$ = Permanent or plastic deformation for the layer/sub layer, in.,
n = Number of axle-load applications,
ε_0 = Intercept determined from laboratory repeated load permanent deformation tests, in,/in.,
ε_r = Resilient strain imposed in laboratory test to obtain material properties ε_0, ε, and ρ, in./in.,
ε_v = Average vertical resilient or elastic strain in the layer/sub layer and calculated by the structural response model, in./in.,
h_{soil} = Thickness of the unbound layer/sub layer, in.,
k_{s1} = Global calibration coefficients; k_{s1} =1.673 for granular materials and 1.35 for fine-grained materials, and,
β_{s1} = Local calibration constant for the rutting in the unbound layers; the local calibration constant was set to 1.0 for the global calibration effort.

Because only total rutting was measured on the roadway segments being looked at in this study, Equation 5-6 and Equation 5.7 had to be analyzed to determine how the local calibration constants ($\beta_{1r}, \beta_{2r}, \beta_{3r}$ for HMA rutting and β_{s1} for soil rutting) could be altered to reduce bias and the sum of squared errors between observed and predicted rutting.

The DARWIN-ME uses incremental (ΔDI) and cumulative damage index (DI) in its calculation of fatigue cracking, which includes both longitudinal and alligator cracking. The cumulative DI is represented as a function of incremental DI as seen in Equation 5.8 (AASHTO, 2008).

Equation 5.8

$$DI = \sum (\Delta DI)_{j,m,l,p,T} = \sum \left(\frac{n}{N_{f-HMA}}\right)_{j,m,l,p,T}$$

where:

n = Actual number of axle-load applications within a specific time period,
j = Axle-load interval,
m = Axle load type (single, tandem, tridem, quad, or specific axle configuration),
l = Truck type using the truck classification groups included in the DARWIN-ME,
p = Month, and
t = Median temperature for the five temperature intervals or quintiles used to subdivide each month, °F.

Next, using the damage index calculated from Equation 5-8, fatigue cracking that originates from the bottom of the HMA layer and propagates to the surface, referred to in this report as alligator cracking, is determined by the DARWIN-ME using Equation 5.9 (AASHTO, 2008).

Equation 5.9

$$FC_{Bottom} = \left(\frac{1}{60}\right)\left(\frac{C_4}{1 + e^{(C_1 C_1{}^* + C_2 C_2{}^* Log(DI_{Bottom} * 100))}}\right)$$

where:

FC_{Bottom} = Area of alligator cracking that initiates at the bottom of the HMA layers, % of the total lane area,
DI_{Bottom} = Cumulative damage index at the bottom of the HMA layers,
C_1, C_2, C_4 = Transfer function regression constants; C_4 = 6,000, C_1 = 1.00, and C_2 = 1.00
$C_2^* = -2.40874 - 39.748(1 + H_{HMA})^{-2.856}$
H_{HMA} = Total HMA thickness, in., and
$C_1^* = -2C_2^*$

From Equation 5.9, it can be seen that the variables $C_1, C_2, and\ C_4$ can be altered to reduce bias and sum of squared errors between predicted and observed alligator cracking.

Longitudinal cracking is also calculated using the damage index. The equation used for determining predicted top-down fatigue cracking (longitudinal cracking) can be seen in Equation 5.10 (AASHTO, 2008).

Equation 5.10

$$FC_{Top} = 10.56\left(\frac{C_4}{1 + e^{(C_1 - C_2 Log(DI_{Top}))}}\right)$$

where:

FC_{Top} = Length of longitudinal cracks that initiate at the top of the HMA layer, ft./mi.,
DI_{Top} = Cumulative damage index near the top of the HMA surface, and
C_1, C_2, C_4 = Transfer function regression constants; C_1 = 7.00; C_2 = 3.5; and C_4 = 1,000

As with the function used to calculate alligator cracking, the transfer function regression constants C_1, C_2 and C_4 can be altered in the longitudinal cracking equation in order to reduce bias and the sum of squared errors between observed and predicted distress.

Transverse cracking is calculated by the DARWIN-ME using an assumed relationship between the probability distribution of the log of the crack depth to HMA-layer thickness ratio and the percent of cracking. This relationship is shown in Equation 5.11 (AASHTO, 2008).

Equation 5.11

$$TC = \beta_{t1} N \left[\frac{1}{\sigma_d} Log\left(\frac{C_d}{H_{HMA}}\right)\right]$$

where:

TC = Predicted amount of thermal cracking, ft./mi.,

B_{t1} = Regression coefficient determined through global calibration (400),

$N[z]$ = Standard normal distribution evaluated at [z],

σ_d =Standard deviation of the log of the depth of cracks in the pavement (0.769), in.,

C_d = Crack depth, in., and

H_{HMA} = Thickness of the HMA layers, in.

In order to reduce bias and sum of squared errors between predicted and observed transverse cracking, the regression coefficient β_{t1} can be altered. Although this is the methodology that would be used for calibration of the transverse cracking model within the DARWIN-ME, this equation was not analyzed during this study. Due to the reality that the pavement structure was assumed to be equal for all road segments being looked at, and that many of the roads shared the same climatic characteristics, there was no variation of predicted transverse cracking when considering roads using the same weather stations for climate information. Because of this, researchers were unable to calibrate the transverse cracking model within the DARWIN-ME.

In addition to the distress equations provided, smoothness (IRI) is calculated and can be calibrated in the DARWIN-ME in a similar fashion. Because IRI is a function of the other distresses as well as initial IRI, they are accounted for in Equation 5.12.

Equation 5.12

$$IRI = IRI_o + 0.0150(SF) + 0.400(FC_{Total}) + 0.0080(TC) + 40.0(RD)$$

where:

IRI = Predicted terminal IRI, in./mi.,
IRI_o = Initial IRI after construction, in./mi.,
$FC_{Total} = FC_{Bottom} + FC_{Top}$ = Area of fatigue cracking, percent of total lane area,
TC = Length of transverse cracking, ft./mi.,
RD = Average rut depth, in.

Equation 5.13

$$SF = Age[0.02003(PI + 1) + 0.007947(Precip + 1) + 0.000636(FI + 1)]$$

where:

Age = Pavement age, yr.,
PI = Percent plasticity index of the soil,
$Precip$ = Average annual precipitation or rainfall, in., and
FI = Average annual freezing index, °F days

Within the IRI equation shown in Equation 5.12, the values 0.0150, 0.400, 0.0080, and 40.0 correspond to calibration coefficients C_4, C_2, C_3, and C_1, respectively. In order to calibrate the IRI transfer function in the DARWIN-ME, these calibration coefficients can be altered to reduce the bias and sum of squared errors between predicted and measured IRI. Equation 5.13 is used in order to calculate the project site factor, which IRI is a function of.

After analysis of all of the distress equations provided, the distress response to altering each calibration coefficient was determined so that appropriate adjustments could be made to reduce bias and sum of squared errors. The findings of this analysis are provided in Table 5.11.

Table 5.11 Calibration Coefficient's Effect on Predicted Distress

Distress Type/ Calibration Coefficient	Action Taken	Effect of Predicted Distress
Total Rutting		
B_{1r}	Increase	Increase
B_{2r}	Increase	Increase
B_{3r}	Increase	Increase
Subgrade Rutting		
k_{s1}	Increase	Increase
Alligator Cracking		
C_1	Increase	Decrease
C_2	Increase	Decrease
C_4	Increase	Increase
Longitudinal Cracking		
C_1	Increase	Decrease
C_2	Increase	Increase
C_4	Increase	Increase
IRI		
C_1	Increase	Increase
C_2	Increase	Increase
C_3	Increase	Increase
C_4	Increase	Increase

Once the relationships provided in Table 5.11 were established, the process of altering the calibration coefficients in order to reduce bias and the sum of squared errors between predicted and observed distresses began. In order to complete this process, an iterative approach of changing the calibration coefficients and measuring the reduction/increase in bias and SSE was used. To complete the initial calibration procedure, a total of 30 iterations were used, producing great success in decreasing both bias and SSE. The results of the final iteration, comparing predicted distresses and IRI to observed values, can be seen in Table 5.12; and the results of each iteration can be seen in Appendix 3.

Table 5.12 Iteration 30 Predicted vs. Observed Distresses

County	Road Number	Road Name	ADTT	Observed Distresses					Iteration 30 Predicted Distresses				
				IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking	IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
			(trucks/day)	(in./mile)	(in.)	(%)	(ft./mile)	(ft./mile)	(in./mile)	(in.)	(%)	(ft./mile)	(ft./mile)
LARAMIE	3	ALBIN / LAGRANGE	22	161.00	0.30	13.00	1789.92	2925.12	188.22	0.32	10.92	1927.73	1899.24
LARAMIE	6	BLACK HILLS	36	209.60	0.32	20.00	2708.64	4313.76	191.23	0.35	16.15	1927.73	2118.13
LARAMIE	222-1	CHALK BLUFF / "78" RD	72	191.90	0.30	14.00	2449.92	1742.40	196.38	0.41	29.07	1927.73	2369.77
LARAMIE	19	OLD HWY BURNS W	26	195.10	0.36	7.00	2381.28	4551.36	189.29	0.33	12.38	1927.73	1982.55
LARAMIE	21	OLD YELLOWSTONE RD.	6	229.20	0.33	21.00	4498.56	1774.08	183.23	0.25	5.17	1927.73	1300.69
LARAMIE	40	CEMETERY/PINE BLUFFS S RD	14	142.00	0.51	0.00	2122.56	1077.12	186.25	0.29	8.51	1927.73	1698.06
GOSHEN	154	DEER CREEK RD	9	143.70	0.22	14.00	3273.60	3590.40	186.18	0.29	6.69	2691.59	1439.59
GOSHEN	178	BUTTERMILK RD	23	229.00	0.21	0.00	3009.60	1198.56	190.56	0.35	11.68	2691.59	1883.94
GOSHEN	191-2	VAN TASSEL RD	11	235.10	0.31	3.00	2122.56	1393.92	186.97	0.3	7.53	2691.59	1536.47
GOSHEN	188	SHEEP CREEK	14	174.50	0.24	0.00	3717.12	2439.36	188.03	0.32	8.69	2691.59	1650.59
GOSHEN	157	WYNCOTE RD	16	158.20	0.24	1.00	3659.04	1742.40	188.66	0.32	9.39	2691.59	1714.11
PLATTE	223-1	BORDEAUX RD	15	203.60	0.29	0.00	47.52	95.04	186.55	0.29	8.86	1927.73	1731.45
PLATTE	139	PALMER CANYON	12	140.50	0.28	4.00	686.40	1198.56	185.62	0.28	7.77	1927.73	1624.8
CONVERSE	195	DEER CREEK RD	10	172.30	0.31	21.00	1008.48	834.24	186.59	0.29	7.12	2691.59	1489.68
CONVERSE	196	HIGHLAND LOOP RD	31	234.70	0.36	36.00	1172.16	570.24	192.36	0.37	14.47	2691.59	2015.46
CONVERSE	200	WALKER CREEK RD	27	195.40	0.27	17.00	971.52	976.80	191.5	0.36	13	2691.59	1954.92
CONVERSE	201-2	55 RANCH RD	21	189.80	0.59	9.00	459.36	285.12	190.05	0.34	11.03	2691.59	1842.1
CONVERSE	214	NATURAL BRIDGE RD	7	175.50	0.30	14.00	1235.52	876.48	185.28	0.27	5.77	2691.59	1323.72

Table 5.13 Bias and SSE attained from Iteration 30

County	Road Number	Road name	Default Calibration Coefficients IRI (in./mile)	Rutting (in.)	Alligator Cracking (%)	Transverse Cracking (ft./mile)	Longitudinal Cracking (ft./mile)	Iteration 30 Calibration Coefficients IRI (in./mile)	Rutting (in.)	Alligator Cracking (%)	Transverse Cracking (ft./mile)	Longitudinal Cracking (ft./mile)
LARAMIE	3	ALBIN / LAGRANGE	38.11	0.095	-11.86	138.13	-1565.26	27.22	0.025	-2.08	137.81	-1025.88
LARAMIE	6	BLACK HILLS	-8.76	0.098	-17.04	-780.59	-2620.63	-18.37	0.028	-3.85	-780.91	-2195.63
LARAMIE	222-1	CHALK BLUFF / "78" RD	12.4	0.18	-3.27	-521.87	718.37	4.48	0.11	15.07	-522.19	627.37
LARAMIE	19	OLD HWY BURNS W	4.55	0.041	-5.63	-453.23	-3089.44	-5.81	-0.029	5.38	-453.55	-2568.81
LARAMIE	21	OLD YELLOWSTONE RD.	-33.47	-0.018	-20.19	-2570.51	-1022.59	-45.97	-0.078	-15.83	-2570.83	-473.39
LARAMIE	40	CEMETERY/PINE BLUFFS S RD	55.79	-0.153	0.93	-194.51	42.24	44.25	-0.223	8.51	-194.83	620.94
GOSHEN	154	DEER CREEK RD	59.27	0.13	-13.14	-582.01	-2717.38	42.48	0.07	-7.31	-582.01	-2150.78
GOSHEN	178	BUTTERMILK RD	-23.09	0.214	1.23	-318.01	129.38	-38.44	0.144	11.68	-318.01	685.38
GOSHEN	191-2	VAN TASSEL RD	-31.57	0.065	-2.11	569.03	-433.05	-48.13	-0.005	4.53	569.03	142.55
GOSHEN	188	SHEEP CREEK	29.75	0.136	0.94	-1025.53	-1367.87	13.53	0.076	8.69	-1025.53	-788.77
GOSHEN	157	WYNCOTE RD	46.47	0.153	-0.02	-967.45	-606.29	30.46	0.083	8.39	-967.45	-28.29
PLATTE	223-1	BORDEAUX RD	-5.9	0.075	0.95	1880.53	1059.26	-17.05	0.005	8.86	1880.21	1636.41
PLATTE	139	PALMER CANYON	56.88	0.075	-3.1	1241.65	-152.96	45.12	0.005	3.77	1241.33	426.24
CONVERSE	195	DEER CREEK RD	30.96	0.047	-20.13	1683.11	83.64	14.29	-0.023	-13.88	1683.11	655.44
CONVERSE	196	HIGHLAND LOOP RD	-27.62	0.088	-33.91	1519.43	940.88	-42.34	0.008	-21.53	1519.43	1445.22
CONVERSE	200	WALKER CREEK RD	11.12	0.159	-15.47	1720.07	446.12	-3.9	0.089	-4	1720.07	978.12
CONVERSE	201-2	55 RANCH RD	15.79	-0.183	-7.87	2232.23	991.98	0.25	-0.253	2.03	2232.23	1556.98
CONVERSE	214	NATURAL BRIDGE RD	26.81	0.04	-13.17	1456.07	-104.86	9.78	-0.03	-8.23	1456.07	447.24
		Average Bias	**14.31**	**0.069**	**-9.05**	**279.25**	**-514.91**	**0.66**	**0.000**	**0.01**	**279.11**	**-0.54**
		SSE	**20106.89**	**0.267**	**3101.74**	**30784100.62**	**33484713.74**	**16347.39**	**0.182**	**1791.26**	**30784908.10**	**28172852.41**

In Iteration 30 of the initial calibration effort, the bias and sum of squared errors were reduced significantly. The bias and SSE associated with this final calibration, compared with the bias and SSE associated with default calibration coefficients, can be seen in Table 5.13. Iteration 30 of the calibration effort produced what is considered to be optimized conditions for both reducing bias and SSE. Table 5.14 shows the final set of calibration coefficients that were developed through this process compared to the global default calibration coefficients embedded into the DARWIN-ME.

Table 5.14 Localized Calibration Coefficients

Global Calibration Coefficients		Local Calibration Coefficients from Iteration 30	
AC Cracking		**AC Cracking**	
C1 Bottom	1	C1 Bottom	0.3
C1 Top	7	C1 Top	3.25
C2 Bottom	1	C2 Bottom	0.535
C2 Top	3.5	C2 Top	0.43435
C3 Bottom	6000	C3 Bottom	3675
C4 Top	1000	C4 Top	1300
AC Rutting		**AC Rutting**	
βr1	1	βr1	1.09
βr2	1	βr2	1
βr3	1	βr3	1
Subgrade Rutting		**Subgrade Rutting**	
Coarse SR, Bs1	1	Coarse SR, BS1	0.95
Fine SR, Bs1	1	Fine SR, Bs1	0.69
IRI		**IRI**	
C1	40	C1	27
C2	0.4	C2	0.48
C3	0.008	C3	0.0015
C4	0.015	C4	0.0152

The localized calibration coefficients presented in Table 5.14 produced the lowest bias and standard error possible during this calibration; and thus provide better prediction capabilities when used with the DARWIN-ME for design of local paved roads that experience heavy truck traffic associated with the oil and gas industry. To demonstrate the significance of the reduction in bias and SSE, a paired t-test was used to compare those calculated using default and locally calibrated coefficients. The resulting p-values were compared to a 0.05 level of significance in testing the following hyporeport:

$$H_0: Mean\ Difference\ Between\ Default\ and\ Calibrated\ Bias/SSE = 0$$

$$H_1: Mean\ Difference\ Between\ Default\ and\ Calibrated\ Bias/SSE \neq 0$$

The paired t-test was conducted in the statistical analysis program R, which produced p-values of 0.3963 when considering bias and 0.3905 when considering SSE. Because both these values are larger than the 0.05 level of significance, the null hyporeport (H_0) is rejected in favor of the alternative (H_1). This indicates there is a significant difference between the bias/SSE calculated using the default calibration coefficients and those using locally calibrated coefficients.

5.4 AASHTO vs. DARWIN-ME Comparisons

As part of implementing the DARWIN-ME in Wyoming in conjunction with the *1993* AASHTO Design Guide on local paved roads, typical designs were developed for both new and rehabilitated flexible pavements. These designs were made to incorporate different rehabilitation strategies based on the roads' current conditions and widths. Within those rehabilitation strategies, designs for 2-R/4-R and 5-R scenarios were established. These typical designs include a thick overlay – greater than 2 inches – for 2-R/4-R and complete reconstruction or new construction for 5-R. The rehabilitation strategies described above have been developed for pavement preservation on local paved roads. Within these strategies, designs for high, medium, and low truck traffic volumes were also developed. The breaks for each classification were considered as follows:

- High Truck Traffic: > 300 trucks/day
- Medium Truck Traffic: 100 – 300 trucks/day
- Low Truck Traffic: <100 trucks/day

For each design, reliability levels were selected using typical values that are used by WYDOT for secondary and miscellaneous roadways. For secondary roads, reliability is not as critical as it is for interstate or primary roadways, so a 75% reliability level was used for these local road designs.

Performance criteria were also selected based on typical WYDOT secondary and miscellaneous road values. Performance criteria are the limiting values that determine whether a specified design will provide the desired level of functionality. After examining the values that WYDOT typically uses for secondary roadways, the following performance criteria were selected:

- Alligator Cracking: 25%
- Total Rutting: 0.67 inches
- Transverse Cracking: 2,500 feet per mile
- International Roughness Index (IRI): 170 inches per mile
- Longitudinal Cracking: 2,500 feet per mile
- Design Life: 20 years

When analyzing each design, the feasibility of an overlay was considered along with the practicality of constructing the road within the prescribed layer thicknesses. WYDOT currently limits its overlay thicknesses to no less than 2 inches. Therefore, a minimum overlay thickness of 2 inches was selected. Also, although AC-20 asphalt was considered to be the asphalt type used during calibration, it is not what would typically be used now. Due to this fact, AC-20 was considered to be the asphalt type on the existing roadway while PG 58-28 was used for the overlay and new construction HMA. This is a typical asphalt type used by WYDOT and probably what would be used most often on county roads (WYDOT, 2012). Aside from asphalt type, typical materials used by WYDOT on secondary roads were also used in design. A-1-a crushed gravel was used as base material while A-2-4 was used as the subgrade material. Material properties for both these materials were used according to typical values that WYDOT achieves in its laboratory testing.

When considering a design for overlay treatment in the DARWIN-ME, it is assumed that the proper treatment is applied to the existing pavement to ensure that the overlay is being applied to level pavement with minimal or treated cracking. For this to be considered with the DARWIN-ME, a mill thickness is calculated to determine how much asphalt pavement will be in place. For the designs in this report, a milling depth of 1 inch was considered for surface treatment.

The new flexible pavement and rehabilitated flexible pavement designs developed during this study did not vary significantly depending on high, medium, or low truck traffic characterizations. Each design was performed separately and considered the different amounts of traffic that would be seen in each scenario. The designs that were developed can be seen in Table 5.15 and Table 5.16.

Table 5.15 Rehabilitation Design Sections

Rehabilitation of Flexible Pavement									
Traffic	Tuck	Overlay Thickness		Existing Pavement		Base		Subgrade	
Classification	Traffic	Material	Thickness (in.)	Material	Thickness (in.)	Material	Thickness (in.)	Material	Thickness (in.)
High	300	PG 58-28	3.0	AC-20	3.0	Crushed Gravel	4.0	A-3	Semi-Infinite
Medium	200	PG 58-28	2.0	AC-20	3.0	Crushed Gravel	4.0	A-3	Semi-Infinite
Low	100	PG 58-28	2.0	AC-20	3.0	Crushed Gravel	4.0	A-3	Semi-Infinite

Table 5.16 New Construction Design Sections

New Construction									
Traffic	Tuck	HMA Layer		Base		Subgrade Layer 1		Natural Subgrade	
Classification	Traffic	Material	Thickness (in.)	Material	Thickness (in.)	Material	Thickness (in.)	Material	Thickness (in.)
High	300	PG 58-28	4.0	Crushed Gravel	6.0	A-2-4	12.0	A-2-4	Semi-Infinite
Medium	200	PG 58-28	3.0	Crushed Gravel	6.0	A-2-4	12.0	A-2-4	Semi-Infinite
Low	100	PG 58-28	3.0	Crushed Gravel	6.0	A-2-4	12.0	A-2-4	Semi-Infinite

Upon completing typical designs for new and rehabilitated design sections using the DARWIN-ME, the *1993* AASHTO Design Guide was used to develop pavement cross-sections for the same truck traffic volumes. In this manner, the AASHTO design equation for flexible pavements was utilized to construct paved cross sections much like those attained from the DARWIN-ME. Before beginning the analysis, assumptions had to be made in regard to the equation components.

- Reliability: 75%
- Standard Deviation: 0.35 (standard practice on AC pavements in the *1993 AASHTO Guide*)
- M_R: 6,000 psi (estimated value WYDOT provided project area)
- Δ PSI: 2.2
- m_1,m_2: Drainage Coefficients: 1.25 (assumed good drainage on new construction)
- Design Life: 20 years

The same truck traffic volumes that were used in the DARWIN-ME design section analysis were used during analysis with the AASHTO Guide. Based on the North Dakota State University report on oil and gas impacts in North Dakota, an average ESAL factor per front-haul miles was computed to be 1.77 (Tolliver & Dybing, 2010). Using this value, the total ESAL expectancy was calculated and applied for design.

The final step was estimating the layer coefficients for determining the new design's structural number. The asphalt layer coefficient was assumed to be 0.44. Crushed gravel with an A-1-a AASHTO soil classification was used for base material, while A-2-4 was used as the subgrade material. Material properties for both these materials were used according to typical values that WYDOT attains in its laboratory testing and projects. This provided a coefficient for road base to be 0.14 and coefficient of compacted subgrade to be 0.06. These values were used in determining necessary thicknesses of each layer for each design scenario.

When considering overlay design, the average effective structural number of 1.43 of the existing surface section was utilized. The remainder of the structural number required for 20-year design had to be derived from asphalt overlay only. This resulted in large overlay thicknesses.

Once typical designs were completed using both the DARWIN-ME and AASHTO Design Guide, the variance in layer thickness was examined to demonstrate what benefits, if any, were achieved from using the DARWIN-ME. As can be seen in Table 5.17, the largest of differences occurred when considering an asphalt overlay. Minimal differences were noted between the AASHTO Design Guide and the DARWIN-ME regarding thickness of new construction of asphalt pavements, with the sole difference occurring in the "Medium" traffic category where the AASHTO design was 0.5 inches thicker than the DARWIN-ME design.

Table 5.17 Comparison of AASHTO Design Guide and DARWIN-ME Cross Sections

	Reconstruction						Overlay	
	AASHTO Design			MEPDG Design			AASHTO Design	MEPDG Design
Traffic Classification	Thickness Pavement	Base	Subgrade	Thickness Pavement	Base	Subgrade	Overlay Thickness	Overlay Thickness
High	4	6	12	4	6	12	5.5	3
Medium	3.5	6	12	3	6	12	5	2
Low	3	6	12	3	6	12	4	2

The greatest differences between the two design methodologies are in the overlay designs. A 2-inch overlay was deemed sufficient for a 20-year design life for both low and medium truck traffic while the overlay thickness increased to 3 inches with high truck traffic using the DARWIN-ME. However, when considering overlays designed with the *1993 AASHTO Design Guide*, they were almost double the overlay thickness for each traffic level. The materials saved by using the DARWIN-ME to come up with an optimal design that meets performance criteria could lead to transportation agencies saving millions of dollars.

Although these designs offer a good representation of the type of design necessary for local paved roads with heavy truck traffic, project level designs need to be developed on a project-by-project basis. These designs were developed using generalized inputs for the region obtained from WYDOT and previous research, but for an optimal design to be produced, project specific data should be used. These designs are typical cross sections that meet the generalized theoretical criteria.

5.5 Sensitivity Analysis

As part of a separate analysis from the calibration efforts described in Section 5.3 of this report, a sensitivity analysis was performed to determine how robust the set of calibration coefficients developed for this study were when considering alternative layer thicknesses. This analysis was determined to be necessary as the layer thicknesses selected for use in calibration were merely averages of the generalized ranges given to researchers by county road and bridge superintendents. The goal of this sensitivity analysis was to determine how varying the assumptions for layer thicknesses would affect the ability of the DARWIN-ME to predict distresses that were similar to those observed on existing roadways.

In order to perform this analysis, a 2 to the 2 factorial with a center point was conducted. This type of statistical analysis allows researchers to determine how varying levels of a design factor affects the response variable. In this analysis, asphalt and base thicknesses were the factors being considered and the levels for each factor were the upper and lower bounds of the assumed layer thicknesses. Because there were two factors being looked at, each with two levels, the factorial design used was a 2^2 factorial with a center point, where the number of levels is the base and the number of factors is the superscript. The center point in this analysis was the combination of averages considered during initial calibration, 3" asphalt and 4" of base. To perform a two-level factorial experiment, each factor was looked at in conjunction with the possible levels. This produced five different combinations, which are expressed as the blue nodes in Figure 5.7.

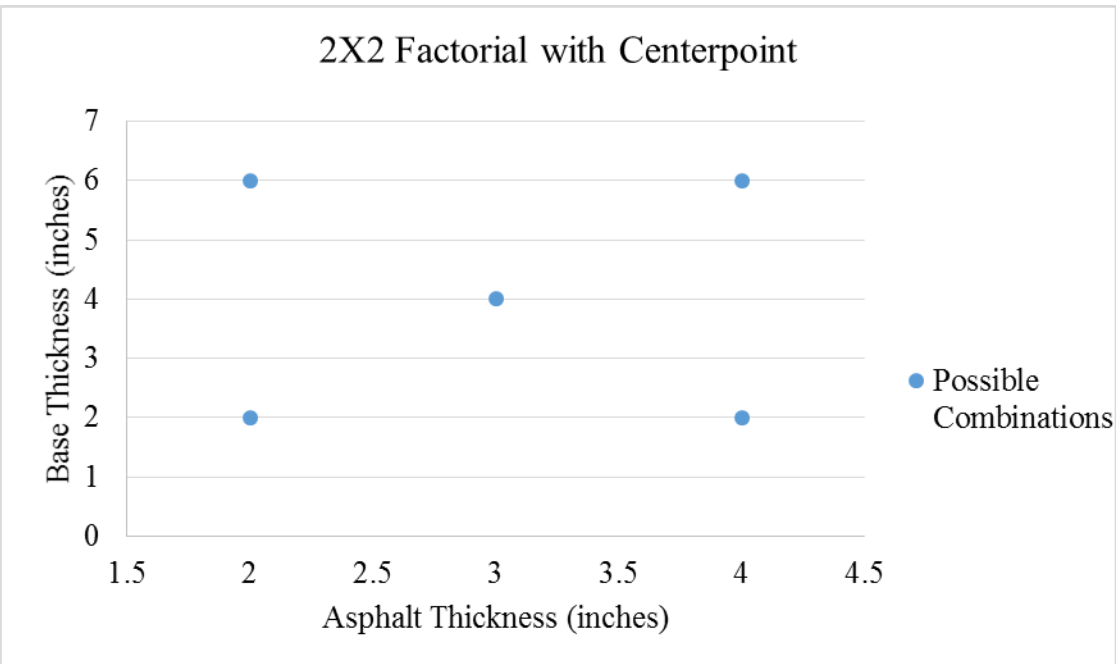

Figure 5.7 2X2 Factorial Experiment Design

Once the five layer thickness combinations had been determined, the local calibration coefficients developed for 3" of asphalt pavement and 4" of base were applied to the trial designs for each of the 18 road segments being analyzed for each layer thickness combination. This procedure was also completed in the same manner using default calibration coefficients. After completing this for both default and localized calibration coefficients, the sum of squared errors and bias were calculated for each factorial point (i.e., each layer thickness combination) and the results were analyzed.

To begin analyzing the results, the effects of asphalt and base layer thickness were first looked at when using default calibration coefficients. Linear models were developed using asphalt thicknesses and base thicknesses as the explanatory variables and sum of squared errors (SSE) and bias as the response variables. Separate models for SSE and bias were developed and the explanatory variables were considered as independent variables.

To analyze the effect that asphalt thicknesses and base thicknesses had on explaining the bias and SSE, p-values for each explanatory variable were compared at a 95% level of significance. That is, if the p-value for a given explanatory variable is greater than 0.05, one can conclude there is no significant variation within the response explained by the predictor variable. If the p-value for an explanatory variable is less than the 0.05 significance level, it is indicated that variation in the response can be described by the predictor variable. This statistical relationship was used to determine if the bias and SSE associated with IRI, rutting, alligator cracking, and longitudinal cracking were dependent on asphalt and base layer thicknesses.

The relationship between bias/SSE and layer thicknesses was first analyzed when considering default calibration coefficients. By completing this analysis first, researchers could determine how default calibration coefficients and those developed during this study differed in their capability to be used across varying layer thicknesses.

When considering the SSE associated with default calibration coefficients used across the five different factorials, it was determined that asphalt thickness played a major role in describing variation of SSE for IRI and rutting. The p-values associated with the linear models developed for SSE when using default calibration coefficients can be seen in Table 5.18.

Table 5.18 P-Values for SSE Models Using Default Calibration Coefficients

Default Calibration Coefficients - SSE		
	Asphalt	**Base**
IRI	**0.01508**	0.53214
Rutting	**0.029**	0.8315
Alligator Cracking	0.92022	0.35788
Longitudinal Cracking	0.0815	0.8527

As can be seen in Table 5.18, the p-values for IRI and rutting when considering asphalt thickness were smaller than the 0.05 level of significance. This indicates that when using default calibration coefficients, the SSE for IRI and rutting attained between predicted and observed distresses varies significantly with different asphalt layer thicknesses. This relationship can also be described using the main effects plot associated with the linear model for SSE as a function of asphalt and base layer thicknesses. A main effects plot shows the relationship between each explanatory variable and the response variable separately. Figure 5.8 displays the main effects plot for IRI when considering default SSE (the SSE calculated using default calibration coefficients) and additional main effects plots for each linear model can be seen in Appendix 4.

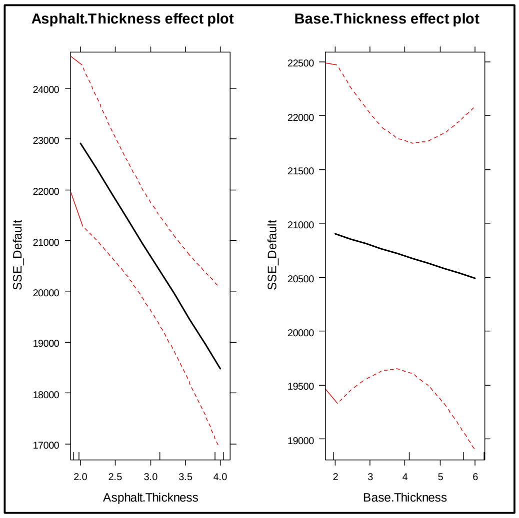

Figure 5.8 Main Effects Plot for Default IRI SSE

Information that can be gathered from the main effects plot shown in Figure 5.8 is similar to that given by the p-values for each linear model. As can be seen, there is a strong linear variation between SSE and asphalt thickness; however, there is much less when considering base thickness. The red dotted lines bordering the black solid lines on the main effects plot represent 95 % confidence bounds on the relationship between SSE and layer thickness. In the main effects plot shown in Figure 5.8, if the black solid line was horizontal, it would indicate there was no variation in SSE depending on the layer thickness. This relationship can be seen in conjunction with the confidence bounds in Figure 5.8. When considering the relationship between SSE and base thickness, the black solid line could be turned horizontal without crossing the dotted red line; meaning that there is no significant relationship between the two. However, if the black solid line corresponding to the relationship between asphalt thickness and SSE was turned horizontal, it would cross the confidence bounds, indicating that there is a significant relationship between the two.

Similar results to those seen when considering SSE calculated using default calibration coefficients were seen when analyzing the bias in the same manner. The bias for IRI and rutting were influenced significantly by the asphalt layer thicknesses. This was determined by comparing the p-values associated with the explanatory variables that were calculated when developing linear models with bias as the response variable, and asphalt thickness and base thickness as explanatory variables. A summary of these p-values can be seen in Table 5.19.

Table 5.19 P-Values for Bias Models Using Default Calibration Coefficients

Default Calibration Coefficients - Bias		
	Asphalt	Base
IRI	**0.00501**	0.42496
Rutting	**0.00256**	0.83283
Alligator Cracking	0.90465	0.37747
Longitudinal Cracking	0.0736	0.7396

As Table 5.19 displays, the p-values for asphalt thickness were less than the 0.05 significance level, and therefore significantly explain variability in the bias when using default calibration coefficients. Because it was found that when using default calibration coefficients bias and sum of squared errors of IRI and rutting were dependent on asphalt thickness, this same procedure was used to test if the same trends were noticed when using the calibration coefficients developed during this report.

When considering the effect of asphalt and base layer thicknesses on SSE using the local calibration coefficients developed during this study, it was found that there was no effect on SSE depending on which layer combination was being analyzed. All the p-values associated with asphalt and base layer thicknesses were greater than the 0.05 level of significance, indicating that the layer thicknesses did not explain any variability of the SSE. The resulting p-values and main effects plot for IRI from this analysis can be seen in Table 5.20 and Figure 5.9, respectively.

Table 5.20 P-Values for SSE Models Using Local Calibration Coefficients

Localized Calibration Coefficients - SSE		
	Asphalt	**Base**
IRI	0.442308	0.911505
Rutting	0.109	0.569
Alligator	0.06329	0.45892
Longitudinal	0.0894	0.9142

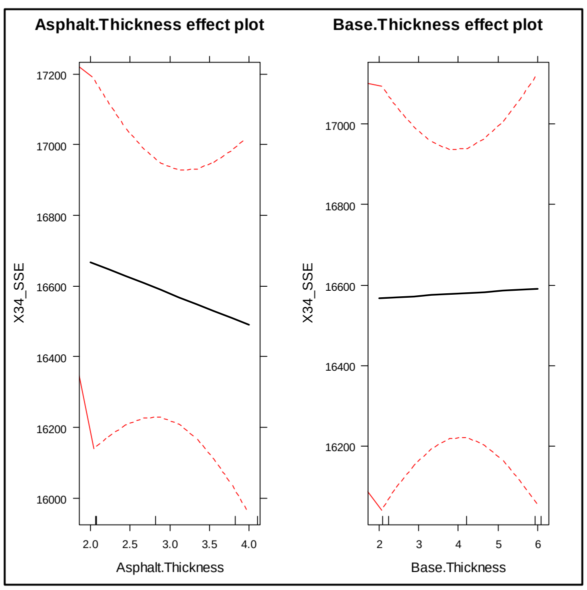

Figure 5.9 IRI Main Effects Plot Considering Local Calibration

When comparing the IRI main effects plot seen in Figure 5.8 to that seen in Figure 5.9, one can see that the confidence bounds have been widened and the relationship between asphalt thickness and SSE has a much flatter slope. This demonstrates the point that using the local calibration coefficients developed during this study allows for the sum of squared errors to remain more constant across all layer thickness combinations than with the default coefficients; that is, the local calibration coefficients are more robust and provide better prediction capabilities when considering SSE across layer thicknesses.

Although it was determined that layer thickness did not have a significant effect on the SSE when considering local calibration coefficients, results for bias when considering IRI were not the same. As seen in Table 5.21, the p-value associated with IRI and asphalt was smaller than the 0.05 significance level, indicating that the bias of predicted levels of IRI varies significantly with different asphalt thicknesses.

Table 5.21 P-Values for Bias Models Using Local Calibration Coefficients

Localized Calibration Coefficients - Bias		
	Asphalt	**Base**
IRI	**0.0301**	0.0943
Rutting	0.0658	0.627
Alligator	0.192	0.513
Longitudinal	0.0771	0.7955

Due to the bias of predicted values of IRI, when considering local calibration coefficients being affected by asphalt thickness, it was determined that in order to mitigate this occurrence calibration coefficients could be developed for each layer combination considered in this factorial experiment. This would allow those using the DARWIN-ME to select the IRI calibration coefficients that correspond to the layer thicknesses being considered in design to produce bias for IRI that was independent of layer thickness. IRI calibration coefficients were developed for each combination in the same manner as the initial calibration, and produced bias and SSE that were similar. The IRI calibration coefficients by layer thickness combination can be seen in Table 5.22.

Table 5.22 IRI Local Calibration Coefficients by Layer Thickness

Asphalt Thickness	Base Thickness	Calibration Coefficients				SSE	Bias
(inches)	(inches)	C1	C2	C3	C4	(in./mile)^2	(in./mile)
2	2	26	0.44	0.0015	0.0152	16340.79	0.762222
2	6	26	0.44	0.0015	0.0152	16346.72	0.788889
3	4	27	0.48	0.0015	0.0152	16347.39	0.658333
4	2	27	0.45	0.0015	0.0152	16317.30	-0.10944
4	6	27	0.45	0.0015	0.0152	16336.57	0.269444

After the IRI calibration coefficients were developed for each layer thickness combination, the resulting biases were compared using the same procedure as before. The result yielded calculated bias between the predicted and observed distresses that were unaffected by which layer thickness was being considered. The resulting p-values can be seen in Table 5.23.

Table 5.23 Bias P-Values for IRI Using Layer Dependent Calibration

IRI Layer Specific Calibration Coefficients - Bias		
	Asphalt	**Base**
IRI	0.0683	0.4012

As can be seen, the p-value for asphalt with no interaction term was increased to above 0.05 when using the layer dependent calibration coefficients; meaning that bias when comparing predicted to observed distresses was no longer dependent on asphalt thickness when using IRI calibration coefficients specific to layer thickness.

5.6 Summary

This section details the data analysis that was performed during this study and provides reasoning for the conclusions and deliverables resulting from this report. Traffic characteristic analysis was performed using data from WIM stations located on the U.S. and state highway system in Wyoming. From this analysis, vehicle class distributions, axle load distributions, and monthly adjustment factors were developed for use within the DARWIN-ME on local paved roads.

Local calibration of the DARWIN-ME was completed during this report in order to improve the prediction capabilities of the DARWIN-ME when being used on local paved roads experiencing heavy truck traffic. Through altering the calibration coefficients within the DARWIN-ME, the bias and sum of squared errors between predicted and observed distresses were decreased significantly, and better calibration coefficients were developed.

When comparing typical designs for low, medium, and high truck traffic, the DARWIN-ME produced significantly thinner overlay thicknesses than the AASHTO Design Guide. However, limited differences were observed when comparing new pavement designs generated using the DARWIN-ME and AASHTO Design Guide.

Due to assumptions made regarding the existing layer thicknesses of the roadways being analyzed in this report, a sensitivity analysis was performed to determine the effect that layer thicknesses have on the prediction capabilities of the DARWIN-ME. It was found that the bias, when looking at IRI, was related to asphalt thickness when using the local calibration coefficients developed during this report. Because of this, IRI calibration coefficients were developed for each layer thickness combination analyzed. It is recommended that, depending on design layer thickness, the corresponding set of IRI calibration coefficients be selected for use.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

Through this study, the DARWIN-ME was calibrated for use on local paved roads that experience heavy truck traffic associated with the oil and gas industry. Calibration efforts performed during this study utilized local traffic data resources, including weigh-in motion stations, to develop traffic distributions and characteristics that are representative of those seen on local paved roads experiencing heavy truck traffic. Along with these detailed traffic distributions, predictive models that are embedded into the DARWIN-ME were also calibrated in order to produce results that more closely matched those seen on existing roadways. These calibration procedures involved reducing the bias and sum of squared errors between predicted distresses found using the DARWIN-ME and observed distress values determined through automated pavement condition surveys.

The deliverables of this study will provide local and state agencies within the region with traffic distributions that are typically seen when dealing with the oil and gas industry, as well as calibration coefficients that provide a more realistic design when considering local paved roads. The methodology developed during this study also lays the foundation for other states looking to implement the DARWIN-ME on the local paved roads network while accounting for heavy truck traffic.

The DARWIN-ME offers significant benefits over the AASHTO Design Guide. However, the full potential of the DARWIN-ME cannot be realized without local calibration procedures taking place. This study completed those calibration procedures along with developing regional traffic distributions, which will allow those using the DARWIN-ME for local paved roads to begin incorporating the new design guide into use. This study, along with a similar study being performed on the interstate and state highway system by the Applied Research Associates for WYDOT, should advance the state of Wyoming in its quest for total implementation of the DARWIN-ME.

6.2 Conclusions

The strategies of this report included the collection of traffic and road conditioning data within Converse, Platte, Goshen and Laramie counties in order to allow for the development of traffic distributions and calibration coefficients. These deliverables are intended to be used within the DARWIN-ME for designs of local paved roads experiencing heavy truck traffic. Conclusions that were generated through the analysis of this study follow:

- WIM station data were utilized to develop vehicle class distributions, axle load distributions, and monthly adjustment factors. After comparing data from WIM stations located on the interstate system and those located on the U.S. and state highway system, it was determined there was significant differences between the two and that data pertaining to highway systems more closely resembled that of local paved roads.
    - Vehicle class distributions developed during this study indicated that FHWA Vehicle Class 5, 9, and 13 were most prevalent.
    - Axle load distributions include a massive amount of data and those developed during this study are representative of the type of loading that a local paved road experiences.
    - The monthly adjustment factors developed in this study account for seasonal variation in traffic volumes.
    - Aside from those traffic distributions developed during this study, default values for all other traffic inputs, excluding ADTT, were used during analysis.

- Automated road conditioning surveys were used to determine observed distresses on existing roadways. These data were then used in the calibration process to compare to predicted distresses from the DARWIN-ME.
    - Road condition data were utilized as part of the selection criteria for road sections to be used during calibration procedures.
- Calibration of the DARWIN-ME was performed on the local paved road network in four counties within southeast Wyoming. These counties included Converse, Platte, Goshen, and Laramie. Calibration efforts aimed at minimizing the bias and sum of squared errors between observed levels of distress and predicted levels of distress from the DARWIN-ME.
    - For assumed layer thicknesses of 3" of asphalt and 4" of base, the bias and sum of squared errors were significantly reduced through calibration.
    - Calibration was completed through an iterative process of altering model coefficients and determining the change in bias and SSE with each iteration.
    - Optimized values for each calibration coefficient were selected when bias and SSE reached minimum values.
    - Final calibration coefficients were determined to increase the predictive capabilities of the DARWIN-ME.
- Through using the DARWIN-ME for design of typical road sections, considerable differences in overlay thickness were found when compared to the AASHTO Design Guide.
    - Results were similar when comparing new construction designs, but overlay thicknesses developed using the DARWIN-ME were significantly thinner than those developed using the AASHTO Design Guide.
- In order to account for the general assumptions made regarding layer thicknesses in calibration, a sensitivity analysis was performed to determine how robust the calibration coefficients developed during this study were. A 2^2 with center point factorial experiment was conducted, in which five different layer thickness combinations were analyzed.
    - Initially, default calibration coefficients were used on all 18 test sections to calculate bias and SSE for each layer combination. Linear models and main effects plots were utilized to determine the relationship between layer thicknesses and bias/SSE.
        - It was determined that bias and SSE of IRI and rutting were dependent upon asphalt layer thickness, but not base layer thickness. Because bias and SSE were higher at lower asphalt thicknesses, it was evident that when designing roads with thin asphalt layers, the prediction capabilities of the DARWIN-ME decreased.
    - After the relationship between bias/SSE and layer thicknesses were analyzed for default calibration coefficients, the localized calibration coefficients developed during this study were analyzed in the same manner.
        - It was noted that SSE was independent of layer thicknesses for all distress types when considering local calibration coefficients.
        - Of the distress types being analyzed, only bias when considering IRI was determined to be dependent on layer thicknesses, more specifically, asphalt thickness.
        - Because of IRI's bias being dependent on asphalt thickness, specific calibration coefficients for each level of layer thicknesses were developed. It is recommended that the IRI calibration coefficients are altered to match layer thicknesses in design.

These conclusions offer a brief summary of the findings of each step in the calibration procedures utilized in this report. These findings will be made available to local agencies and WYDOT in an effort to aid in the total implementation of the DARWIN-ME. Using the conclusions of this study, the predictive capabilities of the DARWIN-ME when used on local paved roads experiencing heavy truck traffic will be increased.

6.3 Recommendations

The recommendations of this study are aimed at assisting DARWIN-ME implementation efforts for use on the local paved road network. Recommendations were developed after in-depth analysis of traffic characteristics throughout the state of Wyoming, as well as analysis of the predictive capability of the DARWIN-ME program when being used for local paved roads. By providing traffic distributions that are representative of those seen on local paved roads in Wyoming, and DARWIN-ME calibration coefficients that are specific to heavy truck traffic on local roads, pavement distresses can be better predicted when considering local roads impacted by the oil and gas industry. Specific recommendations pertaining to this study that can be applied immediately are presented below:

- The findings and results drawn from this report should be applied in conjunction with an implementation plan for asphalt pavement design on local roads that experience heavy amounts of truck traffic.
    - Due to limited funding and resources at the local agency level, it is recommended that the use of the DARWIN-ME program for design of local paved roads be performed by an external party, such WYT^2/LTAP or another consulting firm. This is recommended as the DARWIN-ME program is costly to purchase, and also because proper training and expertise is necessary for correct use of the program. Local agencies likely do not have the money or manpower to implement the DARWIN-ME on the local level themselves.
- The localized DARWIN-ME calibration coefficients and traffic distributions developed during this report are applicable for use when designing local paved roads that experience heavy truck traffic loadings, as well as heavy truck traffic volumes.
    - In addition to the main research performed during this report, it has been demonstrated that when considering minimal amounts of truck traffic on local paved roads, the DARWIN-ME program is unable to generate realistic designs. This claim is further supported by the DARWIN-ME program, which warns the user that ADTTs less than 10 trucks/day are not recommended for use.
    - However, when the pavement design is considering large amounts of truck traffic associated with the oil and gas industry, it has been shown through the research of this report that the calibration coefficients and traffic distributions developed for use within the DARWIN-ME program result in a more reliable and realistic design than when using default calibration coefficients.
- The findings of this report demonstrate the validity of the local calibration coefficients and traffic distributions that were developed for use with the DARWIN-ME.
    - The prediction capabilities of the DARWIN-ME program were significantly improved when using local calibration coefficients. The bias and sum of squared errors between predicted and observed distresses were significantly decreased and minimized when comparing results using default and local calibration coefficients.
    - It should be noted that with additional information regarding material characteristics, pavement ages, layer thicknesses, and an increased sample population, the calibration procedures used during this report can be applied to refining the calibration coefficients. Implementation and calibration are continuous processes that lead to improvement on initial calibration results. The calibration coefficients and traffic distributions developed during this study are sufficient for current implementation, but with additional information, can be improved on.

The recommendations highlighted above discuss recommendations that are provided given the research and findings that have been drawn from this report. In addition to those recommendations that can be applied immediately, recommendations for future research and advancement of this report research can be seen below:

- Continue to collect road conditioning data in the study area of this report (southeast Wyoming) as well as across the state. In doing so, multiple years of data can be used in determining the prediction capabilities of the DARWIN-ME and additional calibration efforts can be applied. If road conditioning data are collected statewide, the findings of this study can be analyzed to determine effectiveness when considering roads outside this report's study area. Additional road segments could also be analyzed with an increase in the sample population.
- It is recommended that resources be applied to re-calibrating the DARWIN-ME program with additional information regarding material characteristics and layer thicknesses of the roadway test segments being analyzed. Material characteristics and layer thicknesses can be determined through coring of the road sections as well as FWD testing of in-place roadways.
    - Knowledge of site-specific material properties and layer thicknesses would increase the hierarchical input level for materials to Level 1 or 2, instead of the Level 3 approach used during this report. The increase in certainty regarding material characteristics and layer properties would increase the reliability of the calibration.
    - Incorporation of test-segment-specific layer thicknesses would allow for the transverse cracking model within the DARWIN-ME program to be locally calibrated. This was not done during this report as predicted values for transverse cracking are a function of asphalt layer thicknesses as climatic conditions, of which asphalt layer thickness was held constant across all road segments being analyzed.
- In addition to determining material characteristics that are representative of each roadway being analyzed in calibration, it is recommended that additional resources be placed into determining traffic volumes and characteristics that are representative of what the road segment has endured through its design life. During this study, current traffic volumes and characteristics were projected back 45 years and the predicted distresses were developed.
    - It is unlikely that the road segments being analyzed during this study have seen the traffic volumes or distributions developed during this study for their entire service life.
    - Traffic volumes have likely increased over time, and a methodology for determining how much of an increase has occurred would allow for the predicted distresses generated with the DARWIN-ME program to be considerate of past as well as current traffic volumes.

The recommendations presented within this section provide steps that should be taken to implement the findings of this report, as well as how to further the research that has already taken place. If these steps are followed, successful implementation of the DARWIN-ME calibration coefficients and traffic distributions will be achievable and necessary improvements can be made.

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APPENDIX 1: AXLE LOAD DISTRIBUTION TABLES

Appendix 1.1 Single Axle Load Distribution Factors for January through June

			Single Axle Load Range																																						
Month	**Class**	**Total**	**3000**	**4000**	**5000**	**6000**	**7000**	**8000**	**9000**	**10000**	**11000**	**12000**	**13000**	**14000**	**15000**	**16000**	**17000**	**18000**	**19000**	**20000**	**21000**	**22000**	**23000**	**24000**	**25000**	**26000**	**27000**	**28000**	**29000**	**30000**	**31000**	**32000**	**33000**	**34000**	**35000**	**36000**	**37000**	**38000**	**39000**	**40000**	**41000**
January	4	100	53.04	3.87	3.87	2.83	2.35	4.46	8.12	8.12	7.35	4.21	0.85	0.31	0.31	0.31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	5	100	13.37	9.14	11.27	11.85	10.4	10.16	8.12	5.55	4.4	4.02	3.3	2.21	2.04	1.75	1.11	0.73	0.28	0.1	0.04	0.04	0.04	0.04	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	6	100	0	0.25	0.25	0.49	5.97	10.9	17.72	21.88	18	10.33	6.09	4.5	2.87	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	7	100	2.14	0.55	2.42	2.7	3.21	5.81	5.26	7.39	6.85	7.42	8.99	8.15	7.77	6.84	5.67	4.63	3.5	2.64	1.9	1.31	0.97	0.67	0.43	1.18	0.26	0.17	0.17	0.08	0.72	0.06	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0
January	8	100	2.01	4.01	7.94	13.57	15.78	16.39	15.64	12.39	5.58	4.15	1.99	0.55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	9	100	1.91	2.84	2.8	2.65	4.92	11.19	18.51	19.22	13.28	7.5	4.29	3.19	2.66	2.05	1.56	0.77	0.4	0.24	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	10	100	0.15	0.1	0.61	3.23	6.07	13.06	18.12	19.71	15.49	10.33	6.3	3.64	2.5	0.67	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	11	100	0	0	12.5	20.83	32.86	16.2	5.56	5.56	5.56	0.93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	12	100	0	6.67	10.83	10.83	10.83	27.5	16.67	16.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	13	100	7.97	7.95	6.42	5	6.38	9.63	11.72	10.8	8.51	6.31	5.5	4.34	3.47	2.62	1.71	0.95	0.36	0.22	0.07	0.06	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	4	100	13.64	0.22	1.14	2.61	5.93	11.12	19.67	21.44	20.08	2.08	1.14	0.93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	5	100	11.18	9.19	11.22	11.37	10.77	9.92	8.42	6.35	4.37	3.81	3.65	2.74	2.13	2.04	1.58	0.86	0.16	0.04	0.04	0.04	0.04	0.04	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	6	100	0	0.21	0.42	0.63	4.85	14.63	16.06	19.71	17.58	11.13	7.8	5.23	1.39	0.21	0.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	7	100	2.14	0.55	2.42	2.7	3.21	5.81	5.26	7.38	6.85	7.41	8.99	8.16	7.78	6.84	5.67	4.63	3.5	2.64	1.9	1.31	0.97	0.67	0.43	1.18	0.26	0.17	0.17	0.08	0.72	0.06	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0
February	8	100	1.55	4.67	8.12	13.25	15.17	16.28	14.27	11.19	8.6	3.04	2.41	1.45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	9	100	1.83	2.75	2.55	2.31	4.73	11.24	18.94	19.52	13.46	7.66	4.38	3.09	2.57	2.01	1.51	0.74	0.43	0.19	0.07	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	10	100	0	0	0.63	2.38	6.13	12.96	19.15	19.72	16.21	10.23	6.65	3.11	2.24	0.59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	11	100	0.93	0.93	11.2	18.7	20.55	20.56	18.24	8.89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	12	100	0	0	11.67	17.22	45	11.67	6.11	8.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	13	100	7.76	8.64	6.19	4.66	6.38	9.38	11.96	10.89	8.51	6.46	5.22	4.25	3.46	2.46	1.67	1.02	0.54	0.42	0.07	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	4	100	36.9	0.19	0.79	1.67	4.72	9.68	10.46	15.23	14.44	2.27	2.08	0.79	0.78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	5	100	12.63	10.25	12.11	11.82	10.91	9.76	7.71	5.56	4.51	3.61	3.48	2.76	1.93	1.6	0.71	0.3	0.09	0.06	0.04	0.04	0.04	0.04	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	6	100	0	0.23	0.39	0.63	6.84	14.18	17.39	17.4	16.64	14.59	7.37	3.41	0.52	0.23	0.16	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	7	100	2.14	0.55	2.42	2.7	3.21	5.81	5.26	7.38	6.85	7.43	8.99	8.15	7.77	6.84	5.67	4.63	3.5	2.64	1.9	1.31	0.97	0.67	0.43	1.18	0.26	0.17	0.17	0.08	0.72	0.06	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0
March	8	100	2.91	4.76	7.51	11.97	15.12	14.48	14.2	12.54	10.06	3.41	2.59	0.45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	9	100	2.16	2.75	2.31	2.21	4.8	11.13	18.5	19.23	13.78	7.9	4.56	3.25	2.65	2.03	1.36	0.89	0.36	0.11	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	10	100	0.19	0	0.52	2.35	7.06	11.81	18.37	20.62	16.37	9.77	6.44	3.91	2.16	0.43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	11	100	0	1.25	13.33	22.71	24.79	22.71	13.13	1.04	1.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	12	100	3.57	7.14	7.14	19.64	7.14	21.73	21.73	11.9	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	13	100	7.41	8.43	6.2	4.44	5.96	9.4	12.15	11.2	8.81	6.35	5.31	4.8	3.72	2.62	1.59	0.98	0.33	0.18	0.11	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	4	100	40.44	0.16	0.78	1.55	7.39	8.32	10.49	11.88	10.94	3.72	2.94	1.39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	5	100	12.98	9.47	11.76	11.6	10.97	10.1	8.16	5.77	4.24	3.42	3.04	2.65	1.88	1.5	1.42	0.46	0.34	0.05	0.03	0.03	0.03	0.03	0.03	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	6	100	0	0.23	0.46	1.03	9.11	13.68	18.48	17.89	15.71	13.14	5.88	2.44	0.86	0.81	0.23	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	7	100	2.14	0.55	2.42	2.7	3.21	5.81	5.26	7.38	6.85	7.42	8.99	8.16	7.77	6.84	5.67	4.63	3.5	2.64	1.9	1.31	0.97	0.67	0.43	1.18	0.26	0.17	0.17	0.08	0.72	0.06	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0
April	8	100	2.98	3.98	7.48	11.39	13.69	15.3	14.94	11.93	10.44	3.65	2.31	1.17	0.73	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	9	100	2.38	2.63	2.22	2.13	5.14	11.94	18.84	19.19	13.45	7.59	4.35	3.17	2.52	1.96	1.25	0.71	0.34	0.13	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	10	100	0.01	0.29	0.29	2.29	5.87	12.54	18.94	21.17	15.69	10.88	6.33	3.74	1.3	0.66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	11	100	0	0	15.52	19.34	19.34	20.03	14.65	9.03	2.08	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	12	100	0	5	5	8.13	12.29	16.25	23.75	19.58	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	13	100	7.62	8.29	6.63	4.77	5.92	9.58	12.01	10.99	8.6	6.71	5.3	4.27	3.8	2.19	1.49	0.92	0.58	0.22	0.08	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	4	100	42.13	0	0.73	1.23	2.58	14.45	16.72	9.75	7.53	2.52	1.12	0.62	0.62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	5	100	13.94	9.82	11.92	11.42	10.97	9.72	7.97	5.38	4.36	3.52	2.96	2.31	1.77	1.57	1.09	0.61	0.15	0.1	0.1	0.08	0.08	0.08	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	6	100	0	0.38	0.82	1.78	8.62	15.31	21.13	19.81	16.63	7.21	3.98	2.49	1.34	0.44	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	7	100	2.14	0.55	2.42	2.7	3.21	5.81	5.26	7.38	6.85	7.41	9.01	8.15	7.77	6.84	5.67	4.63	3.5	2.64	1.9	1.31	0.97	0.67	0.43	1.18	0.26	0.17	0.17	0.08	0.72	0.06	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0
May	8	100	4.18	4.86	7.93	12.63	13.89	14.83	13.58	10.83	7.91	5.29	2.79	1.01	0.2	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	9	100	2.41	2.69	2.37	2.62	5.74	12.95	19.43	18.76	12.9	7.03	4.02	2.88	2.24	1.8	1.11	0.7	0.28	0.06	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	10	100	0.19	0	0.9	2.75	6.56	13.02	19.9	21.16	16.25	9.39	5.76	3.02	1.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	11	100	0	1.04	20.52	24.69	24.69	14.27	11.67	1.04	1.04	1.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	12	100	0	0	7.29	7.29	40.63	19.79	16.67	8.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	13	100	8	8.1	6.44	4.86	6.35	9.96	12.37	11.5	8.36	6.03	4.93	4.18	3.56	2.26	1.37	0.75	0.44	0.29	0.15	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	4	100	26.49	5.1	0.58	1.17	2.79	6.18	16.01	16.51	7.69	8.22	8.22	1.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	5	100	17.02	10.35	10.87	10.77	9.91	9.23	7.91	5.8	4.21	3.45	3.02	2.62	1.51	1.17	1.01	0.63	0.32	0.08	0.04	0.04	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	6	100	0.18	0.22	0.38	1.57	8.11	15.01	19.27	18.68	15.16	11.8	6.6	1.89	0.86	0.22	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	7	100	2.14	0.55	2.42	2.7	3.21	5.81	5.26	7.39	6.85	7.41	8.99	8.16	7.77	6.84	5.67	4.63	3.5	2.64	1.9	1.31	0.97	0.67	0.43	1.18	0.26	0.17	0.17	0.08	0.72	0.06	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0
June	8	100	5.63	5.02	6.56	11.06	12.83	13.46	13.62	10.54	8.42	4.85	3.48	1.73	1.34	0.94	0.52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	9	100	2.48	2.67	2.08	2.34	5.4	12.4	19.27	19.03	13.01	7.42	4.19	2.94	2.45	1.94	1.3	0.66	0.28	0.13	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	10	100	0.01	0.1	1.32	3.5	5.93	12.92	18.26	20.33	15.35	10.01	6.17	4.13	1.91	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	11	100	0	4.36	13.96	14.48	18.65	21.32	15.91	4.76	2.68	2.68	0.6	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	12	100	0	0	0	29.17	33.33	20.83	10.42	6.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	13	100	7.7	8.11	6.05	4.44	6.27	9.95	12.29	11.22	8.67	6.51	5.28	4.39	3.51	2.59	1.52	0.72	0.52	0.24	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1.2 Single Axle Load Distribution Factors for July through December

			Single Axle Load Range																																						
Month	**Class**	**Total**	**3000**	**4000**	**5000**	**6000**	**7000**	**8000**	**9000**	**10000**	**11000**	**12000**	**13000**	**14000**	**15000**	**16000**	**17000**	**18000**	**19000**	**20000**	**21000**	**22000**	**23000**	**24000**	**25000**	**26000**	**27000**	**28000**	**29000**	**30000**	**31000**	**32000**	**33000**	**34000**	**35000**	**36000**	**37000**	**38000**	**39000**	**40000**	**41000**
July	4	100	28.94	9.76	0.7	1.02	1.98	8.33	12.09	11.57	8.56	9.16	6.03	1.86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	5	100	17.61	10.12	10.86	10.55	10	9.31	7.57	5.64	4.12	3.53	2.77	2.54	1.84	1.38	0.87	0.54	0.44	0.17	0.07	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	6	100	0.01	0.2	0.25	1.86	8.6	14	20.03	18.8	15.4	11.84	5.79	2.22	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	7	100	2.14	0.55	2.42	2.7	3.21	5.81	5.26	7.38	6.85	7.42	8.99	8.16	7.77	6.84	5.67	4.63	3.5	2.64	1.9	1.31	0.97	0.67	0.43	1.18	0.26	0.17	0.17	0.08	0.72	0.06	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0
July	8	100	5.12	5.08	6.45	10.5	11.93	13.22	12.76	10.94	8.16	4.98	2.99	2.23	2.23	1.93	1.24	0.06	0.06	0.06	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	9	100	2.65	2.8	2.12	2.47	5.34	12	18.5	18.65	13.24	7.51	4.3	3.1	2.6	1.96	1.4	0.78	0.31	0.16	0.03	0.03	0.03	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	10	100	0	0	1.17	2.83	6.62	11.84	17.78	19.88	15.39	11.15	6.8	3.86	2.34	0.17	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	11	100	1.03	3.54	6.67	18.65	22.81	22.81	15.1	3.13	3.13	3.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	12	100	0	0	2.78	22.22	25	30.56	19.44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	13	100	7.16	8.17	6.33	4.55	5.54	9.08	12.1	11.53	8.49	6.21	4.95	4.57	3.92	2.91	1.73	1.18	0.67	0.58	0.29	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	4	100	33.95	6.92	1.77	0.1	1.63	9.17	15.97	14.36	9.06	5.41	1.27	0.39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	5	100	18.12	9.8	10.34	10.26	10.02	9.22	7.52	5.97	4.16	3.34	2.9	2.51	2.24	1.52	0.97	0.55	0.46	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	6	100	0	0.05	0.05	0.9	8.38	16.1	18.88	18.74	14.69	11.6	7.32	2.05	1.24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	7	100	2.14	0.55	2.42	2.7	3.21	5.81	5.26	7.38	6.85	7.42	8.99	8.16	7.77	6.84	5.67	4.63	3.5	2.64	1.9	1.31	0.97	0.67	0.43	1.18	0.26	0.17	0.17	0.08	0.72	0.06	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0
August	8	100	6.46	5.16	6.83	10.83	11.33	12.7	12.19	11.02	9.36	4.46	3.12	2.69	1.79	1.63	0.43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	9	100	2.92	2.87	2	2.03	4.73	11.44	18.35	19.16	13.93	7.73	4.08	3.06	2.62	2.26	1.38	0.86	0.31	0.18	0.04	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	10	100	0.12	0.11	0.62	2.11	5.82	10.64	17.86	20.49	17.62	11.65	6.1	3.35	2.38	1.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	11	100	0	3.75	9.17	14.79	21.04	35.63	11.04	4.58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	12	100	2.77	2.78	5.56	23.61	16.67	12.5	19.44	0	16.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	13	100	7.58	8.19	6.2	4.38	5.56	8.73	11.89	11.52	8.8	6.47	4.94	4.42	3.6	2.84	1.83	1.35	0.75	0.46	0.35	0.1	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	4	100	24.1	1.99	0.11	1.89	2.84	8.38	22.84	26.26	7.98	2.48	1.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	5	100	15.32	9.54	10.96	10.85	10.28	9.58	7.77	5.76	4.3	3.39	3.05	2.67	2.27	1.47	1.1	0.96	0.52	0.21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	6	100	0	0	0.05	0.81	8.58	15.53	19.47	18.78	16.22	12.01	4.71	2.98	0.86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	7	100	2.14	0.55	2.42	2.7	3.21	5.81	5.26	7.38	6.85	7.42	8.99	8.16	7.77	6.84	5.67	4.63	3.5	2.64	1.9	1.31	0.97	0.67	0.43	1.18	0.26	0.17	0.17	0.08	0.72	0.06	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0
September	8	100	5.09	4.7	6.99	11.09	11.58	14.2	14.2	11.25	9.71	4.75	3.08	2.28	1.03	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	9	100	2.75	2.85	1.97	2.02	4.8	11.71	18.55	19.12	13.9	7.68	4.16	2.99	2.46	2.18	1.46	0.88	0.38	0.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	10	100	0	0.07	0.54	2.41	5.98	12.74	17.72	20.51	16.47	11.07	6.68	3.35	1.89	0.57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	11	100	0	3.74	3.75	18.23	26.56	26.56	12.4	2.5	3.13	3.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	12	100	0	0	0.01	25	58.33	8.33	8.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	13	100	7.68	8.38	6.24	4.12	5.58	9.23	11.94	11.46	8.7	6.32	4.79	4.51	3.96	2.88	1.86	1.21	0.68	0.37	0.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	4	100	51.16	1.04	0.12	0.12	2.62	8.81	12.04	14.12	7.39	2.57	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	5	100	14.42	9.64	11.07	11.11	10.49	10.09	7.83	6.08	4.53	3.62	2.65	2.3	2.28	1.69	1.09	0.75	0.36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	6	100	0	0	0.08	1.07	7.42	12.43	19.4	18.71	16.58	13.23	6.87	3.04	0.93	0.24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	7	100	2.14	0.55	2.42	2.7	3.21	5.81	5.26	7.38	6.85	7.42	8.99	8.16	7.77	6.84	5.67	4.63	3.5	2.64	1.9	1.31	0.97	0.67	0.43	1.18	0.26	0.17	0.17	0.08	0.72	0.06	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0
October	8	100	3.41	4.39	8.26	12.18	14.11	16.36	14.5	9.76	8.76	4.06	2.14	1.14	0.65	0.28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	9	100	2.27	2.94	2.15	1.94	4.35	10.97	18.73	19.92	14.32	7.8	4.11	2.98	2.49	2.18	1.56	0.77	0.36	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	10	100	0.26	0.26	1.19	2.68	5.82	11.17	17.67	20.8	16.7	11.26	6.59	3.56	1.68	0.36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	11	100	0.01	1.79	7.93	18.47	25.01	25.01	17.2	4.58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	12	100	0	0	0	20.83	12.5	16.67	25	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	13	100	7.43	7.99	6.29	4.62	5.78	9.36	12.14	11.29	8.92	6.69	5.06	4.2	3.81	2.78	1.55	1.31	0.61	0.11	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	4	100	11.76	4.27	4.27	0.1	0.21	8.13	21.88	24.79	23.44	1.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	5	100	13.44	10.47	12.35	12.07	11.2	9.7	8.24	6.18	4.52	2.64	2.43	2.27	1.99	1.44	0.87	0.17	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	6	100	0	0	0.09	0.17	4.64	13.72	21.15	20.96	14.88	12.78	5.99	2.44	2.44	0.74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	7	100	2.14	0.55	2.42	2.7	3.21	5.81	5.26	7.38	6.85	7.42	8.99	8.16	7.77	6.84	5.67	4.63	3.5	2.64	1.9	1.31	0.97	0.67	0.43	1.18	0.26	0.17	0.17	0.08	0.72	0.06	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0
November	8	100	3.3	3.93	10.94	13.48	14.33	14.8	15.06	10.15	8.56	3.37	1.58	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	9	100	2.52	2.81	2.18	1.83	4.25	10.5	18.27	19.86	14.3	8.04	4.24	3.07	2.75	2.33	1.62	0.89	0.35	0.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	10	100	0.3	0.28	0.95	1.96	5.92	12.41	18.32	20.1	15.58	10.42	6.75	4.39	2.48	0.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	11	100	0	0	10.84	26.47	28.56	16.06	14.49	1.79	1.79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	12	100	0	0	0	12.5	37.5	25	12.5	12.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	13	100	7.61	7.92	6.49	4.54	5.29	9.14	12.11	11.32	8.77	6.95	5.44	4.84	3.51	2.79	1.53	1.15	0.48	0.06	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	4	100	34.6	5.44	5.44	2.66	2.82	7.05	10.15	22.33	9.35	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	5	100	14.6	9.72	11.52	11.02	10.43	9.85	8.06	5.75	4.54	3.74	2.85	2.26	2.24	1.76	0.98	0.48	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	6	100	0	0	0.09	1.24	7.48	11.63	19.11	19.89	13.16	11.36	8.64	4.1	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	7	100	2.14	0.55	2.42	2.71	3.21	5.81	5.26	7.39	6.85	7.41	8.99	8.15	7.77	6.84	5.67	4.63	3.5	2.64	1.9	1.31	0.97	0.67	0.43	1.18	0.26	0.17	0.17	0.08	0.72	0.06	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0
December	8	100	1.07	4.02	6.27	15.14	16.17	17.56	16.15	12.08	6.53	2.57	2.09	0.35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	9	100	1.96	2.93	2.48	2.64	4.63	10.02	18.23	20.56	14.65	7.93	4.12	2.71	2.47	2.14	1.45	0.66	0.35	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	10	100	0.54	0.26	0.83	3.12	6.21	10.59	17.45	20.27	17.68	11.62	6.33	3.21	1.71	0.18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	11	100	0	2.5	11.16	23.14	23.14	23.14	11.26	2.83	2.83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	12	100	0	0	0	22.22	22.22	11.11	16.67	27.78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	13	100	8.49	8.96	6.7	4.71	6.08	9.59	12.24	11.69	8.26	6.11	4.81	4.07	3.41	2.38	1.39	0.78	0.28	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1.3 Tandem Axle Load Distribution Factors for January through June

			Tandem Axle Load Range																																						
Month	**Class**	**Total**	**6000**	**8000**	**10000**	**12000**	**14000**	**16000**	**18000**	**20000**	**22000**	**24000**	**26000**	**28000**	**30000**	**32000**	**34000**	**36000**	**38000**	**40000**	**42000**	**44000**	**46000**	**48000**	**50000**	**52000**	**54000**	**56000**	**58000**	**60000**	**62000**	**64000**	**66000**	**68000**	**70000**	**72000**	**74000**	**76000**	**78000**	**80000**	**82000**
January	4	100	0	0	0	0	2.08	2.08	4.17	6.67	8.75	13.33	17.92	13.75	11.67	7.08	2.5	2.5	2.5	2.5	2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	5	100	75	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	6	100	0.3	6.71	15.35	13.94	9.69	6.93	4.81	4.81	3.62	3.88	4.46	3.53	6.23	5.74	4.28	2.36	1.22	1.27	0.35	0.26	0	0.26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	7	100	13.76	6.72	6.5	3.46	7.07	4.83	4.97	4.58	4.26	3.85	3.44	6.03	3.68	2.98	2.89	2.54	2.66	2.5	1.57	1.53	2.13	1.89	1.17	1.07	0.87	0.81	0.47	0.49	0.38	0.24	0.15	0.16	0.06	0.13	0.06	0.06	0.02	0.02	0
January	8	100	0	0	6.25	25	31.25	28.47	5.56	1.39	2.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	9	100	0.64	2.16	4.81	7.73	8.91	7.38	5.59	4.67	4.2	4.23	4.94	6.56	8.64	9.68	8.58	5.38	2.87	1.4	0.71	0.43	0.23	0.12	0.05	0.05	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	10	100	0.21	1.19	4.09	6.16	8.61	8.18	7.61	7.66	7.13	6.82	7.04	7.04	6.69	6.66	5.25	4.84	2.54	2.06	0.09	0.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	11	100	7.93	3.15	5.21	8.23	8.88	8.45	7.08	5.49	5.14	5.99	5.73	4.37	6.58	4.61	4.48	2.91	1.83	1.12	0.84	0.68	0.32	0.21	0.21	0.07	0.13	0.15	0.09	0.03	0.06	0.01	0.01	0.01	0	0	0	0	0	0	0
January	12	100	5.23	1.75	3.35	5.89	8.73	8.38	9.77	10.84	10.78	7.24	6.14	4.93	3.93	3.09	2.74	1.73	1.32	1.07	0.58	0.51	0.43	0.22	0.22	0.23	0.2	0.12	0.07	0.19	0.09	0.04	0.02	0.04	0.12	0	0	0	0.01	0	0
January	13	100	7.61	9.97	9.6	8.75	7.87	5.67	4.69	4.72	4.37	3.3	3.83	4.04	5.13	5.43	5.18	3.89	2.69	1.91	0.68	0.39	0.08	0.07	0.07	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	4	100	0	0	0	2.08	2.08	2.08	6.36	8.42	16.94	16.94	12.77	10.69	6.43	4.35	4.35	2.17	2.17	2.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	5	100	58.34	33.33	8.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	6	100	0.33	11.01	16.16	16.32	12.22	3.37	6.93	2.99	3.53	3.48	7.28	3.89	3.14	3.66	2.25	1.06	1.06	1	0.16	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	7	100	13.76	6.72	6.5	3.46	7.07	4.83	4.97	4.58	4.26	3.85	3.44	6.03	3.68	2.98	2.89	2.54	2.66	2.5	1.57	1.53	2.13	1.89	1.17	1.07	0.87	0.81	0.47	0.49	0.38	0.24	0.15	0.16	0.06	0.13	0.06	0.06	0.02	0.02	0
February	8	100	0	0	4.79	37.08	26.67	16.25	2.71	12.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	9	100	0.58	2.14	4.83	7.87	8.76	6.9	5.41	4.42	4.1	4.15	5.36	7.14	9.07	9.87	8.53	5.31	2.59	1.37	0.77	0.43	0.24	0.1	0.05	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	10	100	0.11	1.65	3.77	6.31	7.84	6.74	7.39	7.02	7.87	6.58	7.03	7.03	7.15	7.03	6.4	4.72	2.76	1.53	0.94	0.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	11	100	7.93	3.15	5.21	8.23	8.88	8.45	7.08	5.49	5.14	5.99	5.73	4.37	6.58	4.61	4.48	2.91	1.83	1.12	0.84	0.68	0.32	0.21	0.21	0.07	0.13	0.15	0.09	0.03	0.06	0.01	0.01	0.01	0	0	0	0	0	0	0
February	12	100	5.23	1.75	3.35	5.89	8.73	8.38	9.77	10.84	10.78	7.24	6.14	4.93	3.93	3.09	2.74	1.73	1.32	1.07	0.58	0.51	0.43	0.22	0.22	0.23	0.2	0.12	0.07	0.19	0.09	0.04	0.02	0.04	0.12	0	0	0	0.01	0	0
February	13	100	7.97	10.05	10	8.59	7.95	5.65	4.29	4.36	4.24	3.81	3.69	4.31	5.16	5.83	5.08	4.22	2.28	1.37	0.55	0.38	0.08	0.07	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	4	100	0	0	0	0	0	4.18	4.17	6.35	12.52	16.87	14.7	12.52	10.35	6.17	6.17	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	5	100	80.55	13.89	5.56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	6	100	0.65	6.21	14.7	16.95	15.31	7.48	4.18	3.72	3.68	3.51	5.15	6.35	4.79	3.97	1.64	1.02	0.23	0.23	0.23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	7	100	13.76	6.72	6.5	3.46	7.07	4.83	4.97	4.58	4.26	3.85	3.44	6.03	3.68	2.98	2.89	2.54	2.66	2.5	1.57	1.53	2.13	1.89	1.17	1.07	0.87	0.81	0.47	0.49	0.38	0.24	0.15	0.16	0.06	0.13	0.06	0.06	0.02	0.02	0
March	8	100	0	0	7.19	27.88	27.88	32.05	3.75	1.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	9	100	0.64	2.22	5.08	7.84	8.59	6.68	5.11	4.45	4.17	4.57	5.7	7.54	9.27	9.7	8.15	5.15	2.51	1.24	0.66	0.32	0.19	0.09	0.05	0.04	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	10	100	0.18	1.99	3.84	7.06	8.51	7.2	7.35	6.55	7.57	7.6	7.22	7.05	6.62	6.5	5.98	4.8	1.94	1.42	0.54	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	11	100	7.93	3.15	5.21	8.23	8.88	8.45	7.08	5.49	5.14	5.99	5.73	4.37	6.58	4.61	4.48	2.91	1.83	1.12	0.84	0.68	0.32	0.21	0.21	0.07	0.13	0.15	0.09	0.03	0.06	0.01	0.01	0.01	0	0	0	0	0	0	0
March	12	100	5.23	1.75	3.35	5.89	8.73	8.38	9.77	10.84	10.78	7.24	6.14	4.93	3.93	3.09	2.74	1.73	1.32	1.07	0.58	0.51	0.43	0.22	0.22	0.23	0.2	0.12	0.07	0.19	0.09	0.04	0.02	0.04	0.12	0	0	0	0.01	0	0
March	13	100	6.81	10.33	10.49	9	7.82	5.49	4.34	4.21	4.34	3.63	3.99	4.39	5.32	5.55	5.16	3.89	2.18	1.49	0.91	0.25	0.19	0.09	0.07	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	4	100	0	0	0	0	0	3.92	3.92	5.85	9.77	17.54	19.54	15.69	9.85	5.92	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	5	100	85.42	14.58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	6	100	0.5	10.99	16.58	16.95	13.37	8.13	3.19	3.19	4.86	6.94	4.97	3.08	2.04	1.67	0.87	1.02	0.69	0.22	0.37	0.37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	7	100	13.76	6.72	6.5	3.46	7.07	4.83	4.97	4.58	4.26	3.85	3.44	6.03	3.68	2.98	2.89	2.54	2.66	2.5	1.57	1.53	2.13	1.89	1.17	1.07	0.87	0.81	0.47	0.49	0.38	0.24	0.15	0.16	0.06	0.13	0.06	0.06	0.02	0.02	0
April	8	100	0	0	3.68	28.7	26.61	28.7	10.3	2.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	9	100	0.56	2.22	5.22	8.06	8.62	6.49	5.15	4.58	4.29	4.65	6.08	7.97	9.19	9.37	7.76	4.71	2.46	1.17	0.56	0.38	0.24	0.13	0.06	0.04	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	10	100	0.11	1.64	4.25	6.24	8.12	7.68	7.46	6.98	6.73	7.25	7.25	6.96	7.14	7.14	6	4.61	2.57	1.19	0.43	0.18	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	11	100	7.93	3.15	5.21	8.23	8.88	8.45	7.08	5.49	5.14	5.99	5.73	4.37	6.58	4.61	4.48	2.91	1.83	1.12	0.84	0.68	0.32	0.21	0.21	0.07	0.13	0.15	0.09	0.03	0.06	0.01	0.01	0.01	0	0	0	0	0	0	0
April	12	100	5.23	1.75	3.35	5.89	8.73	8.38	9.77	10.84	10.78	7.24	6.14	4.93	3.93	3.09	2.74	1.73	1.32	1.07	0.58	0.51	0.43	0.22	0.22	0.23	0.2	0.12	0.07	0.19	0.09	0.04	0.02	0.04	0.12	0	0	0	0.01	0	0
April	13	100	7.14	10.03	10.29	9.1	7.81	5.82	4.31	4.39	4.52	3.72	3.87	4.37	5.26	5.31	4.89	3.83	2.31	1.36	0.78	0.57	0.21	0.09	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	4	100	0	0	0	0	0	2.08	4.08	8.17	14.33	18.42	18.42	12.25	8.17	6.08	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	5	100	93.75	6.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	6	100	0	7.29	18.99	16.13	16.11	10.43	5.5	3.28	2.27	2.39	3.44	3.75	4	3.01	2.03	0.46	0.4	0.4	0.06	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	7	100	13.76	6.72	6.5	3.46	7.07	4.83	4.97	4.58	4.26	3.85	3.44	6.03	3.68	2.98	2.89	2.54	2.66	2.5	1.57	1.53	2.13	1.89	1.17	1.07	0.87	0.81	0.47	0.49	0.38	0.24	0.15	0.16	0.06	0.13	0.06	0.06	0.02	0.02	0
May	8	100	0	0	6.24	35.42	29.17	25	4.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	9	100	0.58	2.3	5.43	8.37	8.77	6.58	5.07	4.63	4.31	4.78	6.08	7.9	9.31	9.22	7.34	4.57	2.37	1.12	0.58	0.32	0.18	0.07	0.04	0.04	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	10	100	0	1.67	5.25	6.71	8.27	8.33	7.25	7.48	6.38	6.8	6.47	6.36	6.47	6.12	6.12	4.38	3.5	1.7	0.41	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	11	100	7.93	3.15	5.21	8.23	8.88	8.45	7.08	5.49	5.14	5.99	5.73	4.37	6.58	4.61	4.48	2.91	1.83	1.12	0.84	0.68	0.32	0.21	0.21	0.07	0.13	0.15	0.09	0.03	0.06	0.01	0.01	0.01	0	0	0	0	0	0	0
May	12	100	5.23	1.75	3.35	5.89	8.73	8.38	9.77	10.84	10.78	7.24	6.14	4.93	3.93	3.09	2.74	1.73	1.32	1.07	0.58	0.51	0.43	0.22	0.22	0.23	0.2	0.12	0.07	0.19	0.09	0.04	0.02	0.04	0.12	0	0	0	0.01	0	0
May	13	100	7.81	10.64	10.18	9.01	7.91	5.71	4.35	4.39	4.36	3.46	3.74	4.15	5.24	5.81	4.97	3.43	1.97	1.38	0.69	0.4	0.25	0.08	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	4	100	0	0	0	0	0	1.06	1.78	2.84	4.57	4.9	9.26	14.53	22.2	21.47	10.72	6.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	5	100	97.92	1.04	1.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	6	100	0.37	9.64	13.65	15.06	13.42	9.56	5.61	4.42	2.18	4.38	4.03	4.38	4.57	3.94	2.64	1.57	0.24	0.05	0.24	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	7	100	13.76	6.72	6.5	3.46	7.07	4.83	4.97	4.58	4.26	3.85	3.44	6.03	3.68	2.98	2.89	2.54	2.66	2.5	1.57	1.53	2.13	1.89	1.17	1.07	0.87	0.81	0.47	0.49	0.38	0.24	0.15	0.16	0.06	0.13	0.06	0.06	0.02	0.02	0
June	8	100	1.04	0	12.71	32.5	29.03	16.53	7.15	0	1.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	9	100	0.51	2.42	5.5	8.3	8.75	6.64	5.21	4.67	4.39	4.79	6.17	7.85	8.86	8.92	7.51	4.83	2.52	1.12	0.53	0.27	0.12	0.07	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	10	100	0.15	1.98	4.58	7.2	7.92	7.36	8.22	7.38	7.28	6.87	6.54	6.83	6.89	6.96	5.79	3.65	2.53	1.47	0.14	0.14	0.06	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	11	100	7.93	3.15	5.21	8.23	8.88	8.45	7.08	5.49	5.14	5.99	5.73	4.37	6.58	4.61	4.48	2.91	1.83	1.12	0.84	0.68	0.32	0.21	0.21	0.07	0.13	0.15	0.09	0.03	0.06	0.01	0.01	0.01	0	0	0	0	0	0	0
June	12	100	5.23	1.75	3.35	5.89	8.73	8.38	9.77	10.84	10.78	7.24	6.14	4.93	3.93	3.09	2.74	1.73	1.32	1.07	0.58	0.51	0.43	0.22	0.22	0.23	0.2	0.12	0.07	0.19	0.09	0.04	0.02	0.04	0.12	0	0	0	0.01	0	0
June	13	100	7.9	10.84	10.63	8.97	7.51	5.31	4.35	4.46	4.25	3.23	3.39	4.54	5.21	5.67	5.01	3.54	2.12	1.48	0.81	0.5	0.21	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1.4 Tandem Axle Load Distribution Factors for July through December

			Tandem Axle Load Range																																						
Month	**Class**	**Total**	**6000**	**8000**	**10000**	**12000**	**14000**	**16000**	**18000**	**20000**	**22000**	**24000**	**26000**	**28000**	**30000**	**32000**	**34000**	**36000**	**38000**	**40000**	**42000**	**44000**	**46000**	**48000**	**50000**	**52000**	**54000**	**56000**	**58000**	**60000**	**62000**	**64000**	**66000**	**68000**	**70000**	**72000**	**74000**	**76000**	**78000**	**80000**	**82000**
July	4	100	0	0	0	0	0	0.54	1.09	1.89	2.15	19.38	14	13.9	9.45	14.14	13.88	9.58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	5	100	90.28	8.33	1.39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	6	100	0.02	13.77	14.94	12.97	12.31	11.53	6.94	5.43	3.79	4.62	3.52	2.95	2.16	1.43	1.38	1.38	0.27	0.27	0.27	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	7	100	13.76	6.72	6.5	3.46	7.07	4.83	4.97	4.58	4.26	3.85	3.44	6.03	3.68	2.98	2.89	2.54	2.66	2.5	1.57	1.53	2.13	1.89	1.17	1.07	0.87	0.81	0.47	0.49	0.38	0.24	0.15	0.16	0.06	0.13	0.06	0.06	0.02	0.02	0
July	8	100	3.11	0	5.68	26.09	25.16	31.41	5.63	2.29	0.63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	9	100	0.54	2.31	5.38	8.36	8.57	6.42	4.98	4.53	4.16	4.63	5.84	7.59	8.97	9.1	7.67	5.13	2.85	1.33	0.66	0.38	0.25	0.11	0.1	0.07	0.06	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0
July	10	100	0	1.4	4.09	6.61	7.68	7.3	6.91	7.81	7.87	7.8	6.92	6.4	6.4	6.68	6.16	4.88	2.9	1.52	0.49	0.06	0.06	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	11	100	7.93	3.15	5.21	8.23	8.88	8.45	7.08	5.49	5.14	5.99	5.73	4.37	6.58	4.61	4.48	2.91	1.83	1.12	0.84	0.68	0.32	0.21	0.21	0.07	0.13	0.15	0.09	0.03	0.06	0.01	0.01	0.01	0	0	0	0	0	0	0
July	12	100	5.23	1.75	3.35	5.89	8.73	8.38	9.77	10.84	10.78	7.24	6.14	4.93	3.93	3.09	2.74	1.73	1.32	1.07	0.58	0.51	0.43	0.22	0.22	0.23	0.2	0.12	0.07	0.19	0.09	0.04	0.02	0.04	0.12	0	0	0	0.01	0	0
July	13	100	7.48	10.11	9.83	8.43	7.45	5.68	4.33	4.39	4.09	3.43	3.5	4.34	5.39	5.92	5.35	4.01	2.82	1.66	0.78	0.59	0.22	0.16	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0
August	4	100	0	0	0	0	0	0	2	2	6	10	12	60	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	5	100	97.92	2.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	6	100	2.78	10.78	12.02	12.77	15.73	9.64	4.77	3	2.45	6.45	4.11	3.18	4.06	5.25	1.21	1.21	0.54	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	7	100	13.76	6.72	6.5	3.46	7.07	4.83	4.97	4.58	4.26	3.85	3.44	6.03	3.68	2.98	2.89	2.54	2.66	2.5	1.57	1.53	2.13	1.89	1.17	1.07	0.87	0.81	0.47	0.49	0.38	0.24	0.15	0.16	0.06	0.13	0.06	0.06	0.02	0.02	0
August	8	100	1.05	0.52	8.7	33.7	35.26	11.3	4.79	2.6	2.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	9	100	0.64	2.37	5.38	8.27	8.67	6.23	5.02	4.35	4.12	4.36	5.66	7.65	9.16	9.24	7.7	5.28	2.89	1.48	0.74	0.39	0.17	0.11	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0
August	10	100	0.1	1.59	3.99	6.69	7.63	6.98	7.68	9.4	7.21	6.99	6.67	6.67	6.67	6.27	6.2	4.49	2.65	1.64	0.48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	11	100	7.93	3.15	5.21	8.23	8.88	8.45	7.08	5.49	5.14	5.99	5.73	4.37	6.58	4.61	4.48	2.91	1.83	1.12	0.84	0.68	0.32	0.21	0.21	0.07	0.13	0.15	0.09	0.03	0.06	0.01	0.01	0.01	0	0	0	0	0	0	0
August	12	100	5.23	1.75	3.35	5.89	8.73	8.38	9.77	10.84	10.78	7.24	6.14	4.93	3.93	3.09	2.74	1.73	1.32	1.07	0.58	0.51	0.43	0.22	0.22	0.23	0.2	0.12	0.07	0.19	0.09	0.04	0.02	0.04	0.12	0	0	0	0.01	0	0
August	13	100	8.13	10.22	9.62	8.65	7.41	5.11	4.28	4.07	4.27	3.44	3.63	4.48	5.38	5.98	5.35	3.88	2.64	1.54	0.77	0.59	0.41	0.09	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0
September	4	100	0	0	0	0	0	0	2	2	6	10	62	10	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	5	100	98.61	1.39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	6	100	0	10.72	19.37	13.43	14.84	9.7	5.87	3.22	2.39	2.92	6.25	2.87	3.22	2.86	1.1	0.62	0.57	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	7	100	13.76	6.72	6.5	3.46	7.07	4.83	4.97	4.58	4.26	3.85	3.44	6.03	3.68	2.98	2.89	2.54	2.66	2.5	1.57	1.53	2.13	1.89	1.17	1.07	0.87	0.81	0.47	0.49	0.38	0.24	0.15	0.16	0.06	0.13	0.06	0.06	0.02	0.02	0
September	8	100	0	0	3.12	19.93	33.47	26.18	6.73	3.87	4.91	1.79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	9	100	0.54	2.43	5.4	8.22	8.86	6.52	5.02	4.42	4	4.25	5.58	7.51	9.11	9.51	7.97	5.35	2.82	1.36	0.62	0.3	0.13	0.06	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	10	100	0	1.19	3.78	7.4	8.81	7.28	6.37	6.69	8.1	6.78	7.23	6.44	6.12	6.48	5.51	5.11	4.01	2.18	0.42	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	11	100	7.93	3.15	5.21	8.23	8.88	8.45	7.08	5.49	5.14	5.99	5.73	4.37	6.58	4.61	4.48	2.91	1.83	1.12	0.84	0.68	0.32	0.21	0.21	0.07	0.13	0.15	0.09	0.03	0.06	0.01	0.01	0.01	0	0	0	0	0	0	0
September	12	100	5.23	1.75	3.35	5.89	8.73	8.38	9.77	10.84	10.78	7.24	6.14	4.93	3.93	3.09	2.74	1.73	1.32	1.07	0.58	0.51	0.43	0.22	0.22	0.23	0.2	0.12	0.07	0.19	0.09	0.04	0.02	0.04	0.12	0	0	0	0.01	0	0
September	13	100	8.07	10.66	9.94	8.84	7.61	5.74	4.32	4.22	4.05	3.58	3.76	3.92	4.94	5.72	5.2	3.9	2.62	1.44	1	0.36	0.11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	4	100	0	0	0	0	0	0	4.17	8.33	8.33	16.67	25	20.83	12.5	4.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	5	100	97.92	2.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	6	100	0	9.7	16.67	14.87	11.47	5.59	4.88	3.53	3.16	6.33	3.54	4.13	4.13	4.68	4.82	1.99	0.31	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	7	100	13.76	6.72	6.5	3.46	7.07	4.83	4.97	4.58	4.26	3.85	3.44	6.03	3.68	2.98	2.89	2.54	2.66	2.5	1.57	1.53	2.13	1.89	1.17	1.07	0.87	0.81	0.47	0.49	0.38	0.24	0.15	0.16	0.06	0.13	0.06	0.06	0.02	0.02	0
October	8	100	0	0	11.46	18.4	33.68	26.39	6.74	2.08	1.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	9	100	0.58	2.32	5.1	8.11	8.99	6.7	4.75	4.1	3.83	4.1	4.96	6.79	8.67	9.75	8.62	5.67	3.17	1.63	0.95	0.6	0.42	0.12	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	10	100	0	1.57	4.1	6.69	7.6	7.71	5.65	5.81	7.18	5.99	5.88	6.64	7.23	6.93	5.88	5.58	4.87	3.26	1.15	0.28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	11	100	7.93	3.15	5.21	8.23	8.88	8.45	7.08	5.49	5.14	5.99	5.73	4.37	6.58	4.61	4.48	2.91	1.83	1.12	0.84	0.68	0.32	0.21	0.21	0.07	0.13	0.15	0.09	0.03	0.06	0.01	0.01	0.01	0	0	0	0	0	0	0
October	12	100	5.23	1.75	3.35	5.89	8.73	8.38	9.77	10.84	10.78	7.24	6.14	4.93	3.93	3.09	2.74	1.73	1.32	1.07	0.58	0.51	0.43	0.22	0.22	0.23	0.2	0.12	0.07	0.19	0.09	0.04	0.02	0.04	0.12	0	0	0	0.01	0	0
October	13	100	7.57	10.32	9.63	8.6	7.88	5.91	4.49	4.33	3.93	3.7	3.87	4.41	5	5.67	5.28	4.07	2.59	1.48	0.98	0.29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	4	100	0	0	0	0	0	0	4	8	16	24	20	16	8	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	5	100	96.3	1.85	1.85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	6	100	0	11.06	14.93	19.65	16.88	5.63	3.13	3.47	3.39	4.38	2.46	3.87	3.79	2.37	2.51	1.27	0.99	0.22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	7	100	13.76	6.72	6.5	3.46	7.07	4.83	4.97	4.58	4.26	3.85	3.44	6.03	3.68	2.98	2.89	2.54	2.66	2.5	1.57	1.53	2.13	1.89	1.17	1.07	0.87	0.81	0.47	0.49	0.38	0.24	0.15	0.16	0.06	0.13	0.06	0.06	0.02	0.02	0
November	8	100	0	0	18.75	26.39	26.39	16.67	2.08	9.72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	9	100	0.83	2.48	5.24	8.2	9.08	6.82	5.21	4.36	4.05	4.16	5.11	6.69	8.72	9.78	8.56	5.45	2.84	1.33	0.68	0.28	0.07	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	10	100	0	2	3.45	6.82	7.95	7.74	6.87	7.45	7.35	6.44	6.64	6.51	7.04	6.54	5.48	4.95	3.38	2.34	0.69	0.36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	11	100	7.93	3.15	5.21	8.23	8.88	8.45	7.08	5.49	5.14	5.99	5.73	4.37	6.58	4.61	4.48	2.91	1.83	1.12	0.84	0.68	0.32	0.21	0.21	0.07	0.13	0.15	0.09	0.03	0.06	0.01	0.01	0.01	0	0	0	0	0	0	0
November	12	100	5.23	1.75	3.35	5.89	8.73	8.38	9.77	10.84	10.78	7.24	6.14	4.93	3.93	3.09	2.74	1.73	1.32	1.07	0.58	0.51	0.43	0.22	0.22	0.23	0.2	0.12	0.07	0.19	0.09	0.04	0.02	0.04	0.12	0	0	0	0.01	0	0
November	13	100	7.35	9.92	9.69	8.43	8.3	6.16	4.55	4.56	4.4	3.65	3.65	4.21	5.1	5.64	5.27	3.91	2.66	1.71	0.76	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	4	100	0	0	0	0	0	0	2.27	4.55	6.82	9.09	61.36	9.09	4.55	2.27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	5	100	91.67	8.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	6	100	0	6.31	12.7	12.82	12.94	5.76	4.24	3.83	4.87	5.68	5.68	6.69	6.57	6.75	3.91	1.13	0.12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	7	100	13.76	6.72	6.5	3.46	7.07	4.83	4.97	4.58	4.26	3.85	3.44	6.03	3.68	2.98	2.89	2.54	2.66	2.5	1.57	1.53	2.13	1.89	1.17	1.07	0.87	0.81	0.47	0.49	0.38	0.24	0.15	0.16	0.06	0.13	0.06	0.06	0.02	0.02	0
December	8	100	0	0	5.2	36.81	36.81	10.42	10.76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	9	100	0.62	2.26	4.98	7.51	8.39	6.81	5.43	4.65	4.28	4.29	4.98	6.5	8.6	10.17	9.37	6.1	2.75	1.33	0.52	0.33	0.07	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	10	100	0	1.2	2.98	6.34	7.92	7.24	8.16	8.18	7.19	7.19	6.42	6.42	6.42	6.84	6.72	5.63	3.21	1.78	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	11	100	7.93	3.15	5.21	8.23	8.88	8.45	7.08	5.49	5.14	5.99	5.73	4.37	6.58	4.61	4.48	2.91	1.83	1.12	0.84	0.68	0.32	0.21	0.21	0.07	0.13	0.15	0.09	0.03	0.06	0.01	0.01	0.01	0	0	0	0	0	0	0
December	12	100	5.23	1.75	3.35	5.89	8.73	8.38	9.77	10.84	10.78	7.24	6.14	4.93	3.93	3.09	2.74	1.73	1.32	1.07	0.58	0.51	0.43	0.22	0.22	0.23	0.2	0.12	0.07	0.19	0.09	0.04	0.02	0.04	0.12	0	0	0	0.01	0	0
December	13	100	7.76	10.95	10.15	8.75	8.3	6.27	4.73	4.83	4.24	3.27	3.32	3.92	4.9	5.37	5.34	3.96	2.27	1.25	0.42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1.5 Tridem Axle Load Distribution Factors for January through June

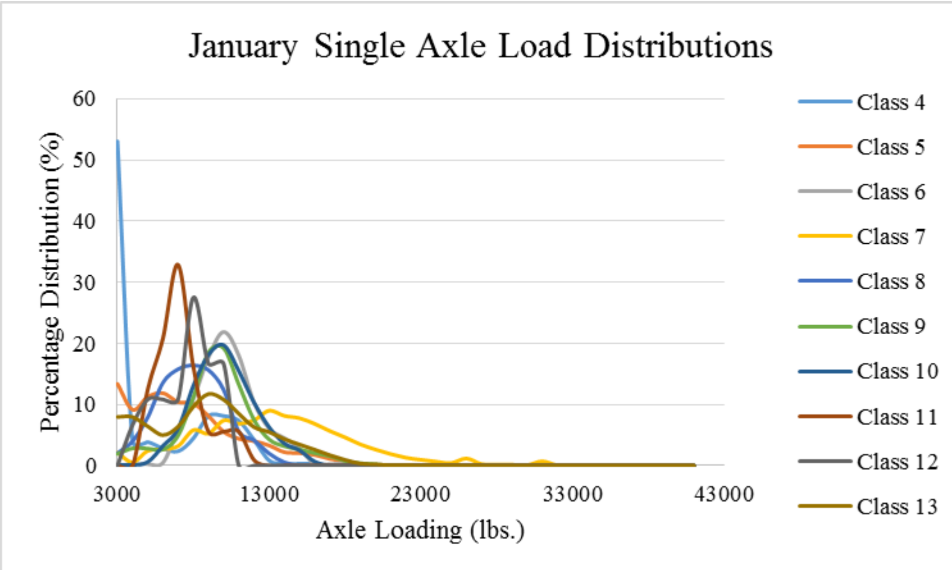
			Tridem Axle Load Range																														
Month	**Class**	**Total**	**12000**	**15000**	**18000**	**21000**	**24000**	**27000**	**30000**	**33000**	**36000**	**39000**	**42000**	**45000**	**48000**	**51000**	**54000**	**57000**	**60000**	**63000**	**66000**	**69000**	**72000**	**75000**	**78000**	**81000**	**84000**	**87000**	**90000**	**93000**	**96000**	**99000**	**102000**
January	4	100	66.67	0	0	0	0	0	0	0	0	0	26.66	6.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	5	100	48.28	1.08	0.43	0.15	0.73	3.13	3.83	0.7	15.59	0.7	3.48	2.93	3.33	1.78	4.48	0	0	0	0	6.25	0	0	0	0	3.13	0	0	0	0	0	0
January	6	100	29.51	9.2	7.6	10.35	4.73	3.55	6.27	4.18	2.11	2.22	1.79	1.7	1.19	3.12	0.96	0	0.1	2.09	1.96	1.47	2.94	0.02	0	1.47	0	0.45	0	0.04	0	0.98	0
January	7	100	5.89	2.18	3.32	2.98	3.27	4.26	4.48	5.11	7.01	6.77	7.21	7.18	6.63	5.84	6.2	6.91	4.34	2.94	2.13	1.42	1.96	0.63	0.46	0.28	0.24	0.12	0.09	0.08	0.02	0.02	0.03
January	8	100	20.89	2.33	3.34	4.26	3.71	4.32	5.24	4.89	3.91	5	3.99	4.53	4.96	4.98	5.98	5	3.1	1.51	1.4	1.59	1.16	0.99	1.12	1.42	0.06	0.05	0.1	0.01	0	0.1	0.06
January	9	100	59.19	13.03	7.89	6.51	2.78	1.87	2.51	1.02	0.66	0.55	0.59	0.84	0.36	0.46	0.27	0.23	0.32	0.12	0.1	0.25	0.12	0.09	0.07	0.05	0.02	0.04	0.02	0.02	0.02	0	0
January	10	100	12.31	11.03	7.82	3.15	2.71	2.86	3.59	8.4	12.1	13.47	11.38	6.28	3.85	1.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	11	100	23.31	20.89	15.88	12	5.8	2.61	2.08	2.06	2.94	1.1	2.98	1.95	1.87	0.72	1.27	0.41	0.4	0.16	0.99	0.2	0.38	0	0	0	0	0	0	0	0	0	0
January	12	100	13.28	6.38	6.74	6	4.37	4.53	8.01	5.61	6.25	8.04	6.7	6.08	3.48	5.81	2.22	0.98	0.89	0.96	1.39	0.38	0.11	0.08	0.23	0.2	0.41	0.07	0.09	0.35	0.03	0.1	0.23
January	13	100	36.39	2.64	0.52	0.52	0.52	0.76	4.23	9.34	14.05	22.33	4.7	3.84	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	4	100	66.67	0	0	0	0	0	0	0	0	0	26.66	6.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	5	100	48.28	1.08	0.43	0.15	0.73	3.13	3.83	0.7	15.59	0.7	3.48	2.93	3.33	1.78	4.48	0	0	0	0	6.25	0	0	0	0	3.13	0	0	0	0	0	0
February	6	100	29.51	9.2	7.6	10.35	4.73	3.55	6.27	4.18	2.11	2.22	1.79	1.7	1.19	3.12	0.96	0	0.1	2.09	1.96	1.47	2.94	0.02	0	1.47	0	0.45	0	0.04	0	0.98	0
February	7	100	5.89	2.18	3.32	2.98	3.27	4.26	4.48	5.11	7.01	6.77	7.21	7.18	6.63	5.84	6.2	6.91	4.34	2.94	2.13	1.42	1.96	0.63	0.46	0.28	0.24	0.12	0.09	0.08	0.02	0.02	0.03
February	8	100	20.89	2.33	3.34	4.26	3.71	4.32	5.24	4.89	3.91	5	3.99	4.53	4.96	4.98	5.98	5	3.1	1.51	1.4	1.59	1.16	0.99	1.12	1.42	0.06	0.05	0.1	0.01	0	0.1	0.06
February	9	100	59.19	13.03	7.89	6.51	2.78	1.87	2.51	1.02	0.66	0.55	0.59	0.84	0.36	0.46	0.27	0.23	0.32	0.12	0.1	0.25	0.12	0.09	0.07	0.05	0.02	0.04	0.02	0.02	0.02	0	0
February	10	100	11.39	12.15	7.92	3.26	1.64	1.99	3.63	9.31	11.75	14.81	11.2	7.08	2.3	1.13	0.44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	11	100	23.31	20.89	15.88	12	5.8	2.61	2.08	2.06	2.94	1.1	2.98	1.95	1.87	0.72	1.27	0.41	0.4	0.16	0.99	0.2	0.38	0	0	0	0	0	0	0	0	0	0
February	12	100	13.28	6.38	6.74	6	4.37	4.53	8.01	5.61	6.25	8.04	6.7	6.08	3.48	5.81	2.22	0.98	0.89	0.96	1.39	0.38	0.11	0.08	0.23	0.2	0.41	0.07	0.09	0.35	0.03	0.1	0.23
February	13	100	32	4.09	0.68	0.68	0.16	0.68	1.72	11.77	17.29	20.67	8.07	2.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	4	100	66.67	0	0	0	0	0	0	0	0	0	26.66	6.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	5	100	48.28	1.08	0.43	0.15	0.73	3.13	3.83	0.7	15.59	0.7	3.48	2.93	3.33	1.78	4.48	0	0	0	0	6.25	0	0	0	0	3.13	0	0	0	0	0	0
March	6	100	29.51	9.2	7.6	10.35	4.73	3.55	6.27	4.18	2.11	2.22	1.79	1.7	1.19	3.12	0.96	0	0.1	2.09	1.96	1.47	2.94	0.02	0	1.47	0	0.45	0	0.04	0	0.98	0
March	7	100	5.89	2.18	3.32	2.98	3.27	4.26	4.48	5.11	7.01	6.77	7.21	7.18	6.63	5.84	6.2	6.91	4.34	2.94	2.13	1.42	1.96	0.63	0.46	0.28	0.24	0.12	0.09	0.08	0.02	0.02	0.03
March	8	100	20.89	2.33	3.34	4.26	3.71	4.32	5.24	4.89	3.91	5	3.99	4.53	4.96	4.98	5.98	5	3.1	1.51	1.4	1.59	1.16	0.99	1.12	1.42	0.06	0.05	0.1	0.01	0	0.1	0.06
March	9	100	59.19	13.03	7.89	6.51	2.78	1.87	2.51	1.02	0.66	0.55	0.59	0.84	0.36	0.46	0.27	0.23	0.32	0.12	0.1	0.25	0.12	0.09	0.07	0.05	0.02	0.04	0.02	0.02	0.02	0	0
March	10	100	10.85	12.32	7.35	2.79	1.85	2.33	4.52	9.83	11.64	12.22	10.67	7.83	3.06	1.52	1.09	0.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	11	100	23.31	20.89	15.88	12	5.8	2.61	2.08	2.06	2.94	1.1	2.98	1.95	1.87	0.72	1.27	0.41	0.4	0.16	0.99	0.2	0.38	0	0	0	0	0	0	0	0	0	0
March	12	100	13.28	6.38	6.74	6	4.37	4.53	8.01	5.61	6.25	8.04	6.7	6.08	3.48	5.81	2.22	0.98	0.89	0.96	1.39	0.38	0.11	0.08	0.23	0.2	0.41	0.07	0.09	0.35	0.03	0.1	0.23
March	13	100	34.17	5.59	0.56	0.56	0.56	0.44	3.38	14.5	16.06	15.92	6.14	1.7	0.42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	4	100	66.67	0	0	0	0	0	0	0	0	0	26.66	6.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	5	100	48.28	1.08	0.43	0.15	0.73	3.13	3.83	0.7	15.59	0.7	3.48	2.93	3.33	1.78	4.48	0	0	0	0	6.25	0	0	0	0	3.13	0	0	0	0	0	0
April	6	100	29.51	9.2	7.6	10.35	4.73	3.55	6.27	4.18	2.11	2.22	1.79	1.7	1.19	3.12	0.96	0	0.1	2.09	1.96	1.47	2.94	0.02	0	1.47	0	0.45	0	0.04	0	0.98	0
April	7	100	5.89	2.18	3.32	2.98	3.27	4.26	4.48	5.11	7.01	6.77	7.21	7.18	6.63	5.84	6.2	6.91	4.34	2.94	2.13	1.42	1.96	0.63	0.46	0.28	0.24	0.12	0.09	0.08	0.02	0.02	0.03
April	8	100	20.89	2.33	3.34	4.26	3.71	4.32	5.24	4.89	3.91	5	3.99	4.53	4.96	4.98	5.98	5	3.1	1.51	1.4	1.59	1.16	0.99	1.12	1.42	0.06	0.05	0.1	0.01	0	0.1	0.06
April	9	100	59.19	13.03	7.89	6.51	2.78	1.87	2.51	1.02	0.66	0.55	0.59	0.84	0.36	0.46	0.27	0.23	0.32	0.12	0.1	0.25	0.12	0.09	0.07	0.05	0.02	0.04	0.02	0.02	0.02	0	0
April	10	100	11.7	11.76	7.04	3.69	2.38	3.15	5.46	10.11	13.23	11.34	9.39	7.19	3.04	0.4	0.12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	11	100	23.31	20.89	15.88	12	5.8	2.61	2.08	2.06	2.94	1.1	2.98	1.95	1.87	0.72	1.27	0.41	0.4	0.16	0.99	0.2	0.38	0	0	0	0	0	0	0	0	0	0
April	12	100	13.28	6.38	6.74	6	4.37	4.53	8.01	5.61	6.25	8.04	6.7	6.08	3.48	5.81	2.22	0.98	0.89	0.96	1.39	0.38	0.11	0.08	0.23	0.2	0.41	0.07	0.09	0.35	0.03	0.1	0.23
April	13	100	25.34	4.32	0.49	0.49	0.49	0.49	2.88	17.29	23.96	20.5	2.36	0.9	0.49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	4	100	66.67	0	0	0	0	0	0	0	0	0	26.66	6.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	5	100	48.28	1.08	0.43	0.15	0.73	3.13	3.83	0.7	15.59	0.7	3.48	2.93	3.33	1.78	4.48	0	0	0	0	6.25	0	0	0	0	3.13	0	0	0	0	0	0
May	6	100	29.51	9.2	7.6	10.35	4.73	3.55	6.27	4.18	2.11	2.22	1.79	1.7	1.19	3.12	0.96	0	0.1	2.09	1.96	1.47	2.94	0.02	0	1.47	0	0.45	0	0.04	0	0.98	0
May	7	100	5.89	2.18	3.32	2.98	3.27	4.26	4.48	5.11	7.01	6.77	7.21	7.18	6.63	5.84	6.2	6.91	4.34	2.94	2.13	1.42	1.96	0.63	0.46	0.28	0.24	0.12	0.09	0.08	0.02	0.02	0.03
May	8	100	20.89	2.33	3.34	4.26	3.71	4.32	5.24	4.89	3.91	5	3.99	4.53	4.96	4.98	5.98	5	3.1	1.51	1.4	1.59	1.16	0.99	1.12	1.42	0.06	0.05	0.1	0.01	0	0.1	0.06
May	9	100	59.19	13.03	7.89	6.51	2.78	1.87	2.51	1.02	0.66	0.55	0.59	0.84	0.36	0.46	0.27	0.23	0.32	0.12	0.1	0.25	0.12	0.09	0.07	0.05	0.02	0.04	0.02	0.02	0.02	0	0
May	10	100	11.11	10.92	8.42	3.26	2.29	3.19	5.09	8.47	11.94	12.61	9.58	6.74	3.36	2.25	0.77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	11	100	23.31	20.89	15.88	12	5.8	2.61	2.08	2.06	2.94	1.1	2.98	1.95	1.87	0.72	1.27	0.41	0.4	0.16	0.99	0.2	0.38	0	0	0	0	0	0	0	0	0	0
May	12	100	13.28	6.38	6.74	6	4.37	4.53	8.01	5.61	6.25	8.04	6.7	6.08	3.48	5.81	2.22	0.98	0.89	0.96	1.39	0.38	0.11	0.08	0.23	0.2	0.41	0.07	0.09	0.35	0.03	0.1	0.23
May	13	100	21.94	4.53	0.16	0.16	0.72	1.04	3.61	16.37	25.41	17.68	4.61	3.77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	4	100	66.67	0	0	0	0	0	0	0	0	0	26.66	6.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	5	100	48.28	1.08	0.43	0.15	0.73	3.13	3.83	0.7	15.59	0.7	3.48	2.93	3.33	1.78	4.48	0	0	0	0	6.25	0	0	0	0	3.13	0	0	0	0	0	0
June	6	100	29.51	9.2	7.6	10.35	4.73	3.55	6.27	4.18	2.11	2.22	1.79	1.7	1.19	3.12	0.96	0	0.1	2.09	1.96	1.47	2.94	0.02	0	1.47	0	0.45	0	0.04	0	0.98	0
June	7	100	5.89	2.18	3.32	2.98	3.27	4.26	4.48	5.11	7.01	6.77	7.21	7.18	6.63	5.84	6.2	6.91	4.34	2.94	2.13	1.42	1.96	0.63	0.46	0.28	0.24	0.12	0.09	0.08	0.02	0.02	0.03
June	8	100	20.89	2.33	3.34	4.26	3.71	4.32	5.24	4.89	3.91	5	3.99	4.53	4.96	4.98	5.98	5	3.1	1.51	1.4	1.59	1.16	0.99	1.12	1.42	0.06	0.05	0.1	0.01	0	0.1	0.06
June	9	100	59.19	13.03	7.89	6.51	2.78	1.87	2.51	1.02	0.66	0.55	0.59	0.84	0.36	0.46	0.27	0.23	0.32	0.12	0.1	0.25	0.12	0.09	0.07	0.05	0.02	0.04	0.02	0.02	0.02	0	0
June	10	100	12.07	11.07	6.59	3.47	2.38	4.76	5.36	9.16	10.16	12.91	9.83	7.45	3	1.12	0.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	11	100	23.31	20.89	15.88	12	5.8	2.61	2.08	2.06	2.94	1.1	2.98	1.95	1.87	0.72	1.27	0.41	0.4	0.16	0.99	0.2	0.38	0	0	0	0	0	0	0	0	0	0
June	12	100	13.28	6.38	6.74	6	4.37	4.53	8.01	5.61	6.25	8.04	6.7	6.08	3.48	5.81	2.22	0.98	0.89	0.96	1.39	0.38	0.11	0.08	0.23	0.2	0.41	0.07	0.09	0.35	0.03	0.1	0.23
June	13	100	22.14	5.28	0.36	0.36	0.36	0.36	4.53	14.56	20.02	17.73	8.98	3.87	1.45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1.5 Tridem Axle Load Distribution Factors for July through December

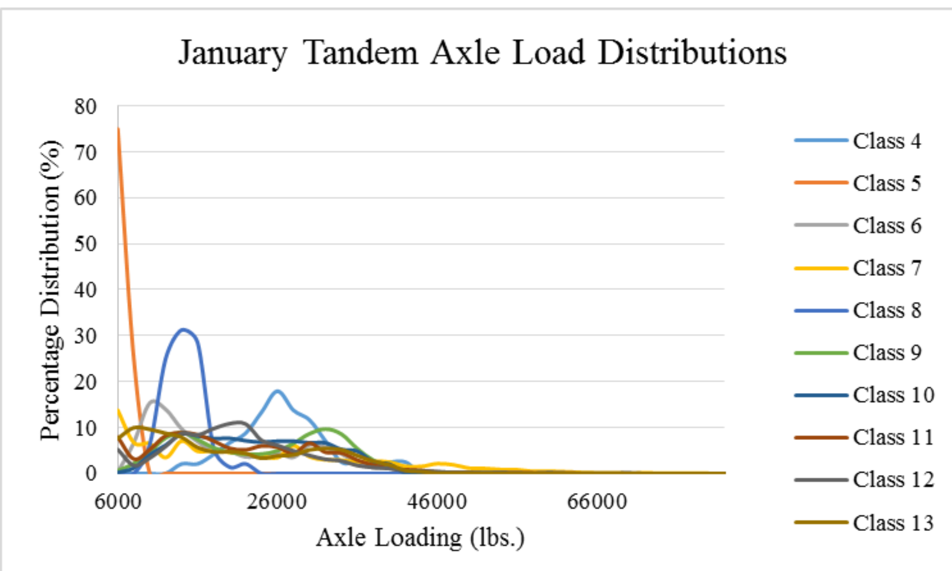
			Tridem Axle Load Range																														
Month	**Class**	**Total**	**12000**	**15000**	**18000**	**21000**	**24000**	**27000**	**30000**	**33000**	**36000**	**39000**	**42000**	**45000**	**48000**	**51000**	**54000**	**57000**	**60000**	**63000**	**66000**	**69000**	**72000**	**75000**	**78000**	**81000**	**84000**	**87000**	**90000**	**93000**	**96000**	**99000**	**102000**
July	4	100	66.67	0	0	0	0	0	0	0	0	0	26.66	6.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	5	100	48.28	1.08	0.43	0.15	0.73	3.13	3.83	0.7	15.59	0.7	3.48	2.93	3.33	1.78	4.48	0	0	0	0	6.25	0	0	0	0	3.13	0	0	0	0	0	0
July	6	100	29.51	9.2	7.6	10.35	4.73	3.55	6.27	4.18	2.11	2.22	1.79	1.7	1.19	3.12	0.96	0	0.1	2.09	1.96	1.47	2.94	0.02	0	1.47	0	0.45	0	0.04	0	0.98	0
July	7	100	5.89	2.18	3.32	2.98	3.27	4.26	4.48	5.11	7.01	6.77	7.21	7.18	6.63	5.84	6.2	6.91	4.34	2.94	2.13	1.42	1.96	0.63	0.46	0.28	0.24	0.12	0.09	0.08	0.02	0.02	0.03
July	8	100	20.89	2.33	3.34	4.26	3.71	4.32	5.24	4.89	3.91	5	3.99	4.53	4.96	4.98	5.98	5	3.1	1.51	1.4	1.59	1.16	0.99	1.12	1.42	0.06	0.05	0.1	0.01	0	0.1	0.06
July	9	100	59.19	13.03	7.89	6.51	2.78	1.87	2.51	1.02	0.66	0.55	0.59	0.84	0.36	0.46	0.27	0.23	0.32	0.12	0.1	0.25	0.12	0.09	0.07	0.05	0.02	0.04	0.02	0.02	0.02	0	0
July	10	100	11.53	10.47	8.13	3.91	3.14	3.55	5.4	9.22	9.87	9.8	10.2	8.11	3.29	2.51	0.77	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	11	100	23.31	20.89	15.88	12	5.8	2.61	2.08	2.06	2.94	1.1	2.98	1.95	1.87	0.72	1.27	0.41	0.4	0.16	0.99	0.2	0.38	0	0	0	0	0	0	0	0	0	0
July	12	100	13.28	6.38	6.74	6	4.37	4.53	8.01	5.61	6.25	8.04	6.7	6.08	3.48	5.81	2.22	0.98	0.89	0.96	1.39	0.38	0.11	0.08	0.23	0.2	0.41	0.07	0.09	0.35	0.03	0.1	0.23
July	13	100	17.83	6.74	1.19	0.93	0	2.49	5.27	14.99	18.76	16.61	9.42	3.89	1.88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	4	100	66.67	0	0	0	0	0	0	0	0	0	26.66	6.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	5	100	48.28	1.08	0.43	0.15	0.73	3.13	3.83	0.7	15.59	0.7	3.48	2.93	3.33	1.78	4.48	0	0	0	0	6.25	0	0	0	0	3.13	0	0	0	0	0	0
August	6	100	29.51	9.2	7.6	10.35	4.73	3.55	6.27	4.18	2.11	2.22	1.79	1.7	1.19	3.12	0.96	0	0.1	2.09	1.96	1.47	2.94	0.02	0	1.47	0	0.45	0	0.04	0	0.98	0
August	7	100	5.89	2.18	3.32	2.98	3.27	4.26	4.48	5.11	7.01	6.77	7.21	7.18	6.63	5.84	6.2	6.91	4.34	2.94	2.13	1.42	1.96	0.63	0.46	0.28	0.24	0.12	0.09	0.08	0.02	0.02	0.03
August	8	100	20.89	2.33	3.34	4.26	3.71	4.32	5.24	4.89	3.91	5	3.99	4.53	4.96	4.98	5.98	5	3.1	1.51	1.4	1.59	1.16	0.99	1.12	1.42	0.06	0.05	0.1	0.01	0	0.1	0.06
August	9	100	59.19	13.03	7.89	6.51	2.78	1.87	2.51	1.02	0.66	0.55	0.59	0.84	0.36	0.46	0.27	0.23	0.32	0.12	0.1	0.25	0.12	0.09	0.07	0.05	0.02	0.04	0.02	0.02	0.02	0	0
August	10	100	12.45	11.18	5.66	3.35	2.49	3.53	5.07	7.52	11.73	11.02	11.34	7.85	4.01	1.56	1.24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	11	100	23.31	20.89	15.88	12	5.8	2.61	2.08	2.06	2.94	1.1	2.98	1.95	1.87	0.72	1.27	0.41	0.4	0.16	0.99	0.2	0.38	0	0	0	0	0	0	0	0	0	0
August	12	100	13.28	6.38	6.74	6	4.37	4.53	8.01	5.61	6.25	8.04	6.7	6.08	3.48	5.81	2.22	0.98	0.89	0.96	1.39	0.38	0.11	0.08	0.23	0.2	0.41	0.07	0.09	0.35	0.03	0.1	0.23
August	13	100	19.03	3.73	0.21	0	0	1.87	5.13	13.97	19.67	15.53	11.4	5.23	3.54	0.69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	4	100	66.67	0	0	0	0	0	0	0	0	0	26.66	6.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	5	100	48.28	1.08	0.43	0.15	0.73	3.13	3.83	0.7	15.59	0.7	3.48	2.93	3.33	1.78	4.48	0	0	0	0	6.25	0	0	0	0	3.13	0	0	0	0	0	0
September	6	100	29.51	9.2	7.6	10.35	4.73	3.55	6.27	4.18	2.11	2.22	1.79	1.7	1.19	3.12	0.96	0	0.1	2.09	1.96	1.47	2.94	0.02	0	1.47	0	0.45	0	0.04	0	0.98	0
September	7	100	5.89	2.18	3.32	2.98	3.27	4.26	4.48	5.11	7.01	6.77	7.21	7.18	6.63	5.84	6.2	6.91	4.34	2.94	2.13	1.42	1.96	0.63	0.46	0.28	0.24	0.12	0.09	0.08	0.02	0.02	0.03
September	8	100	20.89	2.33	3.34	4.26	3.71	4.32	5.24	4.89	3.91	5	3.99	4.53	4.96	4.98	5.98	5	3.1	1.51	1.4	1.59	1.16	0.99	1.12	1.42	0.06	0.05	0.1	0.01	0	0.1	0.06
September	9	100	59.19	13.03	7.89	6.51	2.78	1.87	2.51	1.02	0.66	0.55	0.59	0.84	0.36	0.46	0.27	0.23	0.32	0.12	0.1	0.25	0.12	0.09	0.07	0.05	0.02	0.04	0.02	0.02	0.02	0	0
September	10	100	12.4	11.1	7.71	3.38	2.17	2.72	4.08	7.6	10.27	12.48	12.24	7.81	3.93	1.35	0.76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	11	100	23.31	20.89	15.88	12	5.8	2.61	2.08	2.06	2.94	1.1	2.98	1.95	1.87	0.72	1.27	0.41	0.4	0.16	0.99	0.2	0.38	0	0	0	0	0	0	0	0	0	0
September	12	100	13.28	6.38	6.74	6	4.37	4.53	8.01	5.61	6.25	8.04	6.7	6.08	3.48	5.81	2.22	0.98	0.89	0.96	1.39	0.38	0.11	0.08	0.23	0.2	0.41	0.07	0.09	0.35	0.03	0.1	0.23
September	13	100	21.79	3.56	0.21	0.21	0	1.66	3.33	14.42	17.37	20.25	13.26	3.01	0.93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	4	100	66.67	0	0	0	0	0	0	0	0	0	26.66	6.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	5	100	48.28	1.08	0.43	0.15	0.73	3.13	3.83	0.7	15.59	0.7	3.48	2.93	3.33	1.78	4.48	0	0	0	0	6.25	0	0	0	0	3.13	0	0	0	0	0	0
October	6	100	29.51	9.2	7.6	10.35	4.73	3.55	6.27	4.18	2.11	2.22	1.79	1.7	1.19	3.12	0.96	0	0.1	2.09	1.96	1.47	2.94	0.02	0	1.47	0	0.45	0	0.04	0	0.98	0
October	7	100	5.89	2.18	3.32	2.98	3.27	4.26	4.48	5.11	7.01	6.77	7.21	7.18	6.63	5.84	6.2	6.91	4.34	2.94	2.13	1.42	1.96	0.63	0.46	0.28	0.24	0.12	0.09	0.08	0.02	0.02	0.03
October	8	100	20.89	2.33	3.34	4.26	3.71	4.32	5.24	4.89	3.91	5	3.99	4.53	4.96	4.98	5.98	5	3.1	1.51	1.4	1.59	1.16	0.99	1.12	1.42	0.06	0.05	0.1	0.01	0	0.1	0.06
October	9	100	59.19	13.03	7.89	6.51	2.78	1.87	2.51	1.02	0.66	0.55	0.59	0.84	0.36	0.46	0.27	0.23	0.32	0.12	0.1	0.25	0.12	0.09	0.07	0.05	0.02	0.04	0.02	0.02	0.02	0	0
October	10	100	12.73	8.83	6.92	3.01	2.44	2.59	3.89	6.81	11.01	14.13	13.24	7.83	3.33	2.78	0.46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	11	100	23.31	20.89	15.88	12	5.8	2.61	2.08	2.06	2.94	1.1	2.98	1.95	1.87	0.72	1.27	0.41	0.4	0.16	0.99	0.2	0.38	0	0	0	0	0	0	0	0	0	0
October	12	100	13.28	6.38	6.74	6	4.37	4.53	8.01	5.61	6.25	8.04	6.7	6.08	3.48	5.81	2.22	0.98	0.89	0.96	1.39	0.38	0.11	0.08	0.23	0.2	0.41	0.07	0.09	0.35	0.03	0.1	0.23
October	13	100	26.79	1.81	0	0	0.3	0.3	3.75	17.53	17.12	18	10.24	2.77	1.39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	4	100	66.67	0	0	0	0	0	0	0	0	0	26.66	6.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	5	100	48.28	1.08	0.43	0.15	0.73	3.13	3.83	0.7	15.59	0.7	3.48	2.93	3.33	1.78	4.48	0	0	0	0	6.25	0	0	0	0	3.13	0	0	0	0	0	0
November	6	100	29.51	9.2	7.6	10.35	4.73	3.55	6.27	4.18	2.11	2.22	1.79	1.7	1.19	3.12	0.96	0	0.1	2.09	1.96	1.47	2.94	0.02	0	1.47	0	0.45	0	0.04	0	0.98	0
November	7	100	5.89	2.18	3.32	2.98	3.27	4.26	4.48	5.11	7.01	6.77	7.21	7.18	6.63	5.84	6.2	6.91	4.34	2.94	2.13	1.42	1.96	0.63	0.46	0.28	0.24	0.12	0.09	0.08	0.02	0.02	0.03
November	8	100	20.89	2.33	3.34	4.26	3.71	4.32	5.24	4.89	3.91	5	3.99	4.53	4.96	4.98	5.98	5	3.1	1.51	1.4	1.59	1.16	0.99	1.12	1.42	0.06	0.05	0.1	0.01	0	0.1	0.06
November	9	100	59.19	13.03	7.89	6.51	2.78	1.87	2.51	1.02	0.66	0.55	0.59	0.84	0.36	0.46	0.27	0.23	0.32	0.12	0.1	0.25	0.12	0.09	0.07	0.05	0.02	0.04	0.02	0.02	0.02	0	0
November	10	100	12.36	10.5	6.29	3.22	2.54	2.73	4.23	7.5	10.61	14.73	11.69	8.47	3.39	0.95	0.79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	11	100	23.31	20.89	15.88	12	5.8	2.61	2.08	2.06	2.94	1.1	2.98	1.95	1.87	0.72	1.27	0.41	0.4	0.16	0.99	0.2	0.38	0	0	0	0	0	0	0	0	0	0
November	12	100	13.28	6.38	6.74	6	4.37	4.53	8.01	5.61	6.25	8.04	6.7	6.08	3.48	5.81	2.22	0.98	0.89	0.96	1.39	0.38	0.11	0.08	0.23	0.2	0.41	0.07	0.09	0.35	0.03	0.1	0.23
November	13	100	29.7	3.95	0.61	0	0.23	2.55	4.69	13.51	14.22	19.32	7.88	2.95	0.39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	4	100	66.67	0	0	0	0	0	0	0	0	0	26.66	6.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	5	100	48.28	1.08	0.43	0.15	0.73	3.13	3.83	0.7	15.59	0.7	3.48	2.93	3.33	1.78	4.48	0	0	0	0	6.25	0	0	0	0	3.13	0	0	0	0	0	0
December	6	100	29.51	9.2	7.6	10.35	4.73	3.55	6.27	4.18	2.11	2.22	1.79	1.7	1.19	3.12	0.96	0	0.1	2.09	1.96	1.47	2.94	0.02	0	1.47	0	0.45	0	0.04	0	0.98	0
December	7	100	5.89	2.18	3.32	2.98	3.27	4.26	4.48	5.11	7.01	6.77	7.21	7.18	6.63	5.84	6.2	6.91	4.34	2.94	2.13	1.42	1.96	0.63	0.46	0.28	0.24	0.12	0.09	0.08	0.02	0.02	0.03
December	8	100	20.89	2.33	3.34	4.26	3.71	4.32	5.24	4.89	3.91	5	3.99	4.53	4.96	4.98	5.98	5	3.1	1.51	1.4	1.59	1.16	0.99	1.12	1.42	0.06	0.05	0.1	0.01	0	0.1	0.06
December	9	100	59.19	13.03	7.89	6.51	2.78	1.87	2.51	1.02	0.66	0.55	0.59	0.84	0.36	0.46	0.27	0.23	0.32	0.12	0.1	0.25	0.12	0.09	0.07	0.05	0.02	0.04	0.02	0.02	0.02	0	0
December	10	100	11.15	11.59	7.42	3.18	2.78	2.27	3.59	7.42	9.99	16.68	12.75	8.16	3.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	11	100	23.31	20.89	15.88	12	5.8	2.61	2.08	2.06	2.94	1.1	2.98	1.95	1.87	0.72	1.27	0.41	0.4	0.16	0.99	0.2	0.38	0	0	0	0	0	0	0	0	0	0
December	12	100	13.28	6.38	6.74	6	4.37	4.53	8.01	5.61	6.25	8.04	6.7	6.08	3.48	5.81	2.22	0.98	0.89	0.96	1.39	0.38	0.11	0.08	0.23	0.2	0.41	0.07	0.09	0.35	0.03	0.1	0.23
December	13	100	37.58	6.55	0	0	0.38	1.02	3.15	10.51	19.47	13.53	6.25	1.56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX 2: AXLE LOAD DISTRIBUTION FIGURES

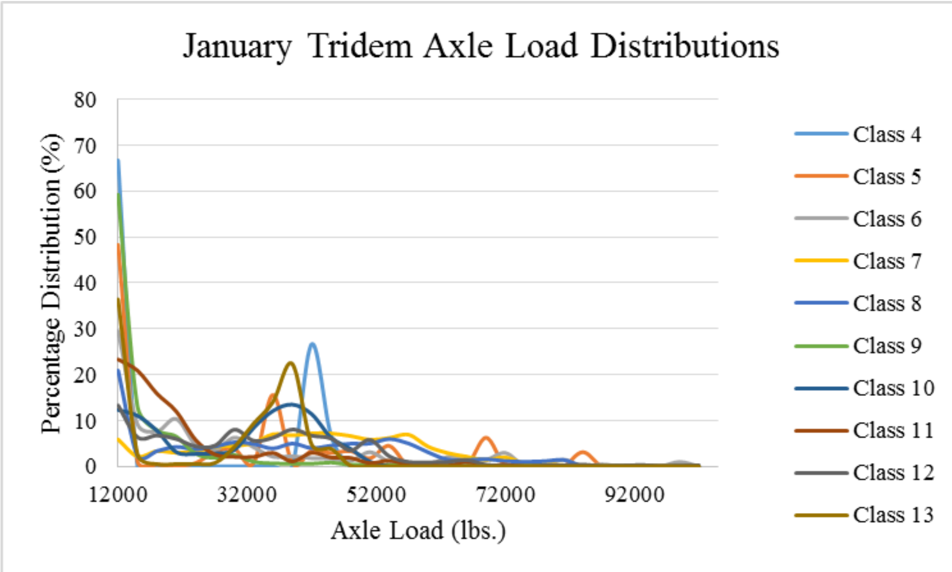
Appendix 2.1 January Single Axle Load Distributions



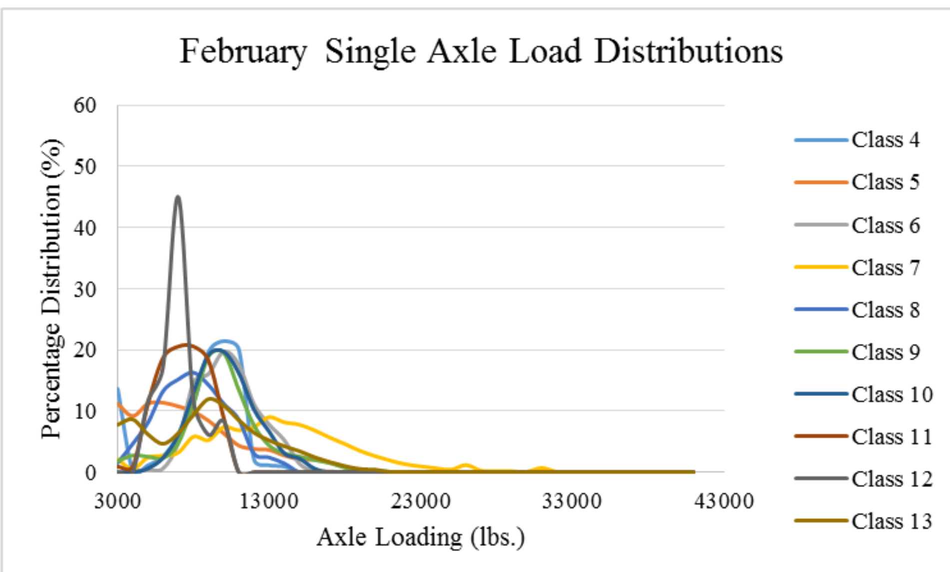
Appendix 2.2 January Tandem Axle Load Distributions



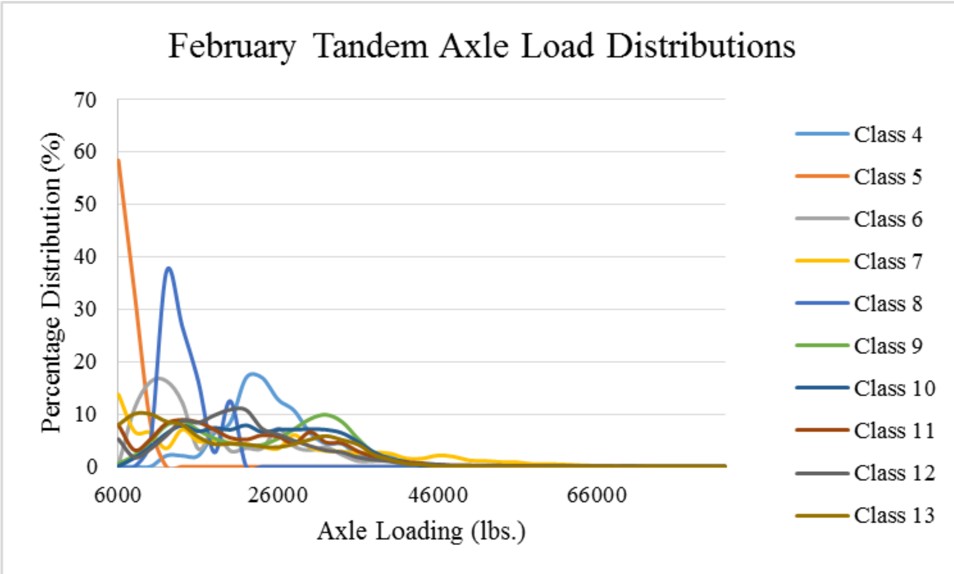
Appendix 2.3 January Tridem Axle Load Distributions



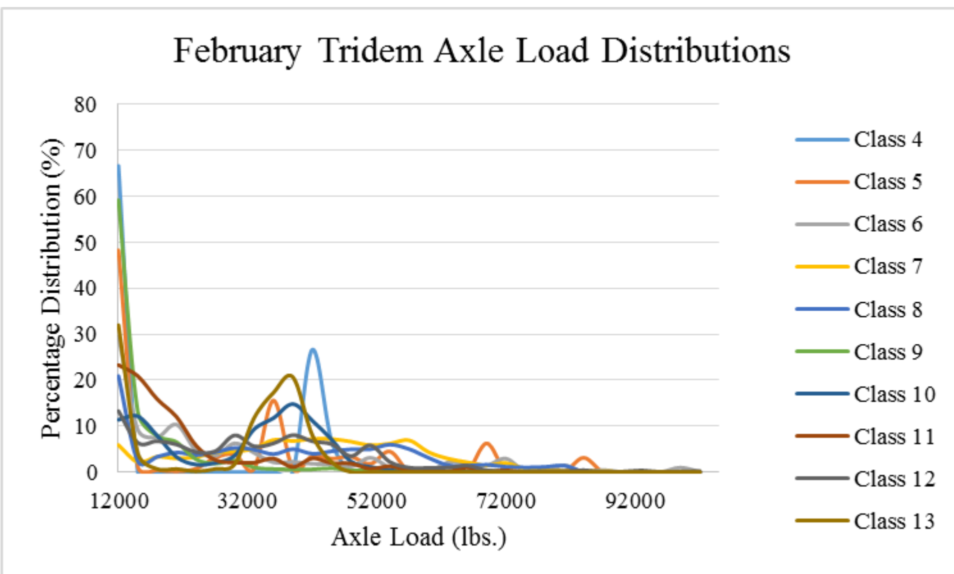
Appendix 2.4 February Single Axle Load Distributions



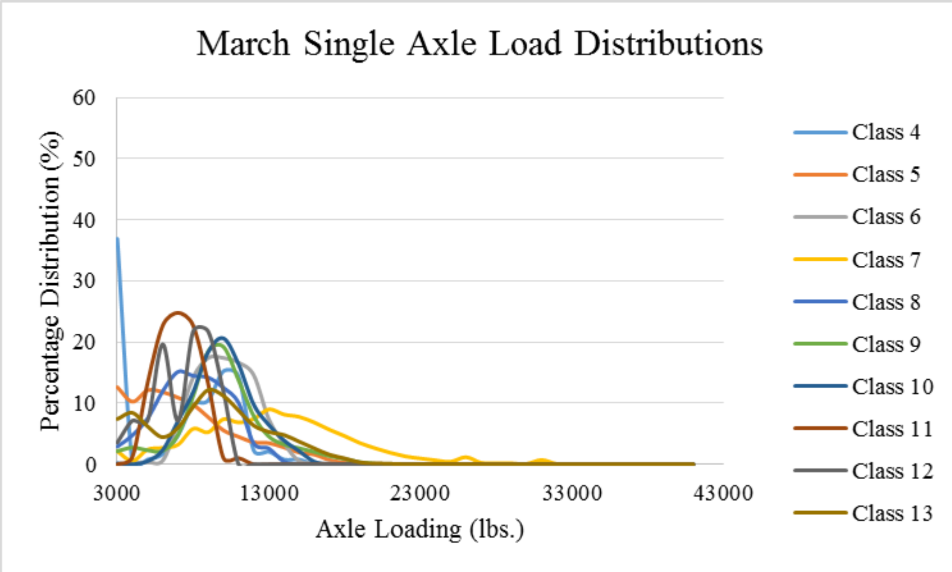
Appendix 2.5 February Tandem Axle Load Distributions



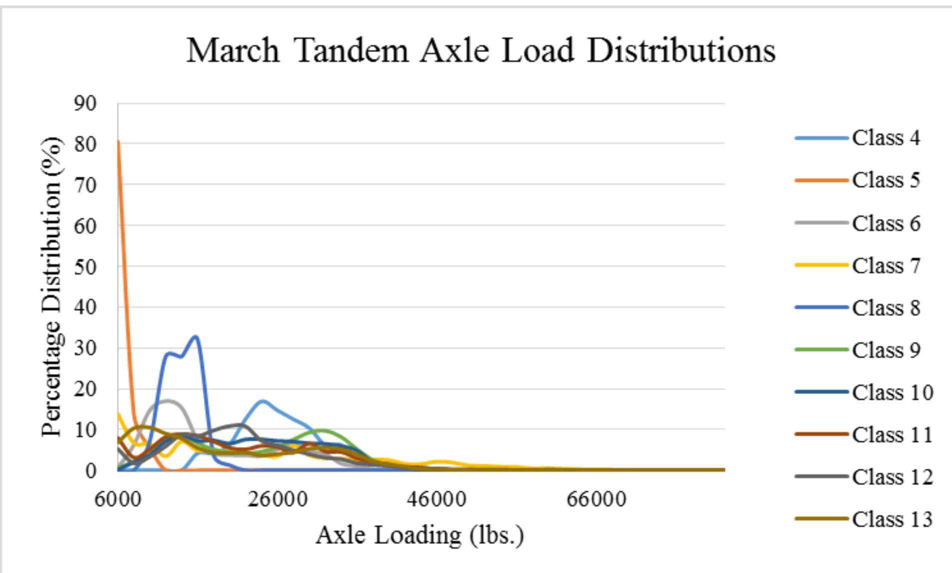
Appendix 2.6 February Tridem Axle Load Distributions



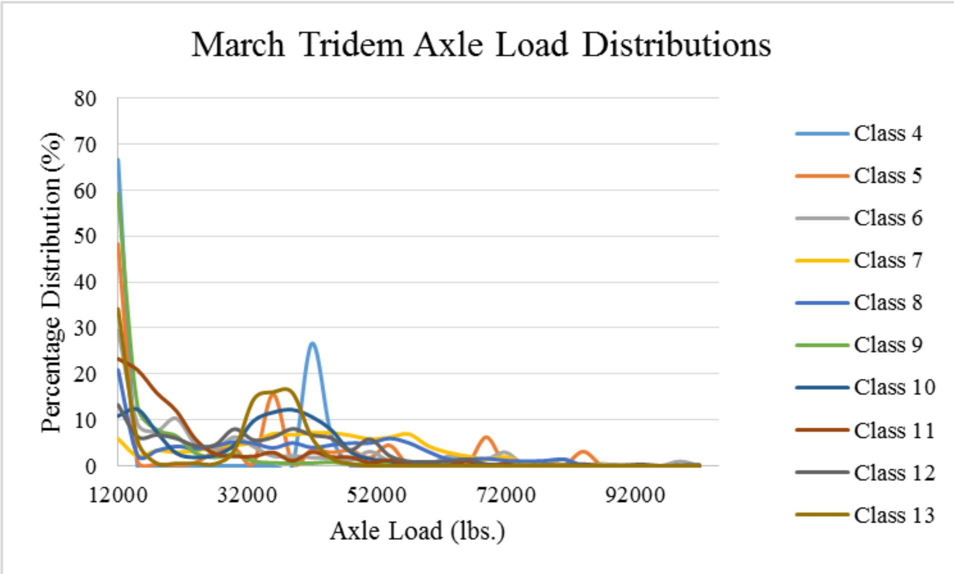
Appendix 2.7 March Single Axle Load Distributions



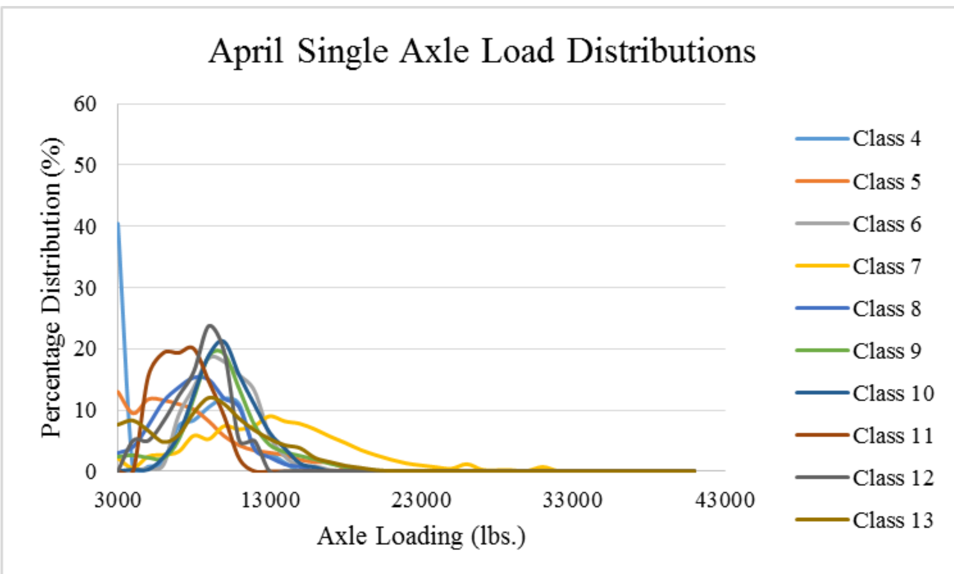
Appendix 2.8 March Tandem Axle Load Distributions



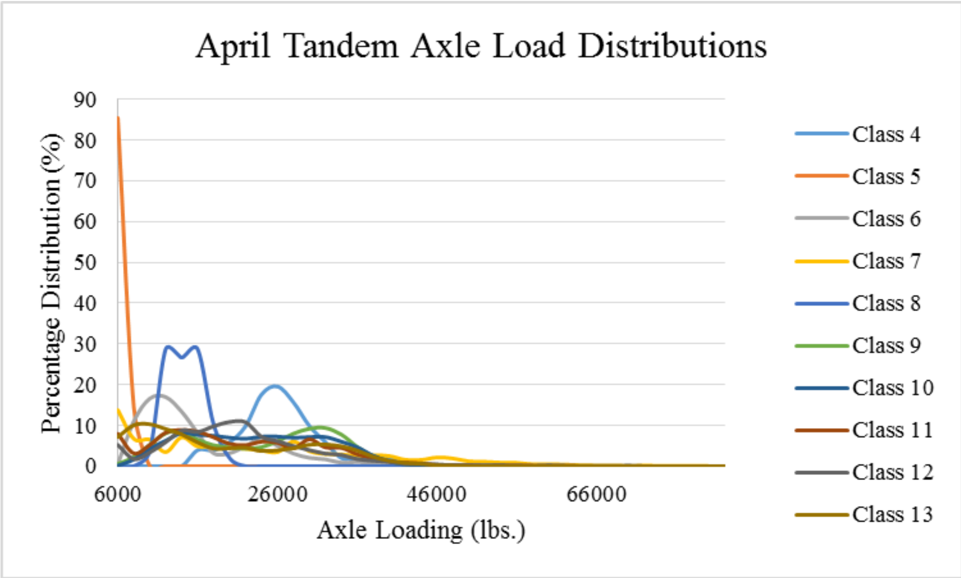
Appendix 2.9 March Tridem Axle Load Distributions



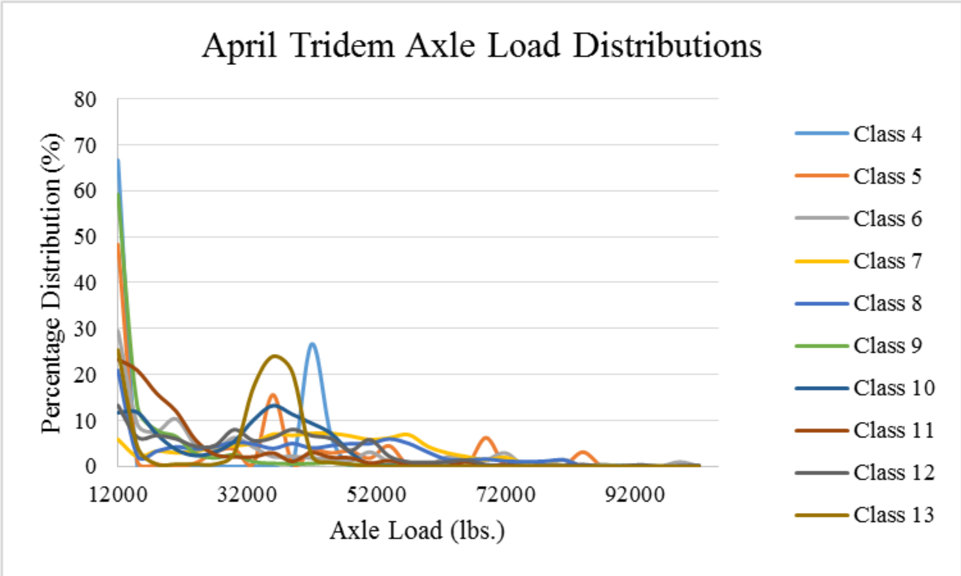
Appendix 2.10 April Single Axle Load Distributions



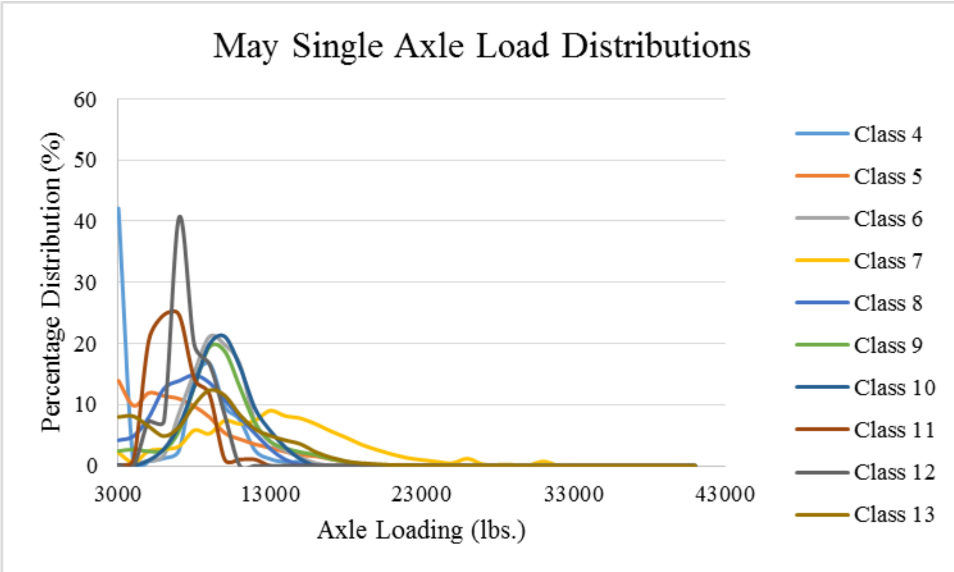
Appendix 2.11 April Tandem Axle Load Distributions



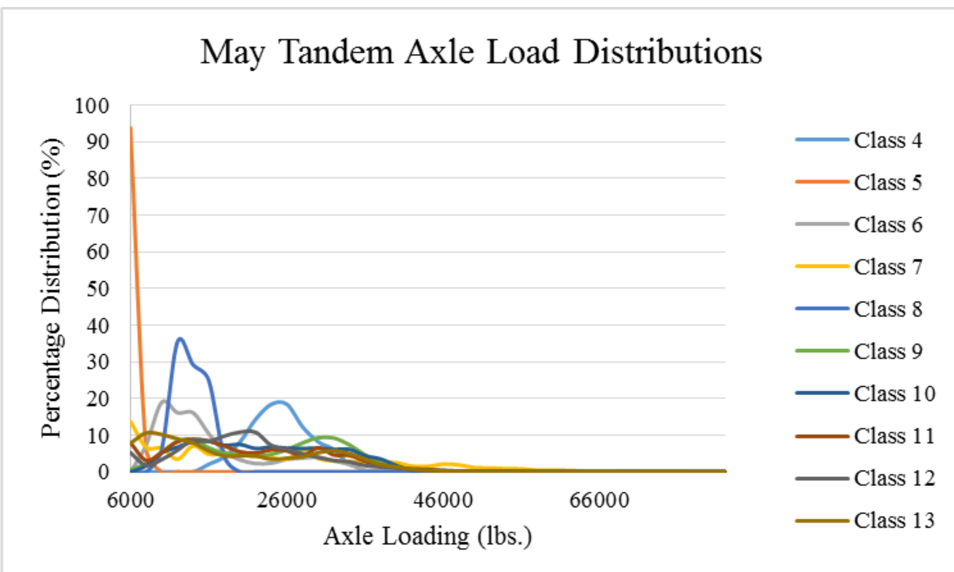
Appendix 2.12 April Tridem Axle Load Distributions



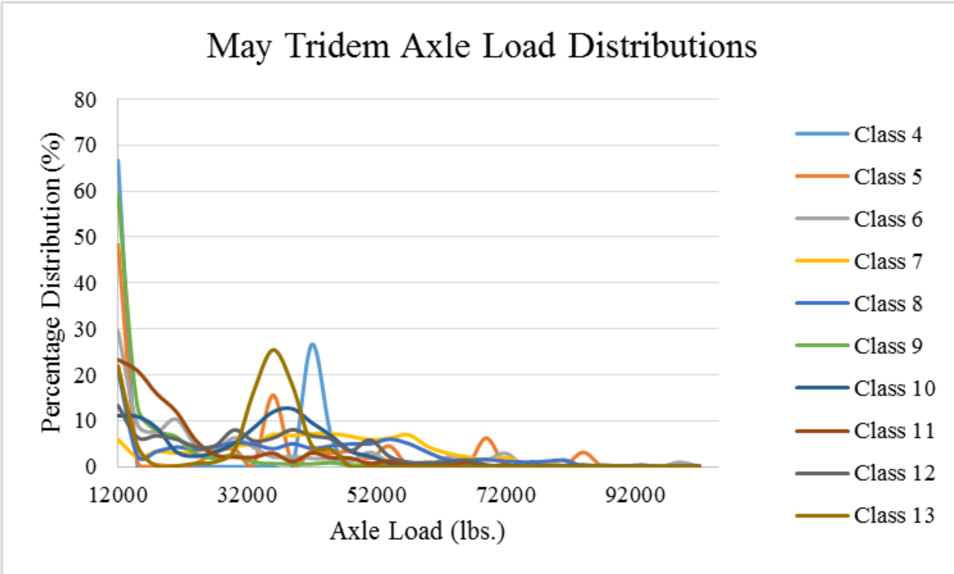
Appendix 2.13 May Single Axle Load Distributions



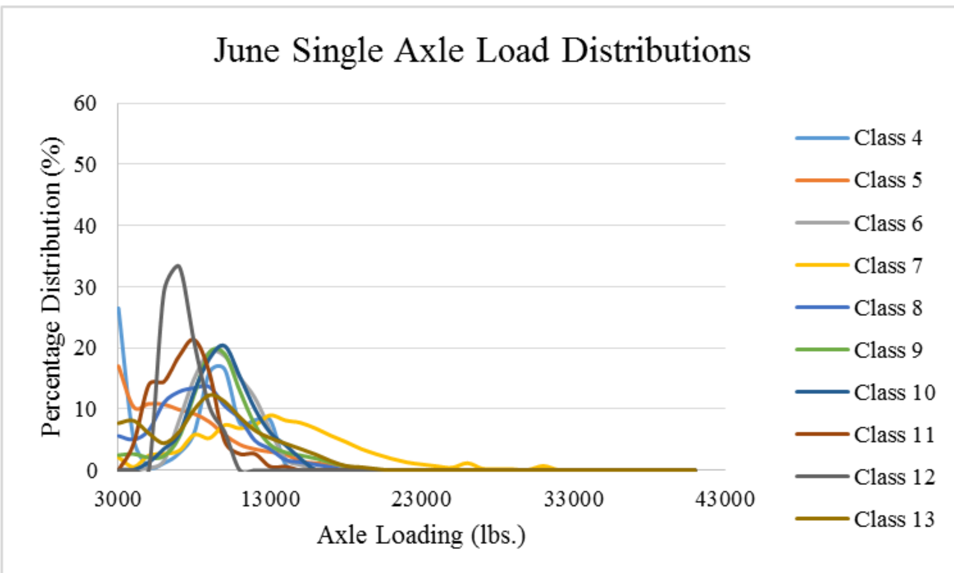
Appendix 2.14 May Tandem Axle Load Distributions



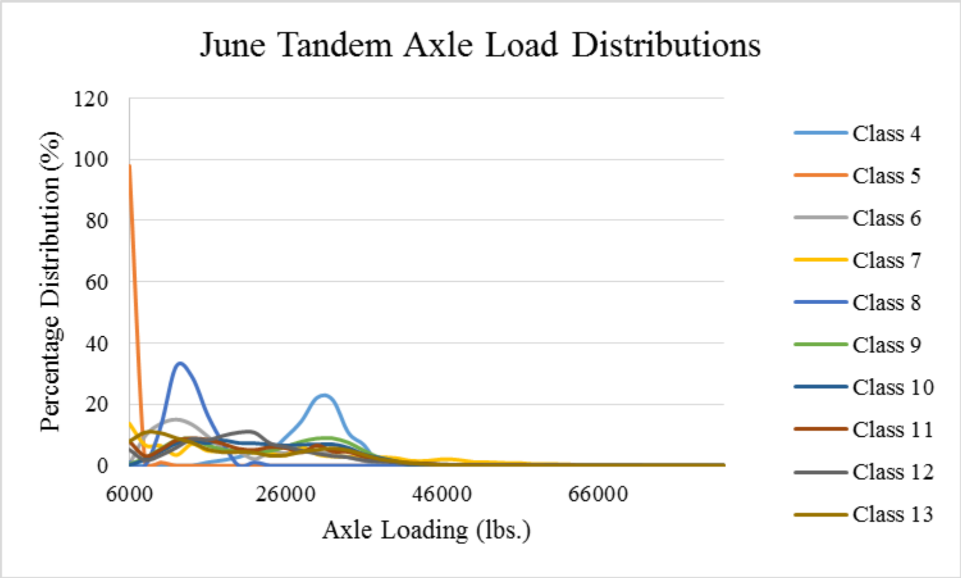
Appendix 2.15 May Tridem Axle Load Distributions



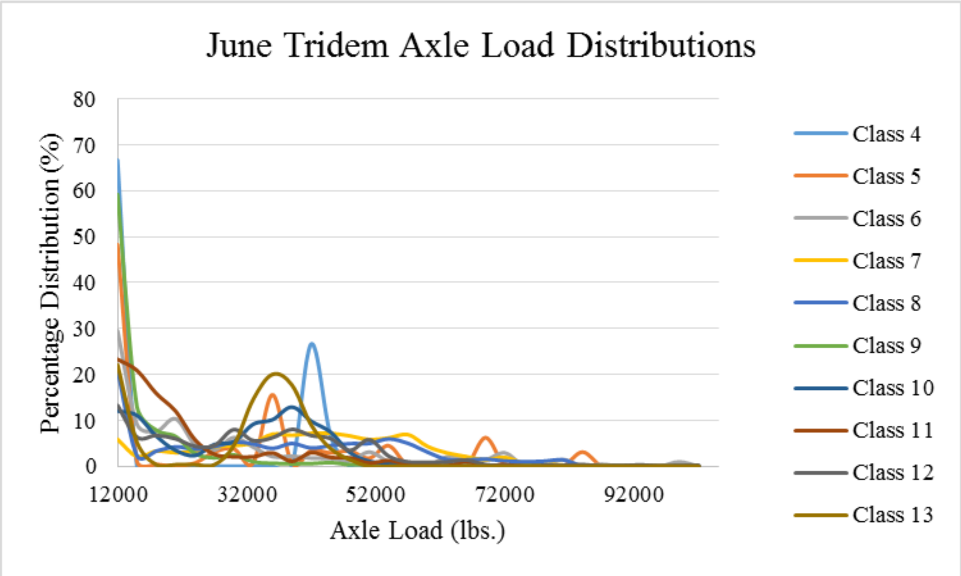
Appendix 2.16 June Single Axle Load Distributions



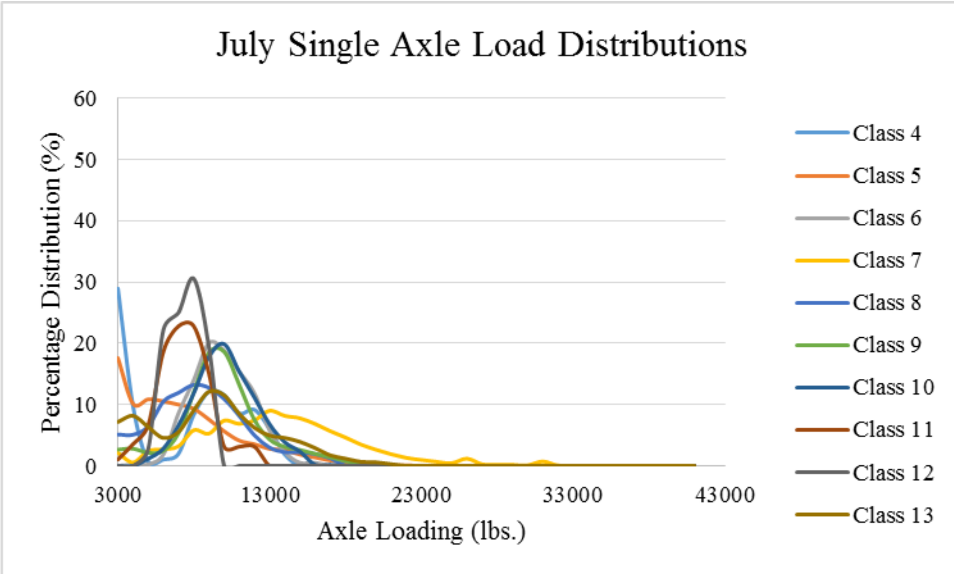
Appendix 2.17 June Tandem Axle Load Distributions



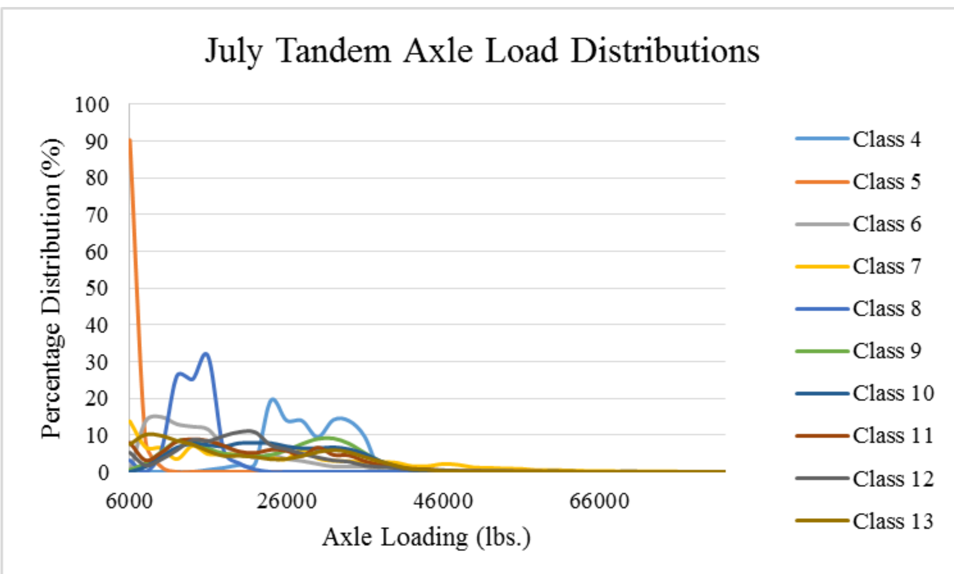
Appendix 2.18 June Tridem Axle Load Distributions



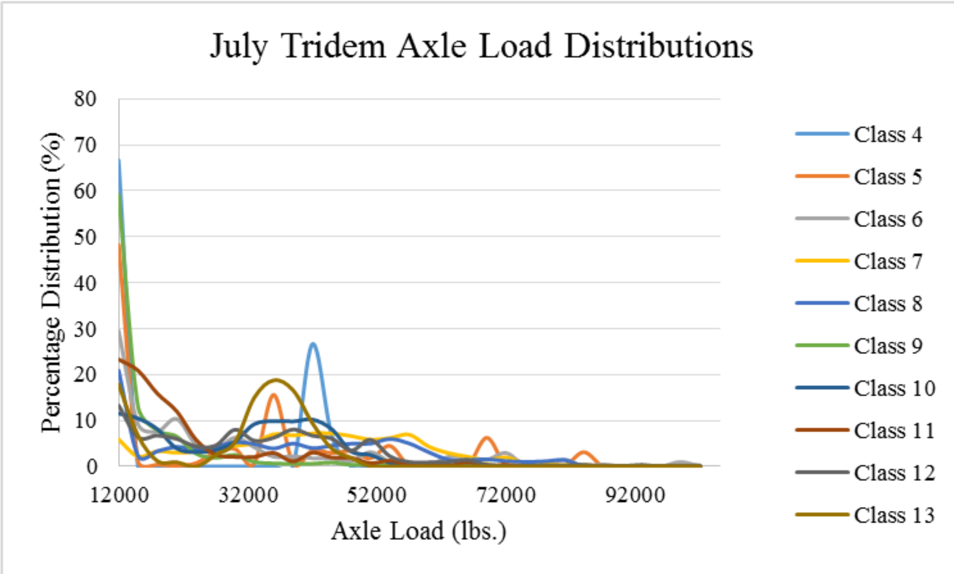
Appendix 2.19 July Single Axle Load Distributions



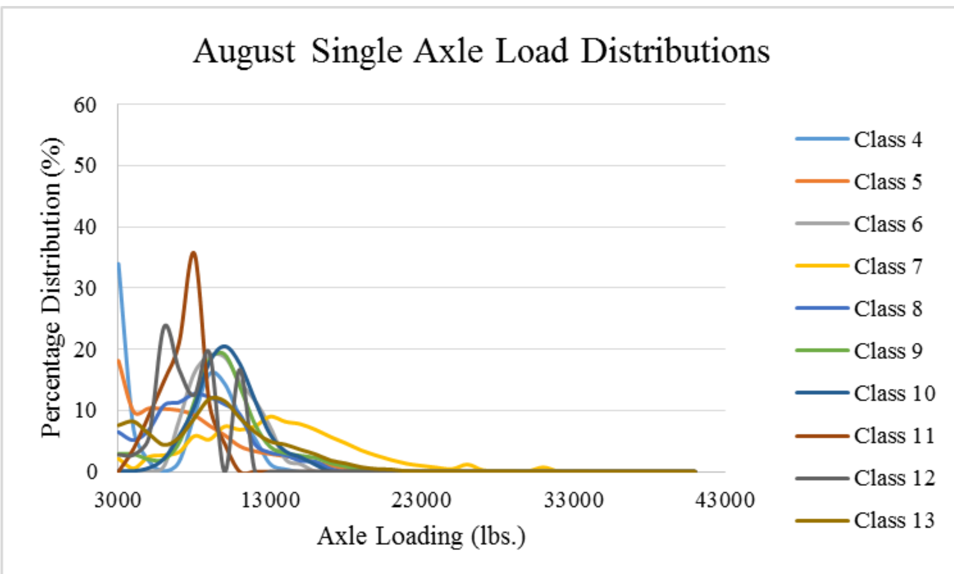
Appendix 2.20 July Tandem Axle Load Distributions



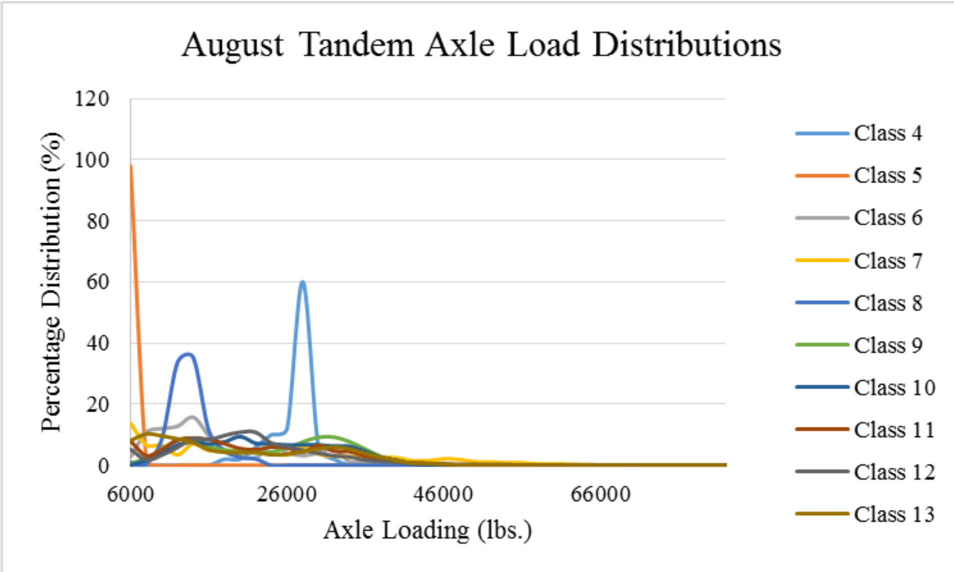
Appendix 2.21 July Tridem Axle Load Distributions



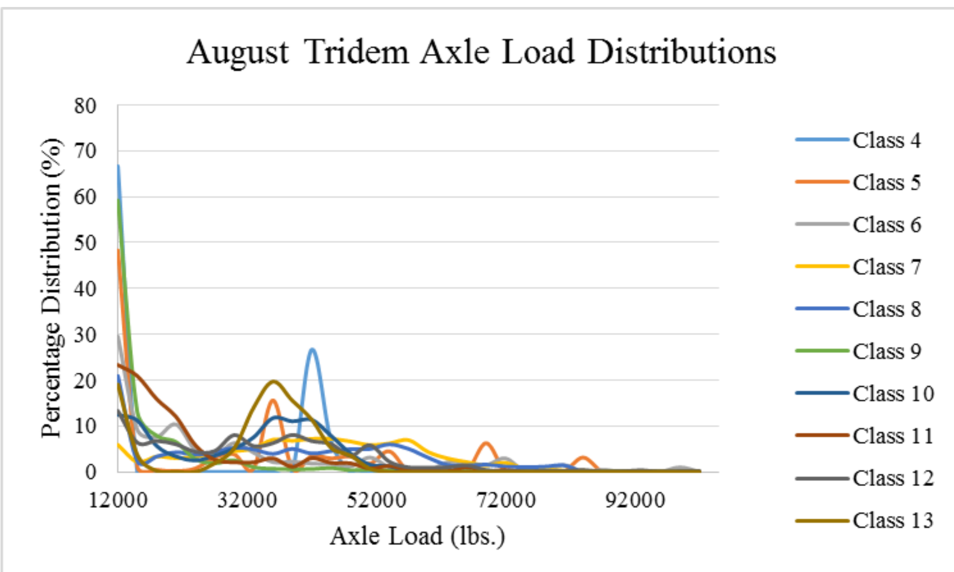
Appendix 2.22 August Single Axle Load Distributions



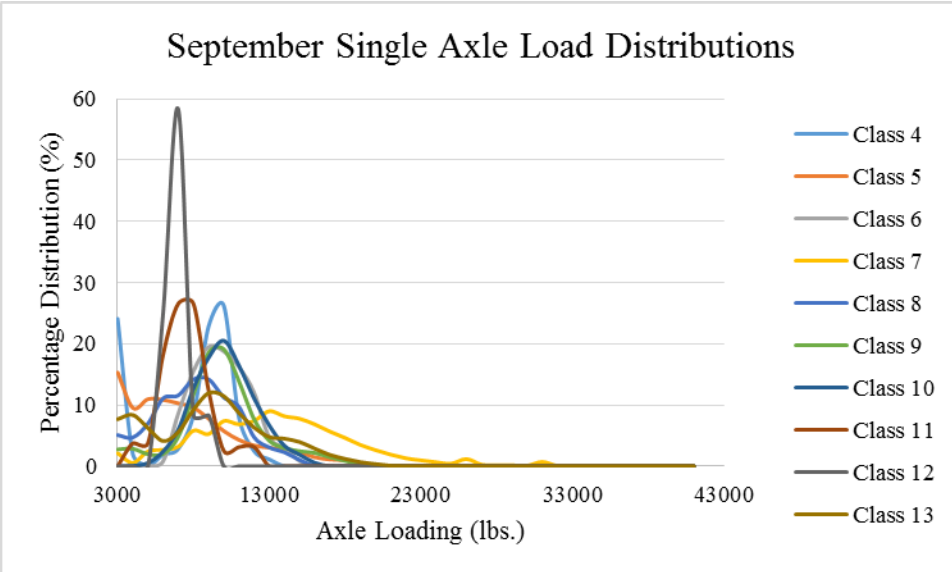
Appendix 2.23 August Tandem Axle Load Distributions



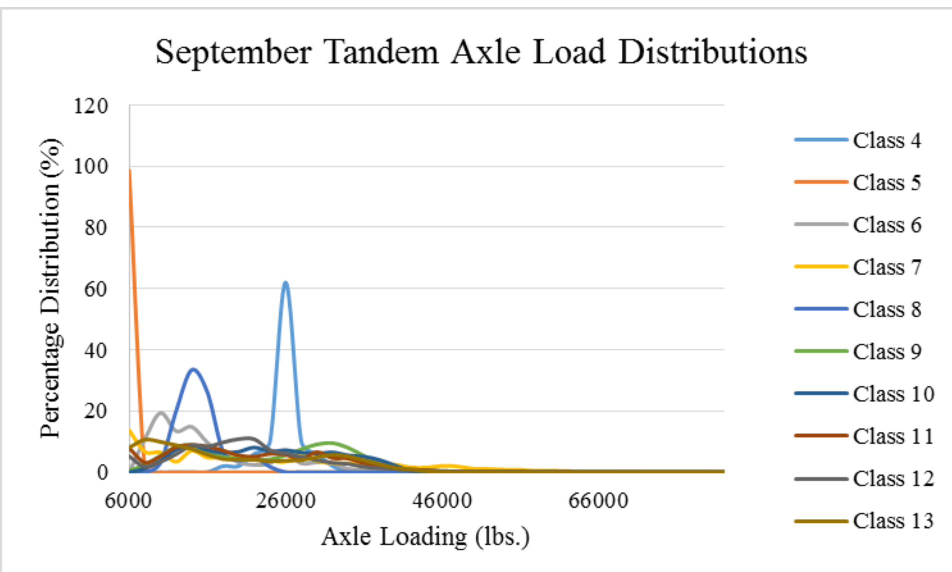
Appendix 2.24 August Tridem Axle Load Distributions



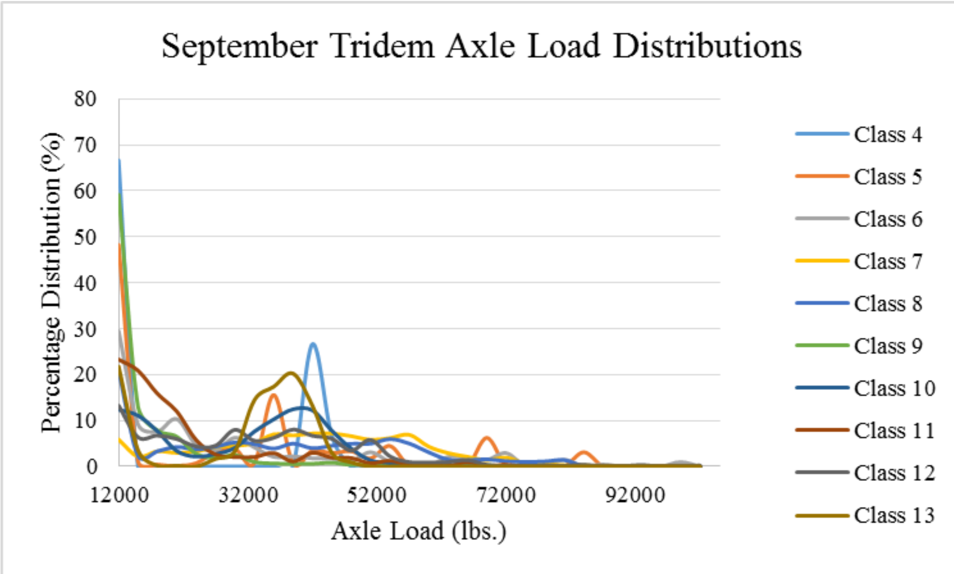
Appendix 2.25 September Single Axle Load Distributions



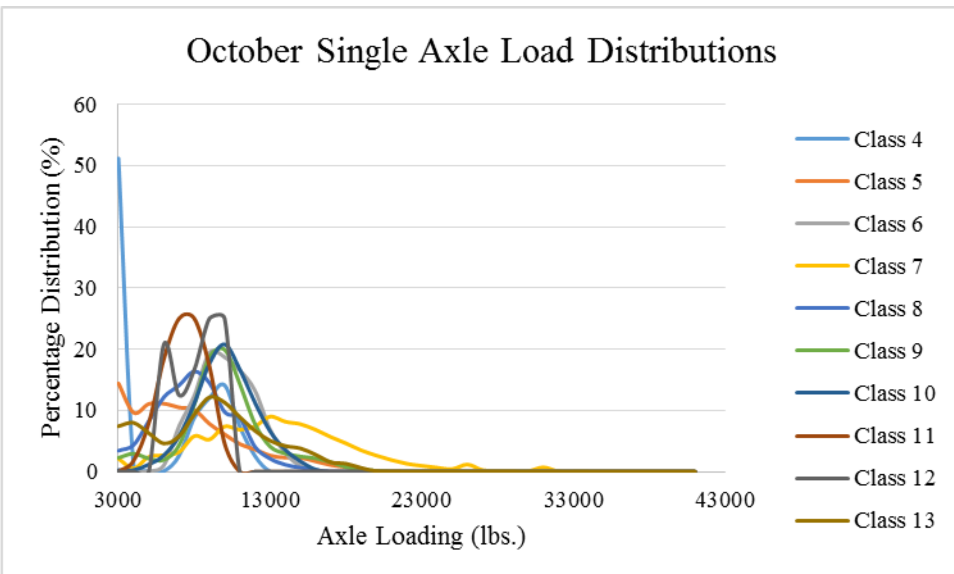
Appendix 2.26 September Tandem Axle Load Distributions



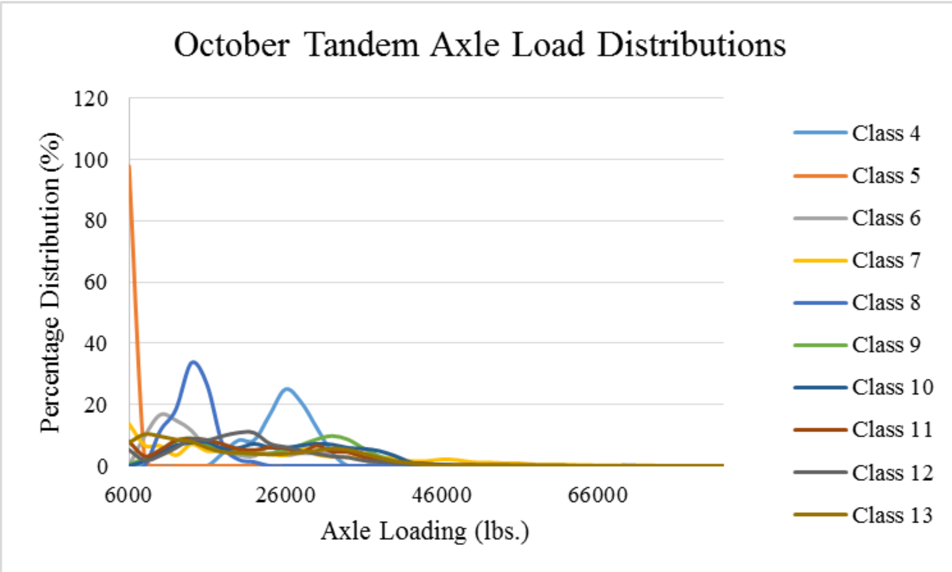
Appendix 2.27 September Tridem Axle Load Distributions



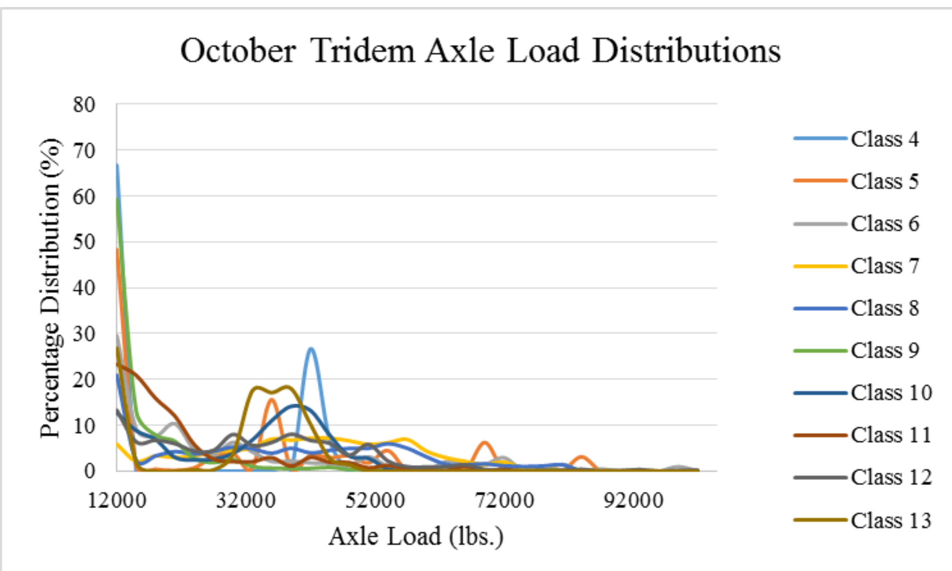
Appendix 2.28 October Single Axle Load Distributions



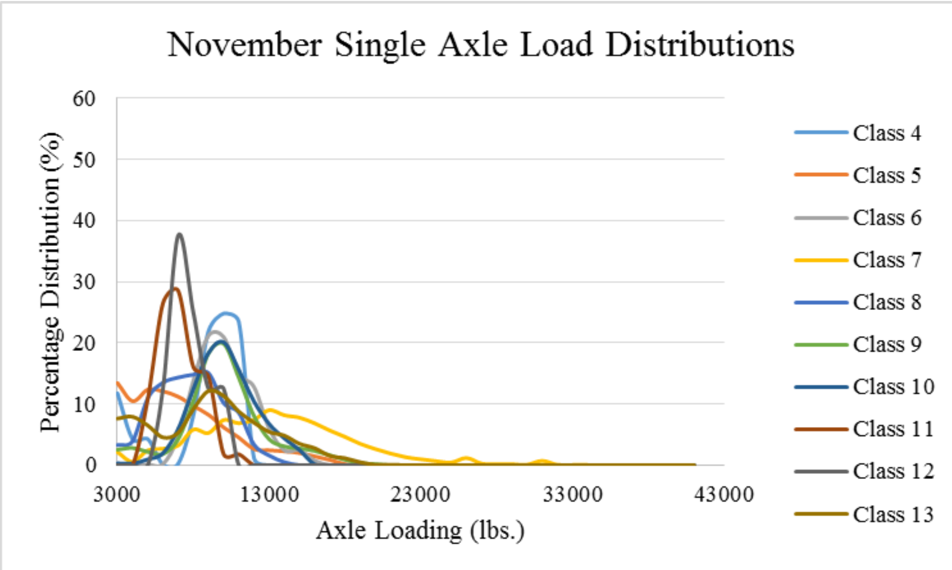
Appendix 2.29 October Tandem Axle Load Distributions



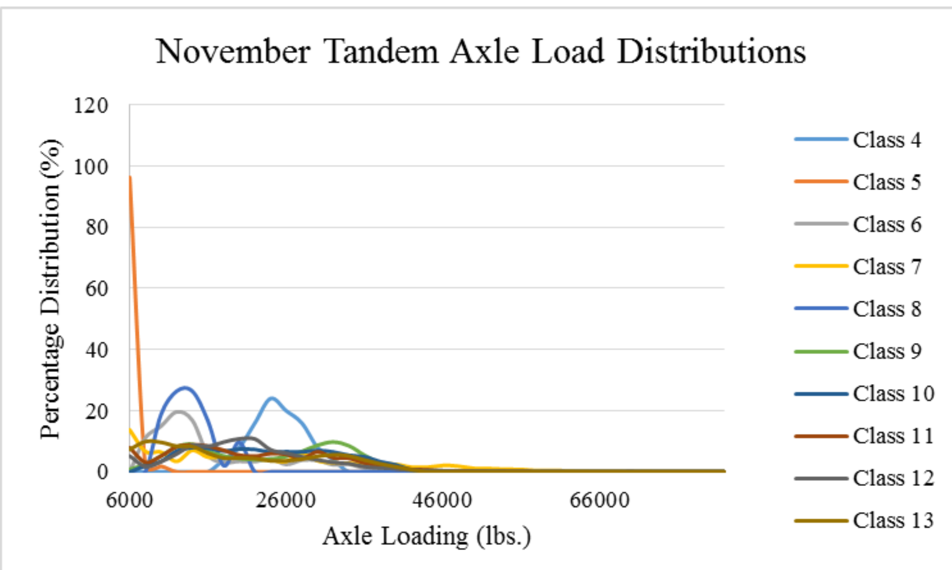
Appendix 2.30 October Tridem Axle Load Distributions



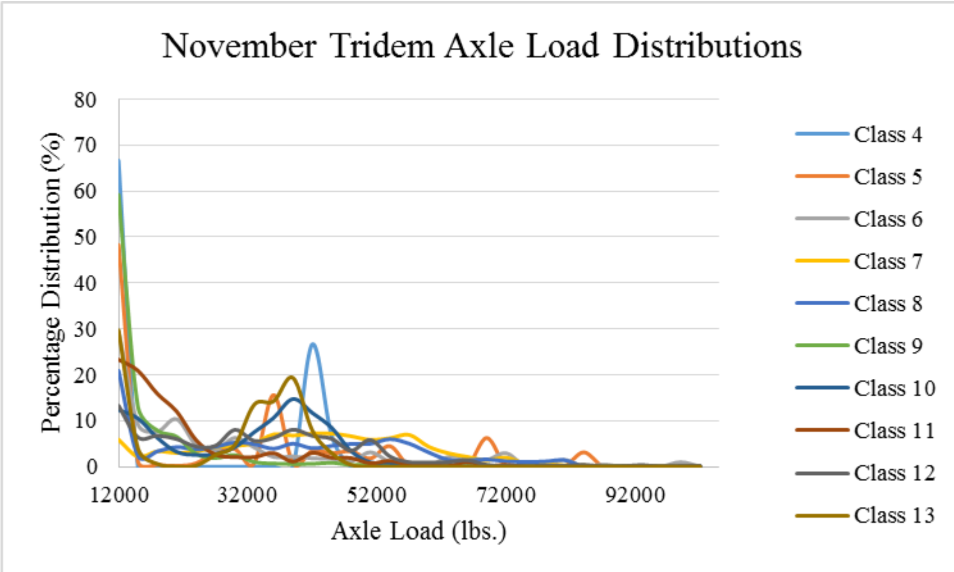
Appendix 2.31 November Single Axle Load Distributions



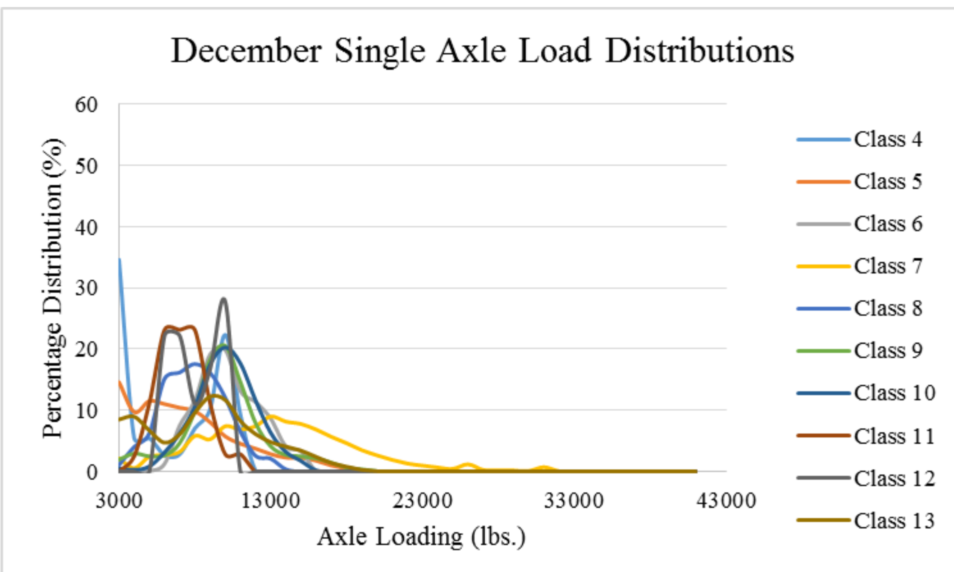
Appendix 2.32 November Tandem Axle Load Distributions



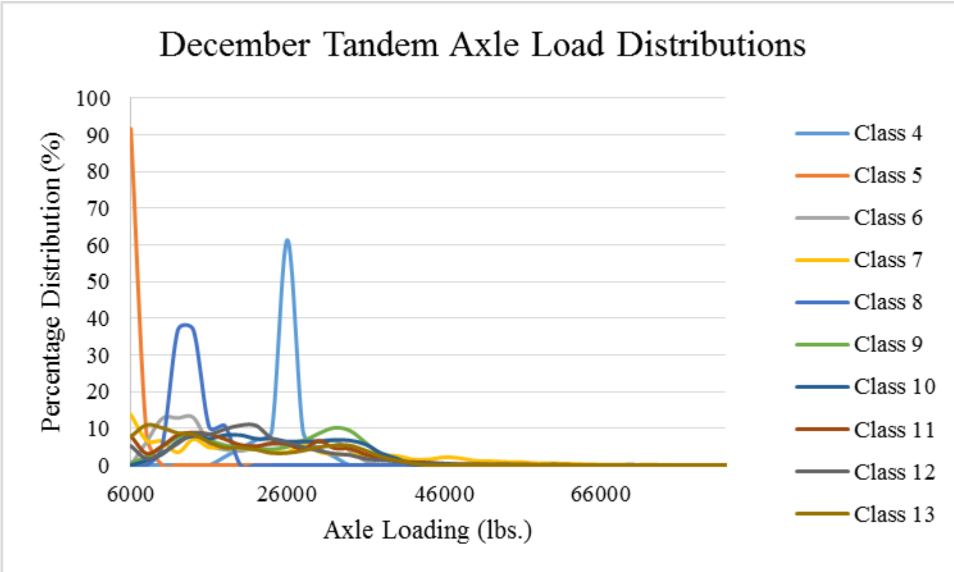
Appendix 2.33 November Tridem Axle Load Distributions



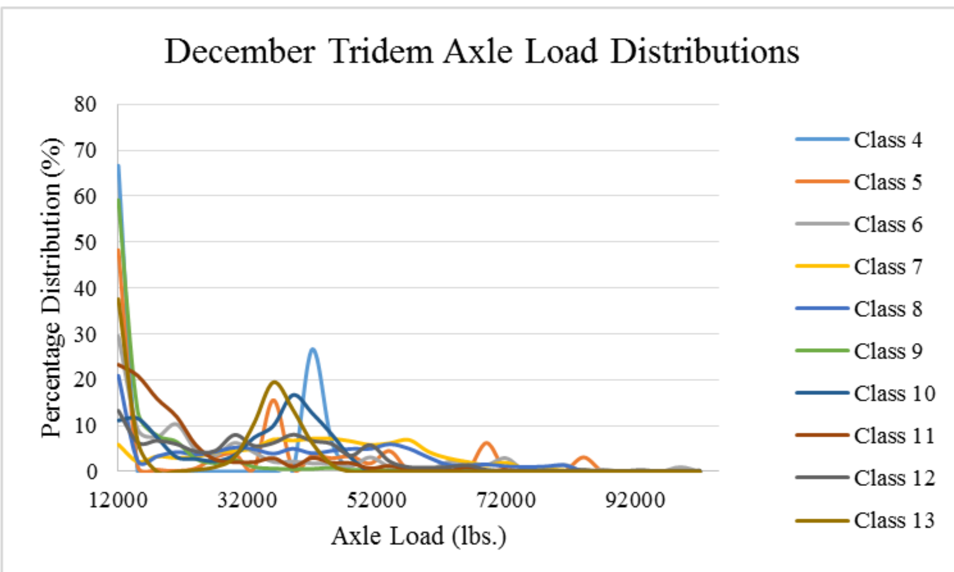
Appendix 2.34 December Single Axle Load Distributions



Appendix 2.35 December Tandem Axle Load Distributions



Appendix 2.36 December Tridem Axle Load Distributions



APPENDIX 3: CALIBRATION ITERATION RESULTS

Appendix 3.1 Iteration 1 (ARA Calibration Coefficient) Average Bias and SSE between Predicted and Observed Distresses

Road ID No.	Road Name	Calibration Coefficients		Iteration 1 – Average Differences: IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		24.02	0.03	-3.17	901.67	-1,565.26
LARAMIE	BLACK HILLS	C1 Bottom	0.50	-18.27	0.03	3.45	-17.05	-2,620.63
LARAMIE	CHALK BLUFF / "78" RD	C2 Bottom	1.47	15.20	0.11	47.27	241.67	718.37
LARAMIE	OLD HWY BURNS W	AC Rutting		-8.37	-0.03	6.18	310.31	-3,089.44
LARAMIE	OLD YELLOWSTONE RD.	BR1	1.09	-49.49	-0.08	-19.53	-1,806.97	-1,022.59
LARAMIE	CEMETERY/PINE BLUFFS S RD	**IRI**		40.05	-0.22	4.59	569.03	42.24
GOSHEN	DEER CREEK RD	C1	20.53	37.31	0.07	-11.53	-582.01	-2,717.38
GOSHEN	BUTTERMILK RD	C2	0.41	-42.66	0.14	11.28	-318.01	129.38
GOSHEN	VAN TASSEL RD	C3	0.00	-53.45	-0.01	0.31	569.03	-433.05
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		8.19	0.08	4.85	-1,025.53	-1,367.87
GOSHEN	WYNCOTE RD	Gran. BS1	0.95	25.23	0.08	5.05	-967.45	-606.29
PLATTE	BORDEAUX RD	Fine BS1	0.69	-21.21	0.01	5.13	2,644.07	1,059.26
PLATTE	PALMER CANYON	1K	7.50	40.91	0.01	-0.42	2,005.19	-152.96
CONVERSE	DEER CREEK RD			9.03	-0.02	-18.13	1,683.11	83.64
CONVERSE	HIGHLAND LOOP RD			-44.59	0.01	-16.93	1,519.43	940.88
CONVERSE	WALKER CREEK RD			-7.23	0.09	-2.10	1,720.07	446.12
CONVERSE	55 RANCH RD			-4.34	-0.25	0.64	2,232.23	991.98
CONVERSE	NATURAL BRIDGE RD			4.90	-0.03	-12.20	1,456.07	-104.86
		Average Bias		**-2.49**	**0.000**	**0.263**	**618.60**	**-514.914**
		SSE		**16,325.98**	**0.18**	**3,801.86**	**33,523,315.64**	**33,484,713.74**

Appendix 3.2 Iteration 2 Average Bias and SSE between Predicted and Observed Distresses

Road ID No.	Road Name	Calibration Coefficients		Iteration 2 – Average Differences: IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		38.57	0.02	-1.57	138.13	-191.26
LARAMIE	BLACK HILLS	C1 Bottom	0.30	-8.01	0.01	-6.25	-780.59	-1,416.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	2.30	14.04	0.07	7.77	-521.87	1,343.37
LARAMIE	OLD HWY BURNS W	C2 Top	0.09	5.14	-0.04	4.88	-453.55	-1,765.81
LARAMIE	OLD YELLOWSTONE RD.	C3 Bottom	4,600.00	-34.13	-0.08	-11.52	-2,570.51	432.61
LARAMIE	CEMETERY/PINE BLUFFS S RD	C4 Top	1,500.00	55.90	-0.22	10.68	-194.51	1,472.94
GOSHEN	DEER CREEK RD	**AC Rutting**		54.49	0.06	-3.92	-582.01	-1,266.78
GOSHEN	BUTTERMILK RD	βr1	1.15	-27.23	0.12	11.58	-318.01	1,507.38
GOSHEN	VAN TASSEL RD	βr3	0.90	-36.19	-0.02	7.36	569.03	1,013.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		8.19	0.08	4.85	-1,025.53	-1,367.87
GOSHEN	WYNCOTE RD	Fine SR, BS1	0.90	25.23	0.08	5.05	-967.45	-606.29
PLATTE	BORDEAUX RD	**IRI**		-5.47	0.01	10.77	1,880.21	2,479.41
PLATTE	PALMER CANYON	C2	0.41	56.85	0.01	6.44	1,241.33	1,286.24
CONVERSE	DEER CREEK RD	C3	0.00	26.28	-0.02	-10.77	1,683.11	1,537.44
CONVERSE	HIGHLAND LOOP RD			-31.62	-0.01	-23.23	1,519.43	2,248.22
CONVERSE	WALKER CREEK RD			7.10	0.07	-4.90	1,720.07	1,790.12
CONVERSE	55 RANCH RD			11.65	-0.26	2.43	2,232.23	2,390.98
CONVERSE	NATURAL BRIDGE RD			21.81	-0.03	-4.27	1,456.07	1,348.24
		Average Bias		**10.14**	**-0.009**	**0.299**	**279.20**	**679.770**
		SSE		**17,403.11**	**0.17**	**1,486.39**	**30,782,392.80**	**42,424,886.33**

Appendix 3.3 Iteration 3 Average Bias and SSE between Predicted and Observed Distresses

Iteration 3								
Road ID No.	Road Name	Calibration Coefficients		Average Differences				
				IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		43.36	0.05	5.83	138.13	-1,722.46
LARAMIE	BLACK HILLS	C1 Bottom	0.25	-3.92	0.04	1.55	-780.59	-2,957.83
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	8.00	16.06	0.10	16.27	-521.87	-214.13
LARAMIE	OLD HWY BURNS W	C2 Top	2.00	9.70	-0.01	12.38	-453.55	-3,294.11
LARAMIE	OLD YELLOWSTONE RD.	C3 Bottom	6,000.00	-28.03	-0.04	-5.24	-2,570.83	-1,041.30
LARAMIE	CEMETERY/PINE BLUFFS S RD	C4 Top	1,000.00	61.20	-0.19	17.67	-194.83	-34.36
GOSHEN	DEER CREEK RD	**AC Rutting**		65.03	0.10	2.76	-582.01	-2,748.84
GOSHEN	BUTTERMILK RD	βr1	1.08	-17.80	0.15	19.08	-318.01	-14.72
GOSHEN	VAN TASSEL RD	βr2	0.90	-25.84	0.02	14.26	569.03	-477.00
GOSHEN	SHEEP CREEK	βr3	0.90	35.36	0.10	17.77	-1,025.53	-1,433.17
GOSHEN	WYNCOTE RD	**Subgrade Rutting**		52.00	0.10	17.07	-967.45	-687.19
PLATTE	BORDEAUX RD	Coarse SR, BS1	1.00	-0.21	0.04	17.87	1,880.21	972.91
PLATTE	PALMER CANYON	C1	30.00	62.35	0.04	13.36	1,241.33	-212.66
CONVERSE	DEER CREEK RD	C2	0.45	36.68	0.01	-4.04	1,683.11	46.14
CONVERSE	HIGHLAND LOOP RD	C3	0.01	-22.67	0.02	-15.53	1,519.43	711.42
CONVERSE	WALKER CREEK RD			16.25	0.10	2.70	1,720.07	260.72
CONVERSE	55 RANCH RD			21.16	-0.23	9.83	2,232.23	867.58
CONVERSE	NATURAL BRIDGE RD			32.64	0.00	2.26	1,456.07	-125.38
		Average Bias		**19.63**	**0.021**	**8.103**	**279.16**	**-672.466**
		SSE		**23,470.46**	**0.17**	**2,840.58**	**30,784,162.62**	**36,344,614.36**

Appendix 3.4 Iteration 4 Average Bias and SSE between Predicted and Observed Distresses

Iteration 4								
Road ID No.	Road Name	Calibration Coefficients		Average Differences				
				IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		23.16	-0.03	0.53	138.13	-813.26
LARAMIE	BLACK HILLS	C1 Bottom	0.40	-18.48	-0.03	9.45	-780.59	-1,966.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.00	12.68	0.02	50.17	-521.87	913.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	1.46	-8.99	-0.09	10.68	-453.55	-2,356.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.50	-51.35	-0.11	-19.15	-2,570.83	-335.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	5,000.00	38.58	-0.26	6.41	-194.83	798.94
GOSHEN	DEER CREEK RD	C4 Top	1,250.00	36.39	0.03	-10.65	-582.01	-1,998.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-42.66	0.08	15.38	-318.01	884.38
GOSHEN	VAN TASSEL RD	βr1	1.07	-54.28	-0.05	1.57	569.03	303.55
GOSHEN	SHEEP CREEK	βr3	0.80	7.53	0.03	6.78	-1,025.53	-614.77
GOSHEN	WYNCOTE RD	**Subgrade Rutting**		24.71	0.03	7.46	-967.45	151.71
PLATTE	BORDEAUX RD	Coarse SR, BS1	0.90	-22.61	-0.04	7.19	1,880.21	1,817.41
PLATTE	PALMER CANYON	Fine SR, Bs1	0.70	39.30	-0.03	0.97	1,241.33	596.24
CONVERSE	DEER CREEK RD	**IRI**		8.14	-0.06	-17.07	1,683.11	812.44
CONVERSE	HIGHLAND LOOP RD	C1	19.00	-44.18	-0.06	-11.33	1,519.43	1,662.22
CONVERSE	WALKER CREEK RD	C2	0.41	-6.96	0.02	2.90	1,720.07	1,188.12
CONVERSE	55 RANCH RD	C3	0.00	-4.50	-0.31	4.23	2,232.23	1,751.98
CONVERSE	NATURAL BRIDGE RD	C4	0.02	3.92	-0.06	-11.66	1,456.07	588.24
		Average Bias		**-3.31**	**-0.050**	**2.992**	**279.16**	**187.942**
		SSE		**16,160.34**	**0.21**	**4,217.19**	**30,784,162.62**	**28,847,569.93**

Appendix 3.5 Iteration 5 Average Bias and SSE between Predicted and Observed Distresses

		Iteration 5						
				Average Differences				
Road ID No.	Road Name	Calibration Coefficients		IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		27.85	-0.05	11.13	138.13	-1,425.26
LARAMIE	BLACK HILLS	C1 Bottom	0.25	-12.45	-0.05	23.25	-780.59	-2,650.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	4.00	15.20	-0.01	56.57	-521.87	100.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	1.47	-3.56	-0.10	22.98	-453.55	-2,993.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.30	-50.71	-0.12	-17.84	-2,570.83	-780.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	4,400.00	41.24	-0.27	12.37	-194.83	250.94
GOSHEN	DEER CREEK RD	C4 Top	1,300.00	37.71	0.01	-7.66	-582.01	-2,478.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-37.64	0.05	26.88	-318.01	280.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-52.41	-0.07	5.82	569.03	-201.45
GOSHEN	SHEEP CREEK	βr2, βr3	0.80	10.29	0.01	13.07	-1,025.53	-1,150.77
GOSHEN	WYNCOTE RD	**Subgrade Rutting**		28.05	0.01	15.07	-967.45	-401.29
PLATTE	BORDEAUX RD	Coarse SR, BS1	0.90	-19.68	-0.05	13.77	1,880.21	1,260.41
PLATTE	PALMER CANYON	Fine SR, Bs1	0.70	41.39	-0.05	5.62	1,241.33	68.24
CONVERSE	DEER CREEK RD	**IRI**		9.73	-0.07	-13.46	1,683.11	319.44
CONVERSE	HIGHLAND LOOP RD	C1	22.00	-38.28	-0.09	2.27	1,519.43	1,014.22
CONVERSE	WALKER CREEK RD	C2	0.41	-1.39	0.00	15.70	1,720.07	560.12
CONVERSE	55 RANCH RD	C3	0.00	0.14	-0.33	14.83	2,232.23	1,160.98
CONVERSE	NATURAL BRIDGE RD	C4	0.02	4.77	-0.08	-9.78	1,456.07	137.24
		Average Bias		**0.01**	**-0.069**	**10.588**	**279.16**	**-385.002**
		SSE		**15,610.06**	**0.25**	**7,046.57**	**30,784,162.62**	**30,855,425.93**

Appendix 3.6 Iteration 6 Average Bias and SSE between Predicted and Observed Distresses

		Iteration 6						
				Average Differences				
Road ID No.	Road Name	Calibration Coefficients		IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		21.88	0.07	-7.97	137.81	-1,185.26
LARAMIE	BLACK HILLS	C1 Bottom	0.60	-22.43	0.07	-5.75	-780.91	-2,383.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.50	8.17	0.13	32.07	-522.19	409.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	1.70	-11.13	0.01	0.03	-453.55	-2,744.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.40	-49.79	-0.04	-20.03	-2,570.83	-600.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	4,600.00	39.03	-0.18	2.28	-194.83	467.94
GOSHEN	DEER CREEK RD	C4 Top	1,300.00	37.63	0.11	-12.65	-582.01	-2,286.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-44.27	0.17	5.87	-318.01	517.38
GOSHEN	VAN TASSEL RD	βr1	1.15	-53.33	0.04	-1.30	569.03	0.55
GOSHEN	SHEEP CREEK	βr3	0.90	7.93	0.11	2.41	-1,025.53	-937.77
GOSHEN	WYNCOTE RD	**Subgrade Rutting**		24.69	0.12	1.99	-967.45	-182.29
PLATTE	BORDEAUX RD	Coarse SR, BS1	0.90	-22.36	0.06	2.54	1,880.21	1,480.41
PLATTE	PALMER CANYON	Fine SR, Bs1	1.00	40.13	0.06	-2.18	1,241.33	278.24
CONVERSE	DEER CREEK RD	**IRI**		9.25	0.02	-19.48	1,683.11	516.44
CONVERSE	HIGHLAND LOOP RD	C1	23.00	-47.43	0.04	-25.01	1,519.43	1,267.22
CONVERSE	WALKER CREEK RD	C2	0.42	-9.45	0.12	-8.84	1,720.07	805.12
CONVERSE	55 RANCH RD	C3	0.00	-5.63	-0.21	-4.08	2,232.23	1,392.98
CONVERSE	NATURAL BRIDGE RD	C4	0.02	5.38	0.02	-12.91	1,456.07	319.24
		Average Bias		**-3.99**	**0.038**	**-4.056**	**279.11**	**-159.224**
		SSE		**16,662.77**	**0.20**	**3,015.04**	**30,784,908.10**	**28,609,336.07**

Appendix 3.7 Iteration 7 Average Bias and SSE between Predicted and Observed Distresses

Road ID No.	Road Name	Calibration Coefficients		IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
				Iteration 7				
				Average Differences				
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		28.03	0.02	7.33	137.81	-776.26
LARAMIE	BLACK HILLS	C1 Bottom	0.30	-11.86	0.02	19.05	-780.59	-1,916.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.00	18.26	0.09	55.67	-522.19	953.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	1.47	-3.37	-0.04	18.78	-453.55	-2,317.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.50	-50.00	-0.09	-18.39	-2,570.83	-307.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	4,600.00	41.65	-0.23	9.99	-194.83	832.94
GOSHEN	DEER CREEK RD	C4 Top	1,300.00	38.54	0.06	-8.90	-582.01	-1,968.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-37.18	0.13	22.78	-318.01	921.38
GOSHEN	VAN TASSEL RD	βr1	1.10	-51.65	-0.02	4.09	569.03	334.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		10.91	0.06	10.56	-1,025.53	-581.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.90	28.58	0.07	12.07	-967.45	185.71
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.65	-19.31	0.00	11.17	1,880.21	1,852.41
PLATTE	PALMER CANYON	**IRI**		41.91	-0.01	3.74	1,241.33	629.24
CONVERSE	DEER CREEK RD	C1	22.80	10.53	-0.03	-14.94	1,683.11	843.44
CONVERSE	HIGHLAND LOOP RD	C2	0.42	-37.50	0.00	-2.03	1,519.43	1,698.22
CONVERSE	WALKER CREEK RD	C3	0.00	-0.81	0.08	11.40	1,720.07	1,225.12
CONVERSE	55 RANCH RD	C4	0.02	0.57	-0.26	10.93	2,232.23	1,787.98
CONVERSE	NATURAL BRIDGE RD			5.62	-0.04	-10.57	1,456.07	617.24
		Average Bias		**0.72**	**-0.011**	**7.929**	**279.13**	**222.942**
		SSE		**15,656.12**	**0.18**	**5,905.76**	**30,784,408.42**	**29,056,874.09**

Appendix 3.8 Iteration 8 Average Bias and SSE between Predicted and Observed Distresses

Road ID No.	Road Name	Calibration Coefficients		IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
				Iteration 8				
				Average Differences				
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		22.97	0.01	-2.88	137.81	-1,007.26
LARAMIE	BLACK HILLS	C1 Bottom	0.45	-19.38	0.01	3.95	-780.59	-2,182.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	11.74	0.07	43.67	-522.19	645.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	1.55	-9.41	-0.05	6.58	-453.55	-2,558.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.45	-50.59	-0.09	-19.58	-2,570.83	-471.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	4,600.00	38.95	-0.23	4.60	-194.83	627.94
GOSHEN	DEER CREEK RD	C4 Top	1,300.00	37.25	0.05	-11.59	-582.01	-2,146.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-42.70	0.12	11.58	-318.01	693.38
GOSHEN	VAN TASSEL RD	βr1	1.10	-53.52	-0.02	0.27	569.03	146.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		8.12	0.06	4.88	-1,025.53	-782.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	25.17	0.07	5.13	-967.45	-21.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-22.31	0.00	5.17	1,880.21	1,642.41
PLATTE	PALMER CANYON	**IRI**		39.81	-0.01	-0.44	1,241.33	432.24
CONVERSE	DEER CREEK RD	C1	21.50	8.96	-0.03	-18.18	1,683.11	659.44
CONVERSE	HIGHLAND LOOP RD	C2	0.41	-44.58	-0.01	-16.33	1,519.43	1,455.22
CONVERSE	WALKER CREEK RD	C3	0.00	-7.22	0.07	-1.60	1,720.07	988.12
CONVERSE	55 RANCH RD	C4	0.02	-4.36	-0.27	0.91	2,232.23	1,564.98
CONVERSE	NATURAL BRIDGE RD			4.85	-0.04	-12.26	1,456.07	450.24
		Average Bias		**-3.13**	**-0.017**	**0.216**	**279.13**	**7.498**
		SSE		**16,225.63**	**0.18**	**3,475.23**	**30,784,408.42**	**28,148,201.87**

Appendix 3.9 Iteration 9 Average Bias and SSE between Predicted and Observed Distresses

Road ID No.	Road Name	Calibration Coefficients		IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
		Iteration 9		Average Differences				
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		22.61	0.02	-4.02	137.81	-1,003.26
LARAMIE	BLACK HILLS	C1 Bottom	0.48	-20.00	0.02	1.95	-780.59	-2,174.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.26	11.38	0.10	41.67	-522.19	660.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	1.57	-9.85	-0.04	5.18	-453.55	-2,552.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.47	-50.71	-0.09	-19.69	-2,570.83	-473.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	4,600.00	38.76	-0.23	4.06	-194.83	628.94
GOSHEN	DEER CREEK RD	C4 Top	1,300.00	37.12	0.06	-11.84	-582.01	-2,147.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-43.05	0.13	10.35	-318.01	698.38
GOSHEN	VAN TASSEL RD	βr1	1.12	-53.66	-0.02	-0.10	569.03	146.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		7.93	0.06	4.30	-1,025.53	-780.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.90	24.95	0.07	4.41	-967.45	-19.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.65	-22.52	0.00	4.56	1,880.21	1,645.41
PLATTE	PALMER CANYON	**IRI**		39.65	-0.01	-0.85	1,241.33	433.24
CONVERSE	DEER CREEK RD	C1	22.10	8.82	-0.03	-18.49	1,683.11	658.44
CONVERSE	HIGHLAND LOOP RD	C2	0.41	-45.14	0.00	-18.23	1,519.43	1,462.22
CONVERSE	WALKER CREEK RD	C3	0.00	-7.69	0.08	-3.20	1,720.07	993.12
CONVERSE	55 RANCH RD	C4	0.02	-4.69	-0.26	-0.21	2,232.23	1,568.98
CONVERSE	NATURAL BRIDGE RD			4.72	-0.04	-12.42	1,456.07	448.24
		Average Bias		**-3.41**	**-0.010**	**-0.698**	**279.13**	**10.664**
		SSE		**16,305.66**	**0.18**	**3,332.89**	**30,784,408.42**	**28,155,887.87**

Appendix 3.10 Iteration 10 Average Bias and SSE between Predicted and Observed Distresses

Road ID No.	Road Name	Calibration Coefficients		IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
		Iteration 10		Average Differences				
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		23.12	0.03	-3.34	137.81	-1,005.26
LARAMIE	BLACK HILLS	C1 Bottom	0.46	-19.21	0.03	3.25	-780.59	-2,178.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.26	12.16	0.11	42.97	-522.19	653.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	1.56	-9.29	-0.03	5.98	-453.55	-2,555.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.46	-50.49	-0.08	-19.63	-2,570.83	-472.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	4,600.00	39.10	-0.22	4.37	-194.83	628.94
GOSHEN	DEER CREEK RD	C4 Top	1,300.00	37.38	0.07	-11.69	-582.01	-2,147.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-42.52	0.14	11.08	-318.01	695.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-53.37	-0.01	0.11	569.03	146.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		8.28	0.08	4.64	-1,025.53	-781.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	25.34	0.08	4.83	-967.45	-20.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-22.15	0.01	4.92	1,880.21	1,643.41
PLATTE	PALMER CANYON	**IRI**		39.95	0.01	-0.62	1,241.33	432.24
CONVERSE	DEER CREEK RD	C1	22.00	9.10	-0.02	-18.31	1,683.11	659.44
CONVERSE	HIGHLAND LOOP RD	C2	0.41	-44.44	0.01	-17.13	1,519.43	1,459.22
CONVERSE	WALKER CREEK RD	C3	0.00	-7.04	0.09	-2.20	1,720.07	991.12
CONVERSE	55 RANCH RD	C4	0.02	-4.19	-0.25	0.46	2,232.23	1,566.98
CONVERSE	NATURAL BRIDGE RD			4.95	-0.03	-12.33	1,456.07	449.24
		Average Bias		**-2.96**	**0.000**	**-0.147**	**279.13**	**9.109**
		SSE		**16,215.99**	**0.18**	**3,422.99**	**30,784,408.42**	**28,155,690.21**

Appendix 3.11 Iteration 11 Average Bias and SSE between Predicted and Observed Distresses

Iteration 11								
Road ID No.	Road Name	Calibration Coefficients		Average Differences				
				IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		23.23	0.03	-3.11	137.81	-1,001.26
LARAMIE	BLACK HILLS	C1 Bottom	0.46	-19.02	0.03	3.65	-780.59	-2,175.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	12.35	0.11	43.37	-522.19	655.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	1.56	-9.14	-0.03	6.28	-453.55	-2,551.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.46	-50.47	-0.08	-19.61	-2,570.83	-467.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	4,600.00	39.16	-0.22	4.49	-194.83	632.94
GOSHEN	DEER CREEK RD	C4 Top	1,300.00	37.41	0.07	-11.64	-582.01	-2,142.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-42.37	0.14	11.38	-318.01	699.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-53.32	-0.01	0.19	569.03	151.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		8.34	0.08	4.75	-1,025.53	-777.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	25.41	0.08	4.98	-967.45	-16.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-22.09	0.01	5.05	1,880.21	1,648.41
PLATTE	PALMER CANYON	**IRI**		40.01	0.01	-0.53	1,241.33	437.24
CONVERSE	DEER CREEK RD	C1	22.00	9.14	-0.02	-18.25	1,683.11	663.44
CONVERSE	HIGHLAND LOOP RD	C2	0.41	-44.25	0.01	-16.73	1,519.43	1,462.22
CONVERSE	WALKER CREEK RD	C3	0.00	-6.89	0.09	-1.90	1,720.07	995.12
CONVERSE	55 RANCH RD	C4	0.02	-4.08	-0.25	0.69	2,232.23	1,570.98
CONVERSE	NATURAL BRIDGE RD			4.97	-0.03	-12.30	1,456.07	454.24
		Average Bias		**-2.87**	**0.000**	**0.042**	**279.13**	**13.220**
		SSE		**16,190.34**	**0.18**	**3,454.61**	**30,784,408.42**	**28,156,245.77**

Appendix 3.12 Iteration 12 Average Bias and SSE between Predicted and Observed Distresses

Iteration 12								
Road ID No.	Road Name	Calibration Coefficients		Average Differences				
				IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		23.23	0.03	-3.20	137.81	-1,008.26
LARAMIE	BLACK HILLS	C1 Bottom	0.46	-19.06	0.03	3.45	-780.91	-2,184.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	12.36	0.11	43.27	-522.19	643.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	1.56	-9.14	-0.03	6.18	-453.55	-2,560.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.45	-50.44	-0.08	-19.62	-2,570.83	-471.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	4,600.00	39.18	-0.22	4.44	-194.83	626.94
GOSHEN	DEER CREEK RD	C4 Top	1,300.00	37.44	0.07	-11.66	-582.01	-2,147.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-42.37	0.14	11.28	-318.01	692.38
GOSHEN	VAN TASSEL RD	βr1	1.10	-53.30	-0.01	0.16	569.03	146.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		8.37	0.08	4.71	-1,025.53	-782.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.96	25.43	0.09	4.92	-967.45	-22.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.70	-22.07	0.02	5.00	1,880.21	1,642.41
PLATTE	PALMER CANYON	**IRI**		40.02	0.01	-0.57	1,241.33	431.24
CONVERSE	DEER CREEK RD	C1	22.00	9.17	-0.01	-18.27	1,683.11	659.44
CONVERSE	HIGHLAND LOOP RD	C2	0.41	-44.24	0.02	-16.83	1,519.43	1,454.22
CONVERSE	WALKER CREEK RD	C3	0.00	-6.89	0.10	-2.00	1,720.07	987.12
CONVERSE	55 RANCH RD	C4	0.02	-4.07	-0.24	0.59	2,232.23	1,563.98
CONVERSE	NATURAL BRIDGE RD			5.00	-0.02	-12.31	1,456.07	450.24
		Average Bias		**-2.85**	**0.004**	**-0.026**	**279.11**	**6.664**
		SSE		**16,192.08**	**0.18**	**3,445.15**	**30,784,908.10**	**28,159,434.05**

Appendix 3.13 Iteration 13 Average Bias and SSE between Predicted and Observed Distresses

Road ID No.	Road Name	Calibration Coefficients		Iteration 13 Average Differences IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		23.20	0.03	-3.16	137.81	-1,011.26
LARAMIE	BLACK HILLS	C1 Bottom	0.46	-19.08	0.03	3.55	-780.91	-2,188.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	12.29	0.11	43.27	-522.19	637.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	1.56	-9.15	-0.03	6.28	-453.55	-2,563.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.44	-50.48	-0.08	-19.61	-2,570.83	-472.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	4,600.00	39.15	-0.22	4.46	-194.83	624.94
GOSHEN	DEER CREEK RD	C4 Top	1,300.00	37.40	0.07	-11.65	-582.01	-2,148.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-42.42	0.14	11.28	-318.01	689.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-53.34	-0.01	0.17	569.03	144.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		8.33	0.08	4.73	-1,025.53	-784.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	25.39	0.08	4.95	-967.45	-24.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-22.11	0.01	5.02	1,880.21	1,639.41
PLATTE	PALMER CANYON	**IRI**		39.99	0.01	-0.55	1,241.33	429.24
CONVERSE	DEER CREEK RD	C1	22.00	9.13	-0.02	-18.26	1,683.11	657.44
CONVERSE	HIGHLAND LOOP RD	C2	0.41	-44.30	0.01	-16.83	1,519.43	1,451.22
CONVERSE	WALKER CREEK RD	C3	0.00	-6.94	0.09	-2.00	1,720.07	984.12
CONVERSE	55 RANCH RD	C4	0.02	-4.11	-0.25	0.64	2,232.23	1,560.98
CONVERSE	NATURAL BRIDGE RD			4.97	-0.03	-12.30	1,456.07	449.24
		Average Bias		**-2.89**	**0.000**	**-0.001**	**279.11**	**4.109**
		SSE		**16,199.07**	**0.18**	**3,446.51**	**30,784,908.10**	**28,152,807.83**

Appendix 3.14 Iteration 14 Average Bias and SSE between Predicted and Observed Distresses

Road ID No.	Road Name	Calibration Coefficients		Iteration 14 Average Differences IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		28.27	0.03	8.03	137.81	-1,014.26
LARAMIE	BLACK HILLS	C1 Bottom	0.30	-11.10	0.03	21.25	-780.91	-2,191.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	18.87	0.11	57.97	-522.19	633.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	1.56	-3.00	-0.03	19.88	-453.55	-2,565.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.44	-50.01	-0.08	-18.58	-2,570.83	-473.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	4,600.00	41.64	-0.22	9.95	-194.83	622.94
GOSHEN	DEER CREEK RD	C4 Top	1,300.00	38.55	0.07	-9.12	-582.01	-2,149.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-36.82	0.14	23.68	-318.01	687.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-51.64	-0.01	3.91	569.03	143.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		10.97	0.08	10.55	-1,025.53	-786.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	28.71	0.08	12.27	-967.45	-26.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-19.32	0.01	11.17	1,880.21	1,638.41
PLATTE	PALMER CANYON	**IRI**		41.86	0.01	3.58	1,241.33	428.24
CONVERSE	DEER CREEK RD	C1	22.00	10.54	-0.02	-15.15	1,683.11	656.44
CONVERSE	HIGHLAND LOOP RD	C2	0.41	-36.86	0.01	-0.33	1,519.43	1,448.22
CONVERSE	WALKER CREEK RD	C3	0.00	-0.26	0.09	12.80	1,720.07	981.12
CONVERSE	55 RANCH RD	C4	0.02	0.87	-0.25	11.63	2,232.23	1,558.98
CONVERSE	NATURAL BRIDGE RD			5.66	-0.03	-10.78	1,456.07	448.24
		Average Bias		**0.94**	**0.000**	**8.484**	**279.11**	**2.164**
		SSE		**15,603.61**	**0.18**	**6,419.58**	**30,784,908.10**	**28,152,972.03**

Appendix 3.15 Iteration 15 Average Bias and SSE between Predicted and Observed Distresses

Iteration 15								
Road ID No.	Road Name	Calibration Coefficients		Average Differences				
				IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		27.18	0.03	5.63	137.81	-1,015.26
LARAMIE	BLACK HILLS	C1 Bottom	0.3	-14.39	0.03	13.95	-780.91	-2,193.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	14.71	0.11	48.67	-522.19	630.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	1.25	-4.76	-0.03	15.98	-453.55	-2,567.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.437	-49.67	-0.08	-17.84	-2,570.83	-473.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	4600	41.70	-0.22	10.10	-194.83	621.94
GOSHEN	DEER CREEK RD	C4 Top	1300	38.92	0.07	-8.31	-582.01	-2,149.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-38.22	0.14	20.58	-318.01	686.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-51.36	-0.01	4.54	569.03	142.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		10.98	0.08	10.59	-1,025.53	-787.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	28.48	0.08	11.77	-967.45	-26.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-19.36	0.01	11.07	1,880.21	1,637.41
PLATTE	PALMER CANYON	**IRI**		42.11	0.01	4.12	1,241.33	427.24
CONVERSE	DEER CREEK RD	C1	22	10.88	-0.02	-14.40	1,683.11	656.44
CONVERSE	HIGHLAND LOOP RD	C2	0.41	-39.61	0.01	-6.43	1,519.43	1,447.22
CONVERSE	WALKER CREEK RD	C3	0.0015	-2.38	0.09	8.10	1,720.07	980.12
CONVERSE	55 RANCH RD	C4	0.015	-0.18	-0.25	9.33	2,232.23	1,557.98
CONVERSE	NATURAL BRIDGE RD			6.03	-0.03	-9.97	1,456.07	448.24
		Average Bias		**0.06**	**0.000**	**6.527**	**279.11**	**1.220**
		SSE		**15,813.37**	**0.18**	**4,674.87**	**30,784,908.10**	**28,156,812.95**

Appendix 3.16 Iteration 16 Average Bias and SSE between Predicted and Observed Distresses

Iteration 16								
Road ID No.	Road Name	Calibration Coefficients		Average Differences				
				IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		26.00	0.03	3.03	137.81	-1,017.26
LARAMIE	BLACK HILLS	C1 Bottom	0.3	-17.82	0.03	6.35	-780.91	-2,195.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	8.51	0.11	34.87	-522.19	627.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	0.9	-6.62	-0.03	11.88	-453.55	-2,569.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.434	-49.12	-0.08	-16.62	-2,570.83	-473.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	4600	41.78	-0.22	10.28	-194.83	620.94
GOSHEN	DEER CREEK RD	C4 Top	1300	39.42	0.07	-7.20	-582.01	-2,150.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-39.71	0.14	17.28	-318.01	684.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-51.00	-0.01	5.33	569.03	142.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		11.00	0.08	10.63	-1,025.53	-788.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	28.21	0.08	11.17	-967.45	-28.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-19.41	0.01	10.97	1,880.21	1,635.41
PLATTE	PALMER CANYON	**IRI**		42.41	0.01	4.79	1,241.33	426.24
CONVERSE	DEER CREEK RD	C1	22	11.31	-0.02	-13.44	1,683.11	655.44
CONVERSE	HIGHLAND LOOP RD	C2	0.41	-42.46	0.01	-12.73	1,519.43	1,445.22
CONVERSE	WALKER CREEK RD	C3	0.0015	-4.60	0.09	3.20	1,720.07	978.12
CONVERSE	55 RANCH RD	C4	0.015	-1.31	-0.25	6.83	2,232.23	1,556.98
CONVERSE	NATURAL BRIDGE RD			6.59	-0.03	-8.72	1,456.07	447.24
		Average Bias		**-0.93**	**0.000**	**4.328**	**279.11**	**-0.224**
		SSE		**16,089.19**	**0.18**	**3,023.97**	**30,784,908.10**	**28,155,737.59**

Appendix 3.17 Iteration 17 Average Bias and SSE between Predicted and Observed Distresses

Road ID No.	Road Name	Calibration Coefficients		IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
		Iteration 17		Average Differences				
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		25.41	0.03	1.73	137.81	-1,016.26
LARAMIE	BLACK HILLS	C1 Bottom	0.3	-19.58	0.03	2.45	-780.91	-2,194.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	4.78	0.11	26.57	-522.19	628.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	0.7	-7.57	-0.03	9.78	-453.55	-2,568.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.435	-48.68	-0.08	-15.67	-2,570.83	-473.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	4600	41.83	-0.22	10.38	-194.83	621.94
GOSHEN	DEER CREEK RD	C4 Top	1300	39.75	0.07	-6.48	-582.01	-2,150.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-40.44	0.14	15.68	-318.01	685.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-50.78	-0.01	5.81	569.03	142.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		11.01	0.08	10.66	-1,025.53	-787.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	28.03	0.08	10.77	-967.45	-27.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-19.41	0.01	10.97	1,880.21	1,636.41
PLATTE	PALMER CANYON	**IRI**		42.59	0.01	5.19	1,241.33	426.24
CONVERSE	DEER CREEK RD	C1	22	11.59	-0.02	-12.82	1,683.11	655.44
CONVERSE	HIGHLAND LOOP RD	C2	0.41	-43.90	0.01	-15.93	1,519.43	1,445.22
CONVERSE	WALKER CREEK RD	C3	0.0015	-5.68	0.09	0.80	1,720.07	979.12
CONVERSE	55 RANCH RD	C4	0.015	-1.85	-0.25	5.63	2,232.23	1,556.98
CONVERSE	NATURAL BRIDGE RD			7.00	-0.03	-7.83	1,456.07	447.24
		Average Bias		**-1.44**	**0.000**	**3.205**	**279.11**	**0.331**
		SSE		**16,266.53**	**0.18**	**2,374.18**	**30,784,908.10**	**28,151,640.51**

Appendix 3.18 Iteration 18 Average Bias and SSE between Predicted and Observed Distresses

Road ID No.	Road Name	Calibration Coefficients		IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
		Iteration 18		Average Differences				
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		27.22	0.03	5.73	137.81	-1,016.26
LARAMIE	BLACK HILLS	C1 Bottom	0.25	-17.27	0.03	7.55	-780.91	-2,195.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	7.48	0.11	32.57	-522.19	628.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	0.7	-5.58	-0.03	14.18	-453.55	-2,568.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.4345	-47.98	-0.08	-14.11	-2,570.83	-473.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	4600	43.18	-0.22	13.37	-194.83	620.94
GOSHEN	DEER CREEK RD	C4 Top	1300	40.76	0.07	-4.25	-582.01	-2,150.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-38.58	0.14	19.78	-318.01	685.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-49.63	-0.01	8.36	569.03	142.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		12.38	0.08	13.67	-1,025.53	-787.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	29.57	0.08	14.17	-967.45	-28.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-18.00	0.01	14.07	1,880.21	1,636.41
PLATTE	PALMER CANYON	**IRI**		43.80	0.01	7.86	1,241.33	426.24
CONVERSE	DEER CREEK RD	C1	22	12.69	-0.02	-10.41	1,683.11	655.44
CONVERSE	HIGHLAND LOOP RD	C2	0.41	-41.73	0.01	-11.13	1,519.43	1,445.22
CONVERSE	WALKER CREEK RD	C3	0.0015	-3.65	0.09	5.30	1,720.07	978.12
CONVERSE	55 RANCH RD	C4	0.015	-0.09	-0.25	9.53	2,232.23	1,556.98
CONVERSE	NATURAL BRIDGE RD			7.83	-0.03	-6.00	1,456.07	447.24
		Average Bias		**0.13**	**0.000**	**6.680**	**279.11**	**0.109**
		SSE		**16,152.95**	**0.18**	**3,243.32**	**30,784,908.10**	**28,152,886.23**

Appendix 3.19 Iteration 19 Average Bias and SSE between Predicted and Observed Distresses

Road ID No.	Road Name	Calibration Coefficients		Iteration 19 Average Differences: IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		25.41	0.03	1.73	137.81	-1,016.26
LARAMIE	BLACK HILLS	C1 Bottom	0.3	-18.76	0.03	4.25	-780.91	-2,195.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	6.98	0.11	31.47	-522.19	627.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	0.9	-7.34	-0.03	10.28	-453.55	-2,568.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.4343	-49.26	-0.08	-16.93	-2,570.83	-473.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	4200	41.41	-0.22	9.45	-194.83	620.94
GOSHEN	DEER CREEK RD	C4 Top	1300	39.18	0.07	-7.73	-582.01	-2,150.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-40.34	0.14	15.88	-318.01	685.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-51.30	-0.01	4.67	569.03	142.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		10.62	0.08	9.78	-1,025.53	-788.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	27.76	0.08	10.17	-967.45	-28.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-19.80	0.01	10.12	1,880.21	1,636.41
PLATTE	PALMER CANYON	**IRI**		42.09	0.01	4.09	1,241.33	426.24
CONVERSE	DEER CREEK RD	C1	22	11.05	-0.02	-14.03	1,683.11	655.44
CONVERSE	HIGHLAND LOOP RD	C2	0.41	-43.31	0.01	-14.63	1,519.43	1,445.22
CONVERSE	WALKER CREEK RD	C3	0.0015	-5.32	0.09	1.60	1,720.07	978.12
CONVERSE	55 RANCH RD	C4	0.015	-1.89	-0.25	5.53	2,232.23	1,556.98
CONVERSE	NATURAL BRIDGE RD			6.41	-0.03	-9.12	1,456.07	447.24
		Average Bias		**-1.47**	**0.000**	**3.143**	**279.11**	**-0.002**
		SSE		**16,153.45**	**0.18**	**2,672.17**	**30,784,908.10**	**28,153,207.03**

Appendix 3.20 Iteration 20 Average Bias and SSE between Predicted and Observed Distresses

Road ID No.	Road Name	Calibration Coefficients		Iteration 20 Average Differences: IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		24.60	0.03	-0.07	137.81	-1,016.26
LARAMIE	BLACK HILLS	C1 Bottom	0.3	-20.75	0.03	-0.15	-780.91	-2,195.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	2.93	0.11	22.47	-522.19	628.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	0.7	-8.47	-0.03	7.78	-453.55	-2,568.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.4344	-48.96	-0.08	-16.27	-2,570.83	-473.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	4000	41.26	-0.22	9.12	-194.83	620.94
GOSHEN	DEER CREEK RD	C4 Top	1300	39.35	0.07	-7.36	-582.01	-2,150.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-41.29	0.14	13.78	-318.01	685.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-51.26	-0.01	4.76	569.03	142.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		10.43	0.08	9.37	-1,025.53	-788.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	27.40	0.08	9.38	-967.45	-28.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-20.02	0.01	9.62	1,880.21	1,636.41
PLATTE	PALMER CANYON	**IRI**		42.09	0.01	4.09	1,241.33	426.24
CONVERSE	DEER CREEK RD	C1	22	11.15	-0.02	-13.79	1,683.11	655.44
CONVERSE	HIGHLAND LOOP RD	C2	0.41	-44.99	0.01	-18.33	1,519.43	1,445.22
CONVERSE	WALKER CREEK RD	C3	0.0015	-6.68	0.09	-1.40	1,720.07	978.12
CONVERSE	55 RANCH RD	C4	0.015	-2.66	-0.25	3.83	2,232.23	1,556.98
CONVERSE	NATURAL BRIDGE RD			6.68	-0.03	-8.53	1,456.07	447.24
		Average Bias		**-2.18**	**0.000**	**1.572**	**279.11**	**0.053**
		SSE		**16,373.05**	**0.18**	**2,080.66**	**30,784,908.10**	**28,154,462.77**

Appendix 3.21 Iteration 21 Average Bias and SSE between Predicted and Observed Distresses

Iteration 21				Average Differences				
Road ID No.	Road Name	Calibration Coefficients		IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		24.10	0.03	-1.17	137.81	-1,016.26
LARAMIE	BLACK HILLS	C1 Bottom	0.3	-21.84	0.03	-2.55	-780.91	-2,195.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	0.86	0.11	17.87	-522.19	627.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	0.6	-9.15	-0.03	6.28	-453.55	-2,568.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.43435	-48.84	-0.08	-16.01	-2,570.83	-473.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	3800	41.09	-0.22	8.75	-194.83	620.94
GOSHEN	DEER CREEK RD	C4 Top	1300	39.36	0.07	-7.33	-582.01	-2,150.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-41.88	0.14	12.48	-318.01	685.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-51.32	-0.01	4.62	569.03	142.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		10.24	0.08	8.95	-1,025.53	-788.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	27.12	0.08	8.76	-967.45	-28.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-20.23	0.01	9.16	1,880.21	1,636.41
PLATTE	PALMER CANYON	**IRI**		42.00	0.01	3.89	1,241.33	426.24
CONVERSE	DEER CREEK RD	C1	22	11.13	-0.02	-13.84	1,683.11	655.44
CONVERSE	HIGHLAND LOOP RD	C2	0.41	-45.89	0.01	-20.33	1,519.43	1,445.22
CONVERSE	WALKER CREEK RD	C3	0.0015	-7.40	0.09	-3.00	1,720.07	978.12
CONVERSE	55 RANCH RD	C4	0.015	-3.16	-0.25	2.73	2,232.23	1,556.98
CONVERSE	NATURAL BRIDGE RD			6.76	-0.03	-8.35	1,456.07	447.24
		Average Bias		**-2.61**	**0.000**	**0.606**	**279.11**	**-0.002**
		SSE		**16,506.69**	**0.18**	**1,877.26**	**30,784,908.10**	**28,153,207.03**

Appendix 3.22 Iteration 22 Average Bias and SSE between Predicted and Observed Distresses

Iteration 22				Average Differences				
Road ID No.	Road Name	Calibration Coefficients		IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		23.83	0.03	-1.77	137.81	-1,016.26
LARAMIE	BLACK HILLS	C1 Bottom	0.3	-22.29	0.03	-3.55	-780.91	-2,195.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	-0.14	0.11	15.67	-522.19	627.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	0.55	-9.47	-0.03	5.58	-453.55	-2,568.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.4343	-48.78	-0.08	-15.88	-2,570.83	-473.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	3700	41.00	-0.22	8.56	-194.83	620.94
GOSHEN	DEER CREEK RD	C4 Top	1300	39.37	0.07	-7.32	-582.01	-2,150.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-42.15	0.14	11.88	-318.01	685.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-51.35	-0.01	4.55	569.03	142.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		10.14	0.08	8.74	-1,025.53	-788.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	26.98	0.08	8.46	-967.45	-28.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-20.34	0.01	8.92	1,880.21	1,636.41
PLATTE	PALMER CANYON	**IRI**		41.96	0.01	3.79	1,241.33	426.24
CONVERSE	DEER CREEK RD	C1	22	11.11	-0.02	-13.88	1,683.11	655.44
CONVERSE	HIGHLAND LOOP RD	C2	0.41	-46.34	0.01	-21.33	1,519.43	1,445.22
CONVERSE	WALKER CREEK RD	C3	0.0015	-7.76	0.09	-3.80	1,720.07	978.12
CONVERSE	55 RANCH RD	C4	0.015	-3.43	-0.25	2.13	2,232.23	1,556.98
CONVERSE	NATURAL BRIDGE RD			6.80	-0.03	-8.26	1,456.07	447.24
		Average Bias		**-2.83**	**0.000**	**0.138**	**279.11**	**-0.002**
		SSE		**16,572.49**	**0.18**	**1,810.01**	**30,784,908.10**	**28,153,207.03**

Appendix 3.23 Iteration 23 Average Bias and SSE between Predicted and Observed Distresses

Road ID No.	Road Name	Calibration Coefficients		IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
		Iteration 23		Average Differences				
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		23.74	0.03	-1.97	137.81	-1,016.26
LARAMIE	BLACK HILLS	C1 Bottom	0.3	-22.56	0.03	-4.15	-780.91	-2,195.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	-0.59	0.11	14.67	-522.19	627.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	0.525	-9.65	-0.03	5.18	-453.55	-2,568.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.4343	-48.75	-0.08	-15.81	-2,570.83	-473.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	3650	40.96	-0.22	8.46	-194.83	620.94
GOSHEN	DEER CREEK RD	C4 Top	1300	39.37	0.07	-7.32	-582.01	-2,150.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-42.29	0.14	11.58	-318.01	685.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-51.37	-0.01	4.51	569.03	142.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		10.09	0.08	8.63	-1,025.53	-788.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	26.92	0.08	8.32	-967.45	-28.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-20.39	0.01	8.81	1,880.21	1,636.41
PLATTE	PALMER CANYON	**IRI**		41.94	0.01	3.74	1,241.33	426.24
CONVERSE	DEER CREEK RD	C1	22	11.10	-0.02	-13.90	1,683.11	655.44
CONVERSE	HIGHLAND LOOP RD	C2	0.41	-46.52	0.01	-21.73	1,519.43	1,445.22
CONVERSE	WALKER CREEK RD	C3	0.0015	-7.94	0.09	-4.20	1,720.07	978.12
CONVERSE	55 RANCH RD	C4	0.015	-3.52	-0.25	1.93	2,232.23	1,556.98
CONVERSE	NATURAL BRIDGE RD			6.82	-0.03	-8.22	1,456.07	447.24
		Average Bias		**-2.92**	**0.000**	**-0.082**	**279.11**	**-0.002**
		SSE		**16,608.09**	**0.18**	**1,782.33**	**30,784,908.10**	**28,153,207.03**

Appendix 3.24 Iteration 24 Average Bias and SSE between Predicted and Observed Distresses

Road ID No.	Road Name	Calibration Coefficients		IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
		Iteration 24		Average Differences				
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		23.63	0.03	-1.87	137.81	-1,016.26
LARAMIE	BLACK HILLS	C1 Bottom	0.3	-22.60	0.03	-3.85	-780.91	-2,195.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	-0.60	0.11	15.07	-522.19	627.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	0.535	-9.72	-0.03	5.38	-453.55	-2,568.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.43435	-48.87	-0.08	-15.83	-2,570.83	-473.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	3675	40.84	-0.22	8.51	-194.83	620.94
GOSHEN	DEER CREEK RD	C4 Top	1300	39.23	0.07	-7.31	-582.01	-2,150.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-42.41	0.14	11.68	-318.01	685.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-51.50	-0.01	4.53	569.03	142.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		9.97	0.08	8.69	-1,025.53	-788.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	26.80	0.08	8.39	-967.45	-28.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-20.51	0.01	8.86	1,880.21	1,636.41
PLATTE	PALMER CANYON	**IRI**		41.82	0.01	3.77	1,241.33	426.24
CONVERSE	DEER CREEK RD	C1	21.5	10.97	-0.02	-13.88	1,683.11	655.44
CONVERSE	HIGHLAND LOOP RD	C2	0.41	-46.61	0.01	-21.53	1,519.43	1,445.22
CONVERSE	WALKER CREEK RD	C3	0.0015	-8.03	0.09	-4.00	1,720.07	978.12
CONVERSE	55 RANCH RD	C4	0.015	-3.64	-0.25	2.03	2,232.23	1,556.98
CONVERSE	NATURAL BRIDGE RD			6.69	-0.03	-8.23	1,456.07	447.24
		Average Bias		**-3.03**	**0.000**	**0.023**	**279.11**	**-0.002**
		SSE		**16,612.54**	**0.18**	**1,790.43**	**30,784,908.10**	**28,153,207.03**

Appendix 3.25 Iteration 25 Average Bias and SSE between Predicted and Observed Distresses

Iteration 25								
				Average Differences				
Road ID No.	Road Name	Calibration Coefficients		IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		24.06	0.03	-1.87	137.81	-1,016.26
LARAMIE	BLACK HILLS	C1 Bottom	0.3	-22.09	0.03	-3.85	-780.91	-2,195.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	0.04	0.11	15.07	-522.19	627.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	0.535	-9.27	-0.03	5.38	-453.55	-2,568.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.43435	-48.58	-0.08	-15.83	-2,570.83	-473.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	3675	41.22	-0.22	8.51	-194.83	620.94
GOSHEN	DEER CREEK RD	C4 Top	1300	39.58	0.07	-7.31	-582.01	-2,150.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-41.95	0.14	11.68	-318.01	685.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-51.13	-0.01	4.53	569.03	142.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		10.37	0.08	8.69	-1,025.53	-788.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	27.21	0.08	8.39	-967.45	-28.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-20.12	0.01	8.86	1,880.21	1,636.41
PLATTE	PALMER CANYON	**IRI**		42.17	0.01	3.77	1,241.33	426.24
CONVERSE	DEER CREEK RD	C1	22.5	11.33	-0.02	-13.88	1,683.11	655.44
CONVERSE	HIGHLAND LOOP RD	C2	0.42	-46.10	0.01	-21.53	1,519.43	1,445.22
CONVERSE	WALKER CREEK RD	C3	0.0015	-7.53	0.09	-4.00	1,720.07	978.12
CONVERSE	55 RANCH RD	C4	0.015	-3.19	-0.25	2.03	2,232.23	1,556.98
CONVERSE	NATURAL BRIDGE RD			7.01	-0.03	-8.23	1,456.07	447.24
		Average Bias		**-2.61**	**0.000**	**0.023**	**279.11**	**-0.002**
		SSE		**16,553.19**	**0.18**	**1,790.43**	**30,784,908.10**	**28,153,207.03**

Appendix 3.26 Iteration 26 Average Bias and SSE between Predicted and Observed Distresses

Iteration 26								
				Average Differences				
Road ID No.	Road Name	Calibration Coefficients		IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		54.73	0.03	-2.08	137.81	-1,025.88
LARAMIE	BLACK HILLS	C1 Bottom	0.3	8.87	0.03	-3.85	-780.91	-2,195.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	31.24	0.11	15.07	-522.19	627.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	0.535	21.60	-0.03	5.38	-453.55	-2,568.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.43435	-18.00	-0.08	-15.83	-2,570.83	-473.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	3675	71.94	-0.22	8.51	-194.83	620.94
GOSHEN	DEER CREEK RD	C4 Top	1300	70.24	0.07	-7.31	-582.01	-2,150.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-11.08	0.14	11.68	-318.01	685.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-20.44	-0.01	4.53	569.03	142.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		41.11	0.08	8.69	-1,025.53	-788.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	57.99	0.08	8.39	-967.45	-28.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	10.61	0.01	8.86	1,880.21	1,636.41
PLATTE	PALMER CANYON	**IRI**		72.87	0.01	3.77	1,241.33	426.24
CONVERSE	DEER CREEK RD	C1	24	42.01	-0.02	-13.88	1,683.11	655.44
CONVERSE	HIGHLAND LOOP RD	C2	0.45	-15.15	0.01	-21.53	1,519.43	1,445.22
CONVERSE	WALKER CREEK RD	C3	0.0015	23.37	0.09	-4.00	1,720.07	978.12
CONVERSE	55 RANCH RD	C4	0.02	27.65	-0.25	2.03	2,232.23	1,556.98
CONVERSE	NATURAL BRIDGE RD			37.63	-0.03	-8.23	1,456.07	447.24
		Average Bias		**28.18**	**0.000**	**0.011**	**279.11**	**-0.537**
		SSE		**30,686.60**	**0.18**	**1,791.26**	**30,784,908.10**	**28,172,852.41**

Appendix 3.27 Iteration 27 Average Bias and SSE between Predicted and Observed Distresses

Iteration 27								
				Average Differences				
Road ID No.	Road Name	Calibration Coefficients		IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		25.35	0.03	-2.08	137.81	-1,025.88
LARAMIE	BLACK HILLS	C1 Bottom	0.3	-20.48	0.03	-3.85	-780.91	-2,195.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	1.97	0.11	15.07	-522.19	627.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	0.535	-7.77	-0.03	5.38	-453.55	-2,568.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.43435	-47.45	-0.08	-15.83	-2,570.83	-473.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	3675	42.53	-0.22	8.51	-194.83	620.94
GOSHEN	DEER CREEK RD	C4 Top	1300	40.83	0.07	-7.31	-582.01	-2,150.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-40.44	0.14	11.68	-318.01	685.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-49.84	-0.01	4.53	569.03	142.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		11.72	0.08	8.69	-1,025.53	-788.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	28.60	0.08	8.39	-967.45	-28.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-18.80	0.01	8.86	1,880.21	1,636.41
PLATTE	PALMER CANYON	**IRI**		43.45	0.01	3.77	1,241.33	426.24
CONVERSE	DEER CREEK RD	C1	24	12.60	-0.02	-13.88	1,683.11	655.44
CONVERSE	HIGHLAND LOOP RD	C2	0.45	-44.49	0.01	-21.53	1,519.43	1,445.22
CONVERSE	WALKER CREEK RD	C3	0.0015	-5.97	0.09	-4.00	1,720.07	978.12
CONVERSE	55 RANCH RD	C4	0.0151	-1.72	-0.25	2.03	2,232.23	1,556.98
CONVERSE	NATURAL BRIDGE RD			8.20	-0.03	-8.23	1,456.07	447.24
		Average Bias		**-1.21**	**0.000**	**0.011**	**279.11**	**-0.537**
		SSE		**16,413.74**	**0.18**	**1,791.26**	**30,784,908.10**	**28,172,852.41**

Appendix 3.28 Iteration 28 Average Bias and SSE between Predicted and Observed Distresses

Iteration 28								
				Average Differences				
Road ID No.	Road Name	Calibration Coefficients		IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		25.77	0.03	-2.08	137.81	-1,025.88
LARAMIE	BLACK HILLS	C1 Bottom	0.3	-19.98	0.03	-3.85	-780.91	-2,195.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	2.61	0.11	15.07	-522.19	627.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	0.535	-7.32	-0.03	5.38	-453.55	-2,568.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.43435	-47.16	-0.08	-15.83	-2,570.83	-473.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	3675	42.90	-0.22	8.51	-194.83	620.94
GOSHEN	DEER CREEK RD	C4 Top	1300	41.18	0.07	-7.31	-582.01	-2,150.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-39.97	0.14	11.68	-318.01	685.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-49.47	-0.01	4.53	569.03	142.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		12.12	0.08	8.69	-1,025.53	-788.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	29.02	0.08	8.39	-967.45	-28.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-18.42	0.01	8.86	1,880.21	1,636.41
PLATTE	PALMER CANYON	**IRI**		43.80	0.01	3.77	1,241.33	426.24
CONVERSE	DEER CREEK RD	C1	25	12.96	-0.02	-13.88	1,683.11	655.44
CONVERSE	HIGHLAND LOOP RD	C2	0.46	-43.97	0.01	-21.53	1,519.43	1,445.22
CONVERSE	WALKER CREEK RD	C3	0.0015	-5.48	0.09	-4.00	1,720.07	978.12
CONVERSE	55 RANCH RD	C4	0.0151	-1.26	-0.25	2.03	2,232.23	1,556.98
CONVERSE	NATURAL BRIDGE RD			8.53	-0.03	-8.23	1,456.07	447.24
		Average Bias		**-0.79**	**0.000**	**0.011**	**279.11**	**-0.537**
		SSE		**16,381.33**	**0.18**	**1,791.26**	**30,784,908.10**	**28,172,852.41**

Appendix 3.29 Iteration 29 Average Bias and SSE between Predicted and Observed Distresses

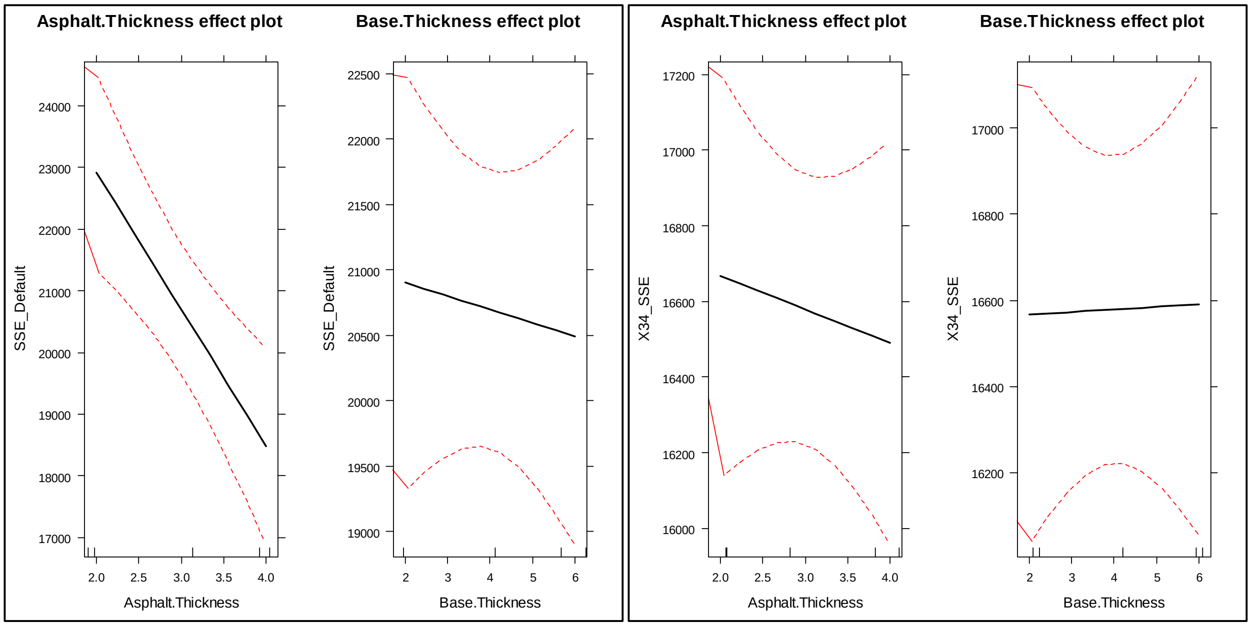
Road ID No.	Road Name	Calibration Coefficients		IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
		Iteration 29		Average Differences				
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		27.77	0.03	-2.08	137.81	-1,025.88
LARAMIE	BLACK HILLS	C1 Bottom	0.3	-17.71	0.03	-3.85	-780.91	-2,195.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	5.37	0.11	15.07	-522.19	627.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	0.535	-5.22	-0.03	5.38	-453.55	-2,568.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.43435	-45.62	-0.08	-15.83	-2,570.83	-473.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	3675	44.72	-0.22	8.51	-194.83	620.94
GOSHEN	DEER CREEK RD	C4 Top	1300	42.91	0.07	-7.31	-582.01	-2,150.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-37.84	0.14	11.68	-318.01	685.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-47.67	-0.01	4.53	569.03	142.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		14.02	0.08	8.69	-1,025.53	-788.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	30.98	0.08	8.39	-967.45	-28.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-16.57	0.01	8.86	1,880.21	1,636.41
PLATTE	PALMER CANYON	**IRI**		45.56	0.01	3.77	1,241.33	426.24
CONVERSE	DEER CREEK RD	C1	28	14.73	-0.02	-13.88	1,683.11	655.44
CONVERSE	HIGHLAND LOOP RD	C2	0.5	-41.67	0.01	-21.53	1,519.43	1,445.22
CONVERSE	WALKER CREEK RD	C3	0.0015	-3.26	0.09	-4.00	1,720.07	978.12
CONVERSE	55 RANCH RD	C4	0.0152	0.82	-0.25	2.03	2,232.23	1,556.98
CONVERSE	NATURAL BRIDGE RD			10.17	-0.03	-8.23	1,456.07	447.24
		Average Bias		**1.19**	**0.000**	**0.011**	**279.11**	**-0.537**
		SSE		**16,342.22**	**0.18**	**1,791.26**	**30,784,908.10**	**28,172,852.41**

Appendix 3.30 Iteration 30 Average Bias and SSE between Predicted and Observed Distresses

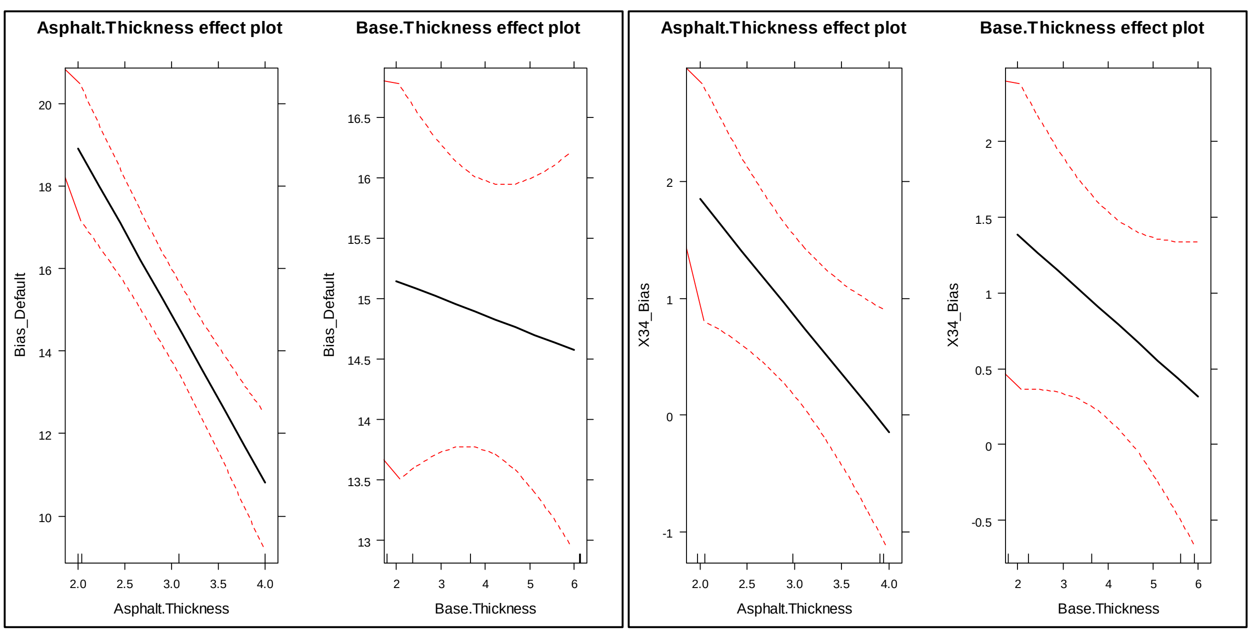
Road ID No.	Road Name	Calibration Coefficients		IRI	Rutting	Alligator Cracking	Transverse Cracking	Longitudinal Cracking
		Iteration 30		Average Differences				
LARAMIE	ALBIN / LAGRANGE	**AC Cracking**		27.22	0.03	-2.08	137.81	-1,025.88
LARAMIE	BLACK HILLS	C1 Bottom	0.3	-18.37	0.03	-3.85	-780.91	-2,195.63
LARAMIE	CHALK BLUFF / "78" RD	C1 Top	3.25	4.48	0.11	15.07	-522.19	627.37
LARAMIE	OLD HWY BURNS W	C2 Bottom	0.535	-5.81	-0.03	5.38	-453.55	-2,568.81
LARAMIE	OLD YELLOWSTONE RD.	C2 Top	0.43435	-45.97	-0.08	-15.83	-2,570.83	-473.39
LARAMIE	CEMETERY/PINE BLUFFS S RD	C3 Bottom	3675	44.25	-0.22	8.51	-194.83	620.94
GOSHEN	DEER CREEK RD	C4 Top	1300	42.48	0.07	-7.31	-582.01	-2,150.78
GOSHEN	BUTTERMILK RD	**AC Rutting**		-38.44	0.14	11.68	-318.01	685.38
GOSHEN	VAN TASSEL RD	βr1	1.09	-48.13	-0.01	4.53	569.03	142.55
GOSHEN	SHEEP CREEK	**Subgrade Rutting**		13.53	0.08	8.69	-1,025.53	-788.77
GOSHEN	WYNCOTE RD	Coarse SR, BS1	0.95	30.46	0.08	8.39	-967.45	-28.29
PLATTE	BORDEAUX RD	Fine SR, Bs1	0.69	-17.05	0.01	8.86	1,880.21	1,636.41
PLATTE	PALMER CANYON	**IRI**		45.12	0.01	3.77	1,241.33	426.24
CONVERSE	DEER CREEK RD	C1	27	14.29	-0.02	-13.88	1,683.11	655.44
CONVERSE	HIGHLAND LOOP RD	C2	0.48	-42.34	0.01	-21.53	1,519.43	1,445.22
CONVERSE	WALKER CREEK RD	C3	0.0015	-3.90	0.09	-4.00	1,720.07	978.12
CONVERSE	55 RANCH RD	C4	0.0152	0.25	-0.25	2.03	2,232.23	1,556.98
CONVERSE	NATURAL BRIDGE RD			9.78	-0.03	-8.23	1,456.07	447.24
		Average Bias		**0.66**	**0.000**	**0.011**	**279.11**	**-0.537**
		SSE		**16,347.39**	**0.18**	**1,791.26**	**30,784,908.10**	**28,172,852.41**

APPENDIX 4: MAIN EFFECTS PLOTS

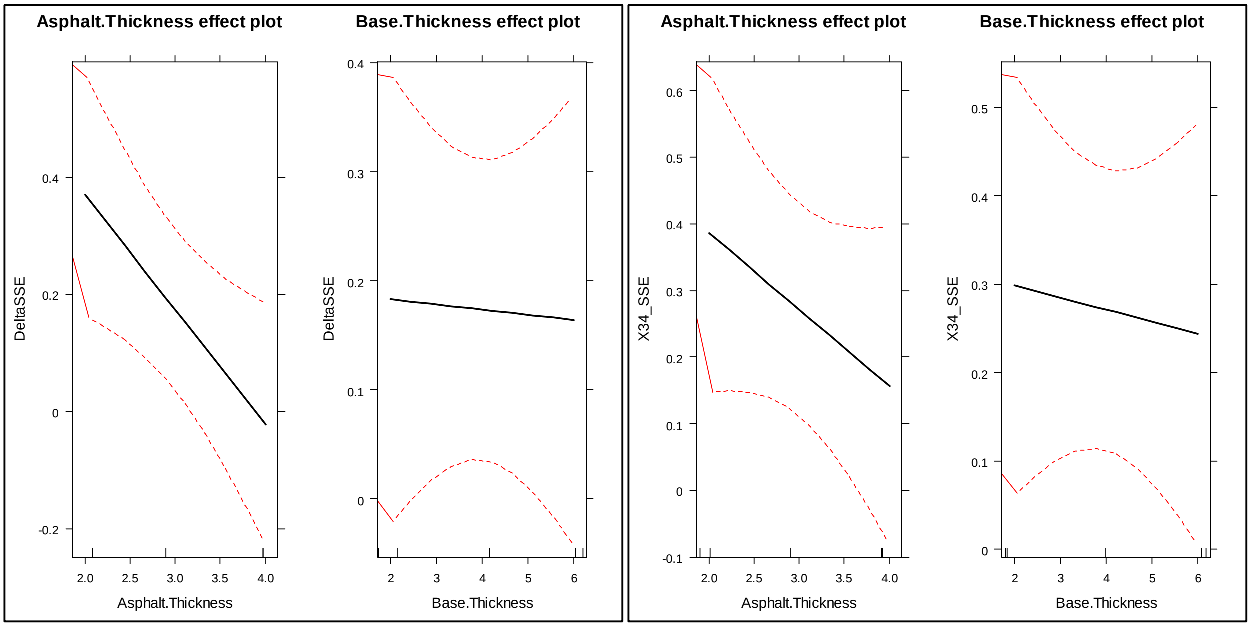
Appendix 4.1 SSE Main Effects Plot for IRI considering Default Calibration Coefficients (Left) and Local Calibration Coefficients (Right)



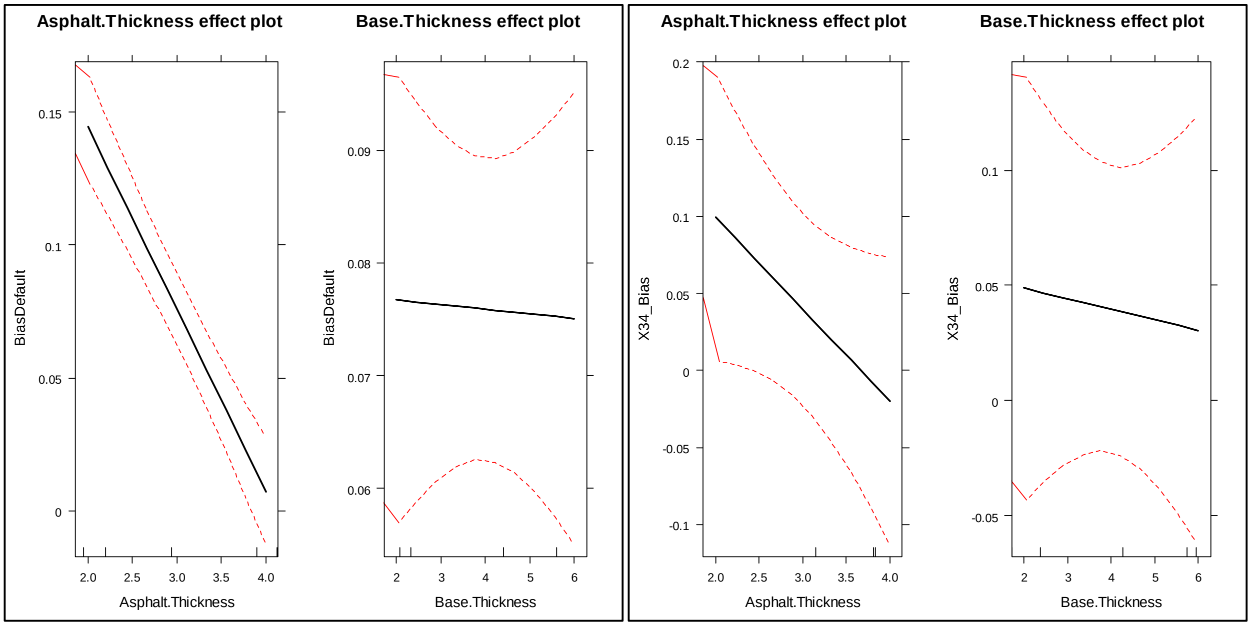
Appendix 4.2 Bias Main Effects Plot for IRI considering Default Calibration Coefficients (Left) and Local Calibration Coefficients (Right)



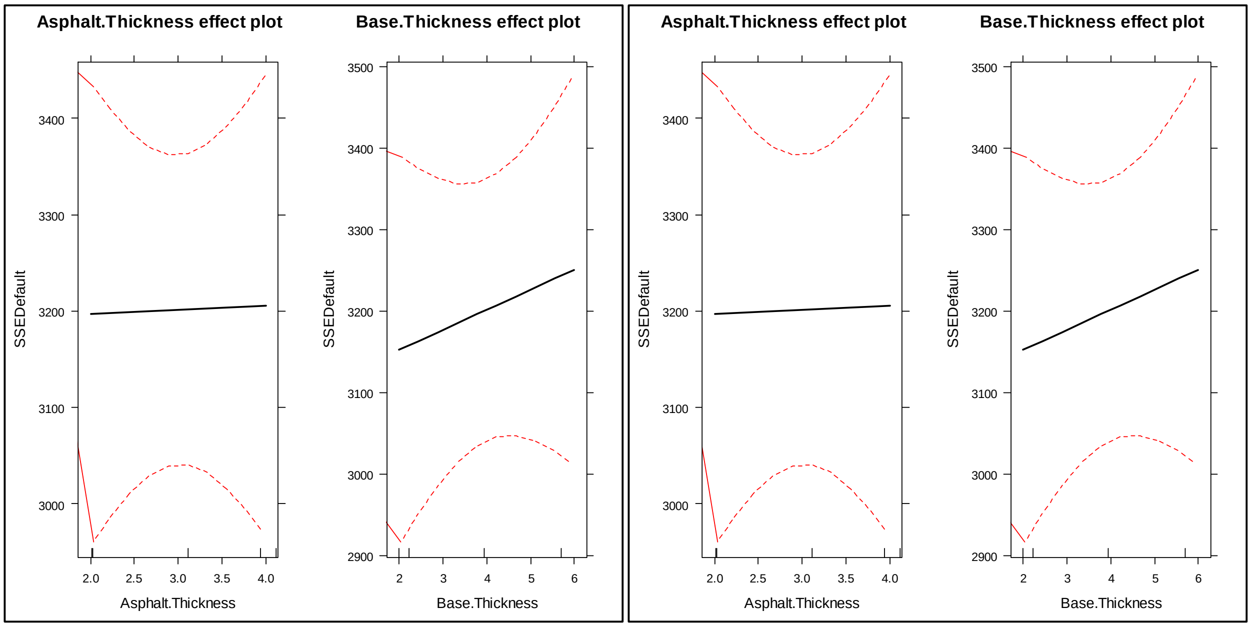
Appendix 4.3 SSE Main Effects Plot for Rutting considering Default Calibration Coefficients (Left) and Local Calibration Coefficients (Right)



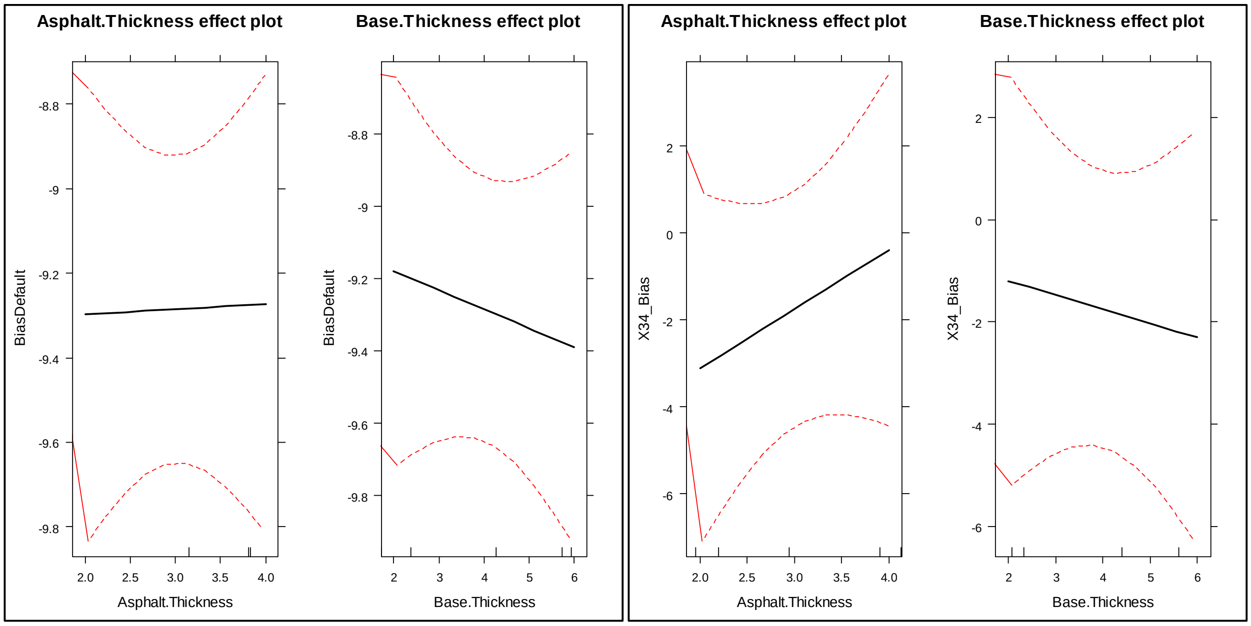
Appendix 4.4 Bias Main Effects Plot for Rutting considering Default Calibration Coefficients (Left) and Local Calibration Coefficients (Right)



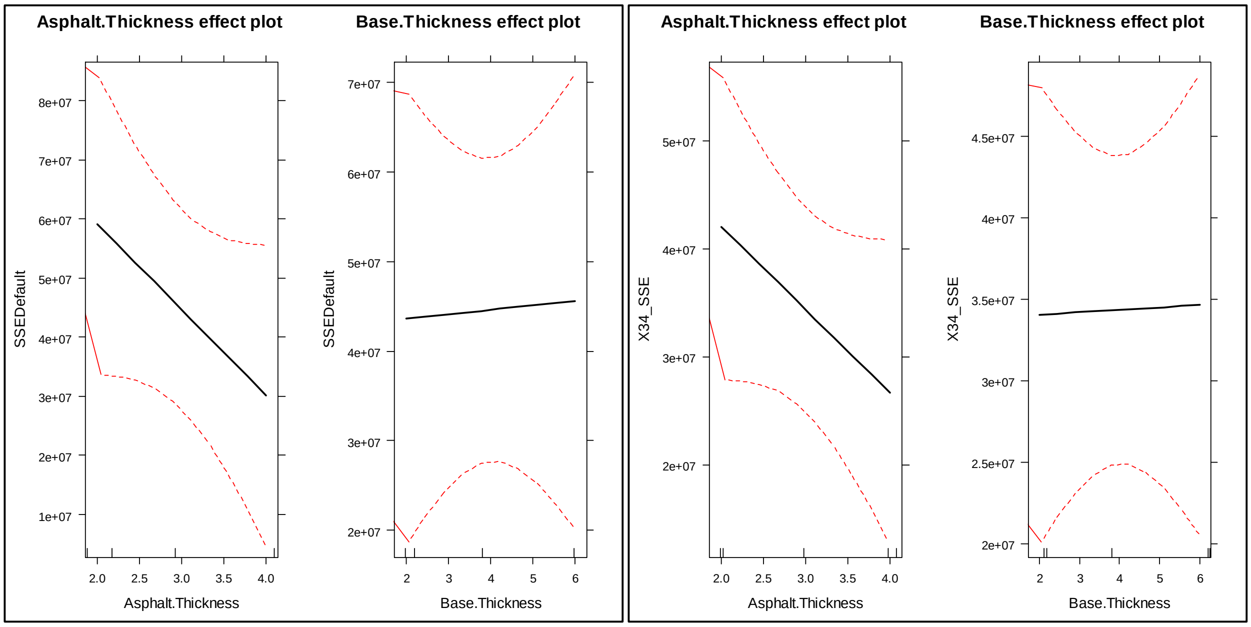
Appendix 4.5 SSE Main Effects Plot for Alligator Cracking considering Default Calibration Coefficients (Left) and Local Calibration Coefficients (Right)



Appendix 4.6 Bias Main Effects Plot for Alligator Cracking considering Default Calibration Coefficients (Left) and Local Calibration Coefficients (Right)



Appendix 4.7 SSE Main Effects Plot for Longitudinal Cracking considering Default Calibration Coefficients (Left) and Local Calibration Coefficients (Right)



Appendix 4.8 Bias Main Effects Plot for Longitudinal Cracking considering Default Calibration Coefficients (Left) and Local Calibration Coefficients (Right)