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IMPACT OF FREIGHT MOVEMENT TRENDS ON HIGHWAY PAVEMENT INFRASTRUCTURE

Final Report

by

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DISCLAIMER

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The major challenge for any pavement is the freight transport carried by the structure. This challenge is expected to increase in the coming years as freight movements are projected to grow and because these movements account for most of the load related distresses for the pavement. The problem is not simple in that the prediction of future freight traffic movements depends on current traffic conditions and an accurate prediction of economic and population growth of the different regions of the United States. The prediction of pavement deterioration also involves along with the future freight traffic, an assessment of the existing pavement and soil conditions and also the part played by the environment.

In this report the issue of freight on the pavement infrastructure is explored by combining freight movement predictions with pavement performance prediction models. This work uses current traffic, climate, soil, and the pavement construction details of major interstate routes in the United States to assess the impacts from freight projections. Interstates are divided into smaller segments and analyzed using the mechanistic-empirical analysis method, to explicitly identify the impacts to fatigue, rutting and IRI of the pavement segments. Pavement segments are classified based on the severity levels of these combined distresses, which represents the segments that are most susceptible to future freight traffic.

Under the scenarios examined, it is found that interstates in the Mountain and South-Atlantic regions of the United States are particularly prone to trends in freight movement. Conversely, pavements along the Pacific coast and West-Central regions are expected to sustain projected freight movements better. The results of this study provide a unique perspective on the issue of freight movement, particularly with respect to its impacts on the pavement infrastructure. It provides a forward looking view of the impact from freight movement and may lead to further research towards a more efficient pavement preservation/maintenance/rehabilitation program that is cognizant of future trends in freight.

1.0 INTRODUCTION

1.1 BACKGROUND

The economic vitality and prosperity of a city/state/region/nation is closely related to freight transportation (Mani and Prozzi 2004). As the world develops and population increase, the demand for freight will likely increase and these impacts are expected to become more severe. As discussed by Kveiborg et al. 2006, changes in freight movement are directly related to the economic growth of the region wherein the increase in the number of trucks is mainly related to the increase in production. In the US, the freight demand is expected to grow from 16 billion tons today to 31.4 billion tons in 2035 (AASHTO 2007). Projection of economic growth prediction for a region is one of the most unpredictable because the growth depends on numerous factors some of which may not be taken up at all. The reliability of these projections decreases with the overall projection period considered, e.g., a 20 year projection is less reliable than a 10 year projection. Nevertheless, many agencies and government groups rely on these projections in order to plan their congestion management strategies and/or their business practices. Much of this freight is being moved via highways, which is a pattern expected to continue into the foreseeable future (Costello 2014).

To date many studies that have evaluated this important issue have considered current and future freight movement in the context of environmental impacts, congestion and/or access reliability (McKinnon 1999, Hensher and Puckett 2005, Sankaran et al. 2005, Facanha et al. 2006, Zeitsman et al. 2006, Alam et al. 2007, Piecyk and McKinnon 2010, Wheeler and Figliozzi 2011). The findings from the Alam et al. (2007) study are particularly relevant, see Figure 1, as they show projected impacts of freight movement on congestion in a very power visual map. All these studies suggest a higher possibility of increase in freight traffic in the United States in the coming years, but none have focused specific attention on the impact of these projected freight trends on the performance of the infrastructure itself.

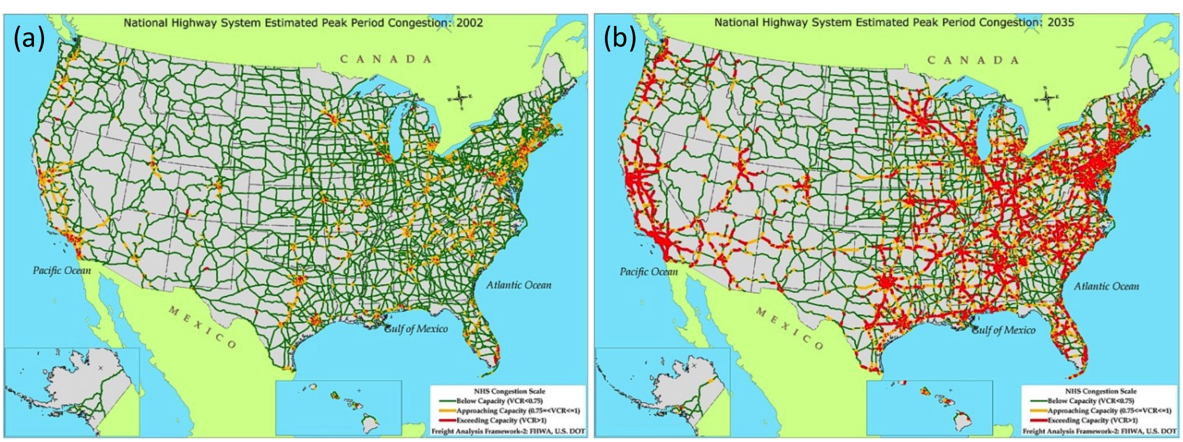


Figure 1: (a) Congestion on major corridors for 2002 and (b) projected congestion along interstate corridors for 2035 (Alam et al. 2007).

Despite the substantial interest in freight movements, one aspect that has received relatively little attention is the potential impacts that the increased movement of goods may have on the transportation infrastructure. Such a lack of attention is surprising that the impacts of decreased pavement performance include:

- Increased user costs in terms of both vehicle operating costs and in delays from maintenance and preservation/rehabilitation activities;
- Higher levels of localized pollution from congested traffic;
- Larger errors in congestion projections due to the unaccounted for increases in pavement maintenance; and
- Incomplete information in the geometric, operations, and pavements planning steps for transportation development, which can result in increasingly less than optimal engineering solutions.

Taken together, these impacts can substantial affect the economic vitality of localities, states, regions, and the nation as a whole.

It is intuitive that an increase in traffic volume will negatively impact the infrastructure since it is known that large trucks are the primary source of road damage due to the high stresses that they impart on the pavement (Gillespie and Karamihas 1994, Salama et al. 2006). However, a unique relationship between traffic volume and rate of deterioration does not exist because other factors (local climate conditions, localized construction and material practices, and interactions between traffic volume and the traffic loads) can also impact the infrastructure performance. One specific challenge is that changes in traffic volume can be generally associated with changes in the loads carried by the traffic, which are in turn nonlinearly related to performance. This nonlinearity is expressed as the rule of three, referring to the exponent of the nonlinear relationship between performance and load. As an example, take the case where the applied pavement load is doubled. According to the rule of three this doubling of load would result in a decrease in fatigue performance by a factor of eight ($2^3 = 8$). Similar issues exist for other distresses in both asphalt concrete and Portland cement concrete as well.

Until recently accurate analysis of these impacts was not possible. The emergence of nationally verified mechanistic-empirical pavement analysis methods has overcome this limitation as this method represents a different paradigm of pavement analysis from that of the empirical process (Li et al. 2011). Factors influencing the pavement performance such as traffic, climate, pavement structure, and material properties are explicitly considered in the inputs. Then the principles of engineering mechanics are used to predict the critical pavement responses, which are coupled to mechanistic and empirical relationships established from engineering experience to predict the material damage and ultimately the pavement distress.

The Mechanistic-Empirical Pavement Design Guide (MEPDG) was first released in 2004 under the NCHRP project I-37A. It provides guidelines for designing the in-common features of flexible, rigid and composite pavements. It also provides procedures for evaluation of existing pavement and recommendations for rehabilitation. The computational software that makes up the MEPDG uses an integrated analysis approach. It predicts pavement performance over time by taking into account the interaction amongst the input factors (climate, structure, materials, and traffic). The software offers hierarchical levels of inputs based on the accuracy of details available. Level 1 input provide for the highest levels of accuracy and the lowest level of uncertainty. Level 1 material input requires extensive laboratory or field testing. Level 2 inputs provide an intermediate level of accuracy that involves a limited testing program and intermediate levels of accuracy. Level 3 inputs require a low level of accuracy, which may include typical average values for the region. National default values provided in the MEPDG software can also be used as level 3 inputs.

The MEPDG also includes comprehensive temperature and moisture consideration of the pavement system over the design life through the incorporation of Enhanced Integrated Climatic Model (EICM). It simulates the changes in the characteristics of the pavement and subgrade in coordination with the climatic conditions. The software has a built-in record of weather stations, which allows user to select the adjacent weather station. It still lacks complete database for some of the weather stations, but has an accommodation to interpolate the climatic data from adjacent weather stations.

The software considers traffic by accounting for the full axle load spectrum. The traffic data are categorized by truck traffic volume, traffic volume adjustment factors, axle load distribution factors, and the general traffic inputs such as axle configuration, wheelbase and the axles per truck. The properties of materials used for construction constitute the material input. Material parameters associated with pavement distress criteria are related to the measure of the material's resistance to damage (tensile strength, plastic deformation resistance, etc.).

Pavement performance is primarily concerned with the functional and structural performance. The structural performance of a pavement relates to its physical condition (such as fatigue cracking and rutting in flexible pavement). Such key distresses can be predicted directly using the mechanistic concepts. Ride quality is the predominant factor in determining the functional performance, which is measured by the International Roughness Index (IRI). In MEPDG, IRI is estimated incrementally over the analysis period by incorporating distresses such as cracking, rutting as major factors influencing the loss of smoothness of pavement. The MEPDG procedure accumulates damage on a monthly basis over the entire analysis period. It simulates how pavement damage occurs in nature, incrementally load by load over continuous time periods. The procedure also allows for aging of pavements.

1.2 STUDY OBJECTIVE

The objective of this research is to investigate the impacts of national freight traffic trends and projections on pavement infrastructure. The outcome is a map of the major transportation corridors that identifies critical locations where projected freight trends may have the strongest negative impact on the transportation infrastructure.

1.3 SCOPE OF WORK

Evaluating the effects of future freight movements on pavement infrastructure is not a simple problem since these projections depend on an assessment of current traffic conditions and an accurate prediction of economic and population growth. In addition, any accurate prediction of pavement deterioration requires along with the future freight traffic, consideration of the existing pavement and soil conditions and the environmental conditions. In this project the current traffic, climate, soil and the pavement construction details for 11 of the major interstate routes in the United States has been considered as the input. Pavement performance is projected for future conditions and the pavement segments are analyzed for current traffic projections as well as freight traffic projections using the MEPDG method. The results thus obtained are analyzed with respect to the fatigue, rutting and IRI characteristics of the pavement segments and those interstate segments that may be most affected by future traffic are identified.

1.4 RELEVANCE TO CENTER THEMES

This proposed research directly addresses the freight efficiency and reliability focus of the national transportation center. Freight mobility has traditionally been investigated in terms of congestion, but in this study another component of the issue will be investigated: the impact of changes in freight movement on the pavement infrastructure. The findings from this study will add another dimension to the discussion of freight efficiency and reliability and inform public policies and infrastructure investment decisions. It will provide both a "current state" analysis as well as establish a framework for future studies that may incorporate alternative or novel geometric design strategies or new materials technologies. This framework could also be used to provide a more accurate assessment of the impacts of freight movement strategies (e.g., rail versus highway at national, regional, and local scales) and better link ports, rail, and highway systems.

2.0 ANALYSIS SECTIONS

2.1 INTRODUCTION

The overall goal of this project is to assess the sensitivity of the pavement infrastructure along key interstate routes to freight movement projections. The interstates selected for this study are shown in Figure 2 and include I-5, I-10, I-15, I-35, I-40, I-70, I-75, I-80, I-90, I-94, and I-95. These interstates are selected based on the vehicular traffic they carry, the strategic importance to freight movement (port connectivity), their inclusion in the MAP-21 Primary Freight Network (MAP 21, 2012), and their geographic diversity. The total mileage length of all these routes is 22,900 miles, which is approximately 48% of the total interstate system. The selected interstates represent approximately 70% of the total freight traffic occurring on all interstates (FHWA 2013). The method used to organize this analysis into manageable pieces and still obtain an accurate assessment involved segmenting the routes into smaller and more uniform sections. This segmentation was based principally upon traffic, climate, and subsurface since these factors are known to contribute substantially to pavement performance. In addition, state boundaries were also used to segment the interstates as each state has its own set of pavement specifications, which will affect the materials utilized along each segment. In total there are 211 segments that have been analyzed for this study, and these are described in more detail below.

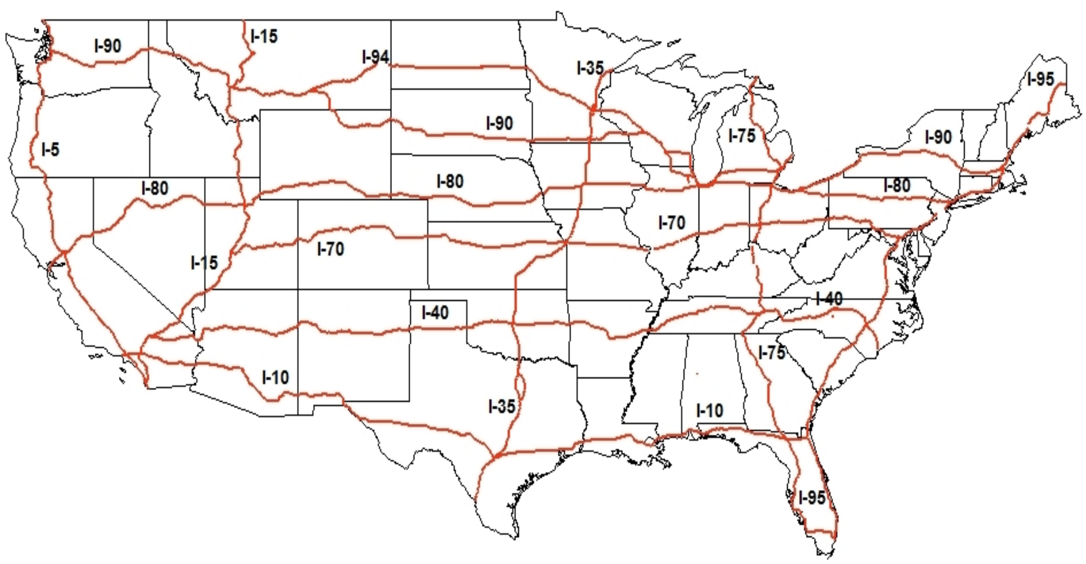


Figure 2: Map of selected interstates.

2.2 SEGMENTATION RULES

The four main factors determining the stability of a pavement section are the traffic carried by the section, the climate in the area of the pavement, the soil over which the pavement is built, and the materials used in the paving layers. All other factors being equal if a pavement carries more traffic the process of deterioration will be faster and the probability of failure of the section will increase. Likewise, more extreme temperatures, greater amounts of precipitation, and inferior soils can hasten pavement deterioration. Materials are generally project specific, but are selected and designed following the guidelines and specifications laid out by State Departments of Transportation. The paragraphs below detail the rules applied in three of these categories (traffic, climate, and soil). The fourth criteria, state boundaries, were identified through geospatial mapping of the interstate routes.

2.2.1 Traffic

To segment the interstate routes by traffic, each available traffic segment (mile marker in some cases or larger sections in other cases) was ranked on a scale of 1 to 5. The assignment was based on the Average Annual Daily Truck Traffic (AADTT) values in the base year (2012);

- 5 = > 20,000,
- 4 = 15,000 – 20,000,
- 3 = 10,000 – 15,000,
- 2 = 5,000 – 10,000, and
- 1 = < 5,000.

To populate this traffic database, data was collected through the various state Departments of Transportation, where it was found that each department generally follows its own format. Some provide the exact AADTT data on a mileage basis, but most do not. Some of the states provide the traffic values by sections on their county maps while some states provide it in other formats such as *.kml (Google earth) and *.shp (GIS applications). In cases where states provided only the average annual traffic, the department's design documentation was reviewed to identify either site specific or generally applied truck factors.

2.2.2 Soil

The second factor considered for the segmentation of interstates was the soil type for the region. The extensive mapping effort completed under NCHRP 9-23B was used for this purpose. In this project, researchers compiled soil maps, like that shown in Figure 3, by reviewing available databases and applying certain empirical predictive equations to estimate engineering properties. In this figure, each colored region represents an area of approximately uniform soil conditions. The database is available as an online application (http://nchrp923b.lab.asu.edu/index.html). An example of the output from this application is given in Figure 4, where it is seen that soil characteristics for a particular site are compiled as a function of depth according to AASHTO classification and engineering properties. In the AASHTO classification system soils are denoted as either A1, A2, A3, A4, A5, A6, or A7 with A1 denoting highly course and A7 denoting very fine soil. The strength of a pavement and the drainage conditions depend on its subgrade soil.

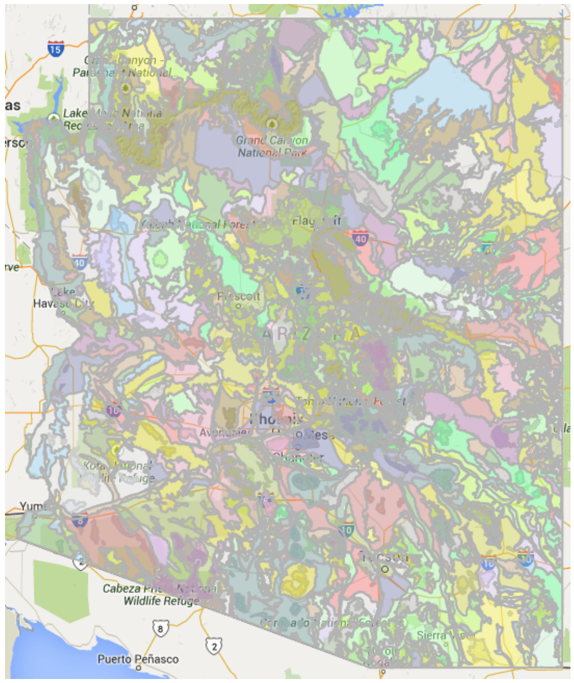
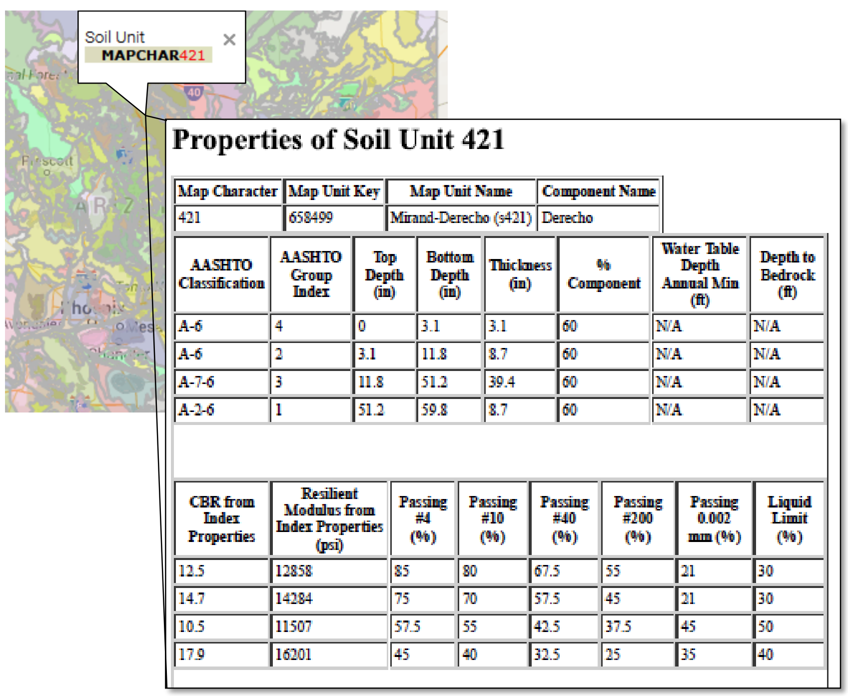


Figure 3: Example map in NCHRP 9-23B soil map application (State of Arizona).



Properties of Soil Unit 421

Map Character	Map Unit Key	Map Unit Name	Component Name
421	658499	Mirand-Derecho (s421)	Derecho

AASHTO Classification	AASHTO Group Index	Top Depth (in)	Bottom Depth (in)	Thickness (in)	% Component	Water Table Depth Annual Min (ft)	Depth to Bedrock (ft)
A-6	4	0	3.1	3.1	60	N/A	N/A
A-6	2	3.1	11.8	8.7	60	N/A	N/A
A-7-6	3	11.8	51.2	39.4	60	N/A	N/A
A-2-6	1	51.2	59.8	8.7	60	N/A	N/A

CBR from Index Properties	Resilient Modulus from Index Properties (psi)	Passing #4 (%)	Passing #10 (%)	Passing #40 (%)	Passing #200 (%)	Passing 0.002 mm (%)	Liquid Limit (%)
12.5	12858	85	80	67.5	55	21	30
14.7	14284	75	70	57.5	45	21	30
10.5	11507	57.5	55	42.5	37.5	45	50
17.9	16201	45	40	32.5	25	35	40

Figure 4: Engineering parameters from NCHRP 9-23B application.

For the process of segmentation, the soil properties need to be known on a mile-by-mile basis, and this required some processing of the database. In this database information can be obtained from by two methods, both of which are discussed here. In the first method, the user chooses to search for route information and is taken to a second screen where he/she selects state, route type (Interstate in this case), and milepost are first selected. The web application then identifies the latitude and longitude coordinates, which the user must then paste into the appropriate boxes on the main screen of the application. Next, the user selects the 'Get Map' button and the soil layer corresponding to that particular point is displayed in color. By then moving the cursor on top of the colored map region and selecting the region a soil unit, referred to as a 'MapChar', is then displayed and the user enters this into the report box to generate a soil unit report. In the second method the soil report selection procedure is the same, but to identify the search 'MapChar', the user first gets a state-wide map and then manually identifies the requisite milepost locations.

The soil unit report describes the AASHTO type of soil present in that region, the thickness of each layer, water table depth (if known), depth to bedrock, and the other engineering properties of the soil. The search databases identified and functions developed by the NCHRP 9-23b research team are capable of estimating the soil properties at multiple depths (more than 60 inches in some cases). Some soil units are completely homogenous with depth, e.g., they show the same soil type for the entire profile. However, in some cases there are two or more types of soils present. In such cases, the weakest type of soil present at that location is considered. For example, if a given location contains an A2 soil for the top 3 inches and A4 soil for the next 12 inches, the soil type of the location is set as A4 for the segmentation process.

Based on its engineering properties, the high quality soils are given a low rating and the lower quality soils were given a higher rating. The rating scale is as follows.

- A1 & A2 – 1
- A3 – 2
- A4 – 3
- A5 – 4
- A6 & A7 – 5

2.2.3 Climate

The third factor considered in segmentation was climate with special reference to the total precipitation over the region. One of the main reasons for pavement failure is the seepage of water into the pavement and its effect on the subgrade. Hence the effect of precipitation on the pavement deterioration was also used. In order to accommodate the severity of damage caused due to rainfall on the pavement segments, the following methodology was used.

Those places experiencing no or very little rainfall are least susceptible to pavement deterioration due to water seepage, and following the general convention followed in this report, those places were given a rating 1. Analysis of rainfall data for the 51 major cities in the US, Table 1 shows that the annual rainfall distribution in these cities fell into the range of approximately 15 to 60 inches per year as shown in Figure 5.

Additional investigations also showed that there were also areas, like Laurel mountain in Oregon and Forks in Washington, that receive exceptionally high rainfall of more than 80 inches per year (NCDC 2010). Owing to the fact that the overall resolution of this study was larger than the scale of many of these microclimates, the index ranges were established based on the city-wise analysis. As shown in Figure 4 the distribution of precipitation in these cities was close to normal with a mean of 37 inches and a standard deviation of 14 inches. Using this distribution as a guide and with the desire to choose ranges with convenient rainfall totals and spaced in approximately one standard deviation intervals, the rating system of 1-5 was devised with the following ranges;

- 5 = > 60 inches per year
- 4 = 45 – 60 inches per year,
- 3 = 30 – 45 inches per year,
- 2 = 15 – 30 inches per year, and
- 1 = < 15 inches per year.

Table 1: Rainfall data for 51 major US cities.

City	Rainfall (in.)	City	Rainfall (in.)	City	Rainfall (in.)
Atlanta, GA	49.7	Jacksonville, FL	52.4	Portland, OR	43.5
Austin, TX	34.2	Kansas City, MO	39.1	Providence, RI	47.2
Baltimore, MD	41.9	Las Vegas, NV	4.2	Raleigh, NC	46.0
Birmingham, AL	53.7	Los Angeles, CA	12.8	Richmond, VA	43.6
Boston, MA	43.8	Louisville, KY	44.9	Riverside, CA	10.3
Buffalo, NY	40.5	Memphis, TN	53.7	Rochester, NY	34.3
Charlotte, NC	41.6	Miami, FL	61.9	Sacramento, CA	18.5
Chicago, IL	36.9	Milwaukee, WI	34.8	Salt Lake City, UT	16.1
Cincinnati, OH	41.9	Minneapolis, MN	30.6	San Antonio, TX	32.3
Cleveland, OH	39.1	Nashville, TN	47.3	San Diego, CA	10.3
Columbus, OH	39.3	New Orleans, LA	62.7	San Francisco, CA	20.7
Dallas, TX	37.6	New York, NY	49.9	San Jose, CA	15.8
Denver, CO	15.6	Oklahoma City, OK	36.5	Seattle, WA	37.7
Detroit, MI	33.5	Orlando, FL	50.7	St. Louis, MO	41.0
Hartford, CT	45.9	Philadelphia, PA	41.5	Tampa, FL	46.3
Houston, TX	49.8	Phoenix, AZ	8.2	Virginia Beach, VA	46.5
Indianapolis, IN	42.4	Pittsburg, PA	38.2	Washington, DC	39.7

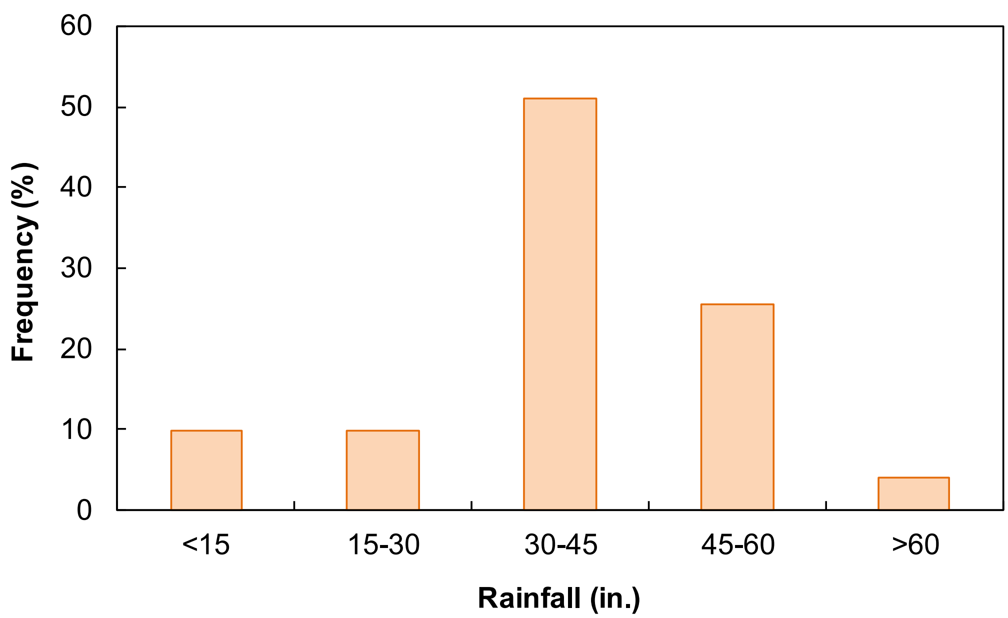


Figure 5: Rainfall distribution in 51 major cities.

2.2.4 Combining Factors

The final segmentation of the interstate routes was based on the combined effect of all these factors, which was calculated by averaging the ratings of each of the three individual factors. Mileage sections with average ratings within the same whole point score were then taken to be a single section. Whenever there was an increase or decrease to the next whole point, a section was assigned to another segment. So for example, if generic section A had an average score of 3.4 and the following section (Section B) had a score of 3.9 they were taken to exist in the same segment. If Section B had a score of 4.1 the two sections would be assigned to different segments. The routes were also divided at the state boundaries because the design and construction details varied between states. Exceptions to the state boundary rule were made in cases where the interstate traversed one of the states for fewer than 40 miles. Additional limits on maximum and minimum length were assigned (200 and 50 miles respectively). The lower limit may be relaxed at few sections where the entire length of an interstate section in a state is less than 50 miles. Interstate 15 which run for only 30 miles in the state of Arizona was added to the next segment in the state of Nevada as the input factors were similar. Similar cases were encountered in the Interstate 95 which runs through Delaware for 23 miles and New Hampshire for 16 miles. The segments in these states were combined with Maryland and Massachusetts respectively.

2.3 INTERSTATE SEGMENTS

In the following paragraphs a brief summary of the segmentation of each interstate is given. Appendix A contains a more detailed description of each analysis segment.

2.3.1 Interstate 5

Interstate 5 (I-5) runs north-south along the western coast connecting Mexico (near San Diego, CA) with Canada (near Blaine, WA). In total it traverses three states California, Oregon, and Washington and connects the major population centers of San Diego, Santa Ana, Anaheim, Los Angeles, Sacramento, Portland, and Seattle. It also provides connections to the San Francisco area through Interstates 580 and 505. It is the twelfth longest interstate in the US and the fifth longest north-south interstate. The total length of I-5 is 1,382 miles, with 797 miles in California, 308 miles in Oregon, and 277 miles in Washington. It has been segmented into a total of 12 sections. These sections, their length and approximate descriptions are provided in Table 2.

2.3.2 Interstate 10

Interstate 10 (I-10) is the southernmost transcontinental highway in the interstate system. It is one of the three coast to coast interstates in the country. It stretches from Santa Monica, California to Jacksonville, Florida. It is the fourth longest interstate in the US with a total length of 2,460 miles. Almost one third of its length lies within the state of Texas, but it also travels through major cities such as Los Angeles, California; Phoenix, Arizona; El Paso, Texas; San Antonio, Texas; Houston, Texas; New Orleans, Louisiana and Jacksonville, Florida. To the east of Phoenix, Arizona (between Phoenix and Tucson) the route is a part of high priority corridor 26: CANAMEX Corridor. The length of I-10 in various states and the number of segments in each state is summarized in Table 3.

Table 2: Interstate 5 segments.

State	Length (Miles)	Sections			
		Name	Length (Miles)	MP	Description
California	797	I5-CA-1	85	0 to 85	San Diego Co. to Orange Co.
		I5-CA-2	189	85 to 274	Orange Co. to Kern Co.
		I5-CA-3	194	274 to 468	Kern Co. to San Joaquin Co.
		I5-CA-4	132	468 to 600	San Joaquin Co. to Glenn Co.
		I5-CA-5	197	600 to 797	Glenn Co. to Oregon border
Oregon	308	I5-OR-1	55	0 to 55	California border to Josephine Co.
		I5-OR-2	64	55 to 119	Josephine Co. to Douglas Co.
		I5-OR-3	115	119 to 234	Douglas Co. to Linn Co.
		I5-OR-4	74	234 to 308	Linn Co. to Washington border
Washington	277	I5-WA-1	112	0 to 112	Oregon border to Thurston Co.
		I5-WA-2	99	112 to 211	Thurston Co. to Snohomish Co.
		I5-WA-3	66	211 to 277	Snohomish Co. to Canadian border

Table 3: Interstate 10 segments.

State	Length (Miles)	Sections			
		Name	Length (Miles)	MP	Description
California	251	I10-CA-1	86	0 to 86	Los Angeles Co. to San Bernardino Co.
		I10-CA-2	165	86 to 251	San Bernardino Co. to Arizona border
Arizona	393	I10-AZ-1	126	0 to 126	California border to Maricopa Co.
		I10-AZ-2	126	126 to 252	Maricopa Co. to Pima Co.
		I10-AZ -3	141	252 to 393	Pima Co. to New Mexican border
New Mexico	164	I10-NM-1	85	0 to 85	Arizona border to Luna Co.
		I10-NM-2	79	85 to 164	Luna Co. to Texas border
Texas	881	I10-TX-1	136	0 to 136	New Mexico border to Hudspeth Co.
		I10-TX-2	124	136 to 260	Hudspeth Co. to Pecos Co.
		I10-TX-3	125	260 to 385	Pecos Co. to Sutton Co.
		I10-TX-4	125	385 to 510	Sutton Co. to Kerr Co.
		I10-TX-5	80	510 to 590	Kerr Co. to Bexar Co.
		I10-TX-6	110	590 to 700	Bexar Co. to Colorado Co.
		I10-TX-7	105	700 to 805	Colorado Co. to Chambers Co.
		I10-TX-8	76	805 to 881	Chambers Co. to Louisiana border
Louisiana	274	I10-LA-1	94	0 to 94	Texas border to Lafayette Co.
		I10-LA-2	127	94 to 221	Lafayette Co. to Jefferson Co.
		I10-LA-3	53	221 to 274	Jefferson Co. to Mississippi border
Mississippi	77	I10-MS-1	77	0 to 77	Louisiana border to Alabama border
Alabama	66	I10-AL-1	66	0 to 66	Mississippi border to Florida border
Florida	362	I10-FL-1	103	0 to 103	Alabama border to Washington Co.
		I10-FL-2	138	103 to 241	Washington Co. to Madison Co.
		I10-FL-3	121	241 to 362	Madison Co. to Duval Co.

2.3.3 Interstate 15

Interstate 15 (I-15) is the eleventh longest interstate highway in the US and the fourth longest north-south interstate in the US. In total it traverses through six states of California, Nevada, Arizona, Utah, Idaho and Montana and covers the region between San Diego County and the

Canadian border. It forms a part of CANAMEX corridor, a high priority corridor as a result of North American Free Trade Agreement.

After the construction of Interstate 15, California, Nevada and Utah have consistently ranked in the fastest growing states in the country, and subsequently, the route of I-15 has increased in population and traffic burden. It is estimated that more than 19% of the population of California, 70% of the population of Nevada, and 75% of the population of Utah lives in counties where I-15 is the primary interstate highway. The length of Interstate 15 in various states and the number of sections considered in each state are provided in Table 4.

Table 4: Interstate 15 segments.

State	Length (Miles)	Sections			
		Name	Length (Miles)	MP	Description
California	287	I15-CA-1	119	0 to 119	San Diego Co. to San Bernardino Co.
		I15-CA-2	168	119 to 168	San Bern. Co. to Arizona boundary
Nevada, Arizona	124+ 30	I15-NV-1	154	0 to 124, 0 to 30	California border to Utah border
Utah	401	I15-UT-1	77	0 to 77	Arizona border to Iron Co.
		I15-UT-2	170	77 to 247	Iron Co. to Utah Co.
		I15-UT-3	80	247 to 327	Utah Co. to Davis Co.
		I15-UT-4	74	327 to 401	Davis Co. to Idaho border
Idaho	196	I15-ID-1	75	0 to 75	Utah border to Bingham Co.
		I15-ID-2	121	75 to 196	Bingham Co. to Montana border
Montana	396	I15-MT-1	134	0 to 134	Idaho border to Jefferson Co.
		I15-MT-2	140	134 to 274	Jefferson Co. to Cascade Co.
		I15-MT-3	122	274 to 396	Cascade Co. to Canadian border

2.3.4 Interstate 35

Interstate 35 (I-35) is the ninth longest Interstate in the US highway system. It stretches from Texas in the south up to Canadian border in Minnesota. The entire interstate is a part of high priority corridor 23. Interstate 35 together with Interstate 29 provides a direct freeway connection between Mexico and Canada. The total length of the highway is 1,568 miles and it passes through six states. The length of Interstate 35 in each state and the number of sections considered for analysis are provided in Table 5.

2.3.5 Interstate 40

Interstate 40 (I-40) is the third longest Interstate in the United States and it travels from California in the west to North Carolina in the east. In total it traverses through eight states and some of the important cities including Raleigh, North Carolina; Nashville, Tennessee; Memphis, Tennessee; Oklahoma City, Oklahoma and Albuquerque, New Mexico. Interstate 40 through California and Arizona is part of High Priority Corridor 16 and 70: Economic Lifeline Corridor. The length of Interstate 40 and the number of sections in each of the states are given in Table 6.

Table 5: Interstate 35 segments.

State	Length (Miles)	Sections			
		Name	Length (Miles)	MP	Description
Texas	686	I35-TX-1	102	0 to 102	Mexican border to Frio Co.
		I35-TX-2	146	102 to 248	Frio Co. to Travis Co.
		I35-TX-3	81	248 to 329	Travis Co. to McLennan Co.
		I35-TX-4	175	329 to 504	McLennan Co. to Cooke Co.
		I35E-TX	97	0 to 97	Hill Co. to Denton Co.
		I35W-TX	85	0 to 85	Hill Co. to Oklahoma border
Oklahoma	236	I35-OK-1	151	0 to 151	Texas border to Oklahoma Co.
		I35-OK-2	85	151 to 236	Oklahoma Co. to Kansas border
Kansas	236	I35-KS-1	141	0 to 141	Oklahoma border to Lyon Co.
		I35-KS-2	95	141 to 236	Lyon Co. to Missouri border
Missouri	115	I35-MO-1	115	0 to 115	Kansas border to Iowa border
Iowa	218	I35-IA-1	102	0 to 102	Missouri border to Story Co.
		I35-IA-2	116	102 to 218	Story Co. to Minnesota border
Minnesota	260	I35-MN-1	97	0 to 97	Iowa border to Dakota Co.
		I35-MN-2	163	97 to 260	Dakota Co. to Canadian border

Table 6: Interstate 40 segments.

State	Length (Miles)	Sections			
		Name	Length (Miles)	MP	Description
California	155	I40-CA-1	79	0 to 79	Barstow Co. to Ludlow Co.
		I40-CA-2	76	79 to 155	Ludlow Co. to Arizona border
Arizona	359	I40-AZ-1	122	0 to 122	Mohave Co. to Yavapai Co.
		I40-AZ-2	135	122 to 257	Yavapai Co. to Navajo Co.
		I40-AZ-3	102	257 to 359	Navajo Co. to New Mexico border
New Mexico	373	I40-NM-1	114	0 to 114	Arizona border to Cibola Co.
		I40-NM-2	142	114 to 256	Cibola Co. to Guadalupe Co.
		I40-NM-3	117	256 to 373	Guadalupe Co. to Texas border
Texas	177	I40-TX-1	114	0 to 114	New Mexico border to Gray Co.
		I40-TX-2	63	114 to 177	Gray Co. to Oklahoma border
Oklahoma	332	I40-OK-1	83	0 to 83	Texas border to Custer Co.
		I40-OK-2	138	83 to 221	Custer Co. to Okfuskee Co.
		I40-OK-3	111	221 to 332	Okfuskee Co. to Arkansas border
Arkansas	285	I40-AR-1	136	0 to 136	Oklahoma border to Faulkner Co.
		I40-AR-2	149	136 to 285	Faulkner Co. to Tennessee border
Tennessee	455	I40-TN-1	100	0 to 100	Arkansas border to Henderson Co.
		I40-TN-2	123	100 to 223	Henderson Co. to Wilson Co.
		I40-TN-3	98	223 to 321	Wilson Co. to Cumberland Co.
		I40-TN-4	134	321 to 455	Cumb. Co. to North Carolina border
North Carolina	419	I40-NC-1	104	0 to 104	Tennessee border to Burke Co.
		I40-NC-2	140	104 to 244	Burke Co. to Orange Co.
		I40-NC-3	175	244 to 419	Orange Co. to New Hanover Co.

2.3.6 Interstate 70

Interstate 70 (I-70) is an East West highway, bisecting the country and traversing ten states. It runs through cities such Denver, Colorado; Kansas City, Missouri; St. Louis, Missouri; Indianapolis, Indiana; Columbus, Ohio; and Baltimore, Maryland. The interstate does not connect the two coasts as it ends at I-15 near Cove Fort, Utah. Between Denver and Limon in Colorado, I-70 is part of high priority corridor 38, the Ports to Plains corridor, and the section of through Missouri is part of High Priority Corridor 61. The length of Interstate 70 and the number of sections in each state is summarized in Table 7.

Table 7: Interstate 70 segments.

State	Length (Miles)	Sections			
		Name	Length (Miles)	MP	Description
Utah	232	I70-UT-1	93	0 to 93	Millard Co. to Emery Co.
		I70-UT-2	139	93 to 139	Emery Co. to Colorado border
Colorado	452	I70-CO-1	142	0 to 142	Utah border to Eagle Co.
		I70-CO-2	112	142 to 254	Eagle Co. to Jefferson Co.
		I70-CO-3	110	254 to 364	Jefferson Co. to Lincoln Co.
		I70-CO-4	88	364 to 452	Lincoln Co. to Kansas border
Kansas	424	I70-KS-1	96	0 to 96	Colorado border to Gove Co.
		I70-KS-2	121	96 to 217	Gove Co. to Ellsworth Co.
		I70-KS-3	127	217 to 344	Ellsworth Co. to Shawnee Co.
		I70-KS-4	80	344 to 424	Shawnee Co. to Missouri border
Missouri	250	I70-MO-1	148	0 to 148	Kansas border to Callaway Co.
		I70-MO-2	102	148 to 250	Callaway Co. to Illinois border
Illinois	138	I70-IL-1	138	0 to 138	Missouri border to Indiana border
Indiana	157	I70-IN-1	92	0 to 92	Illinois border to Hancock Co.
		I70-IN-2	65	92 to 157	Hancock Co. to Ohio border
Ohio, West Virginia	226+14	I70-OH-1	129	0 to 129	Indiana border to Licking Co.
		I70-OH-2	111	129 to 226, 0 to 14	Licking Co. to Pennsylvania border
Pennsylvania	169	I70-PA-1	82	0 to 82	W. Vir. border to Westmoreland Co.
		I70-PA-2	87	82 to 169	West. Co. to Maryland border
Maryland	94	I70-MD-1	94	0 to 94	Penn. border to Baltimore Co.

2.3.7 Interstate 75

Interstate 75 (I-75) is a major north-south highway traversing from Florida to Michigan. It provides a major link between the Southeast and Great Lakes regions and serves the cities of Miami, Florida; Naples, Florida; Fort Myers, Florida; Tampa, Florida; Atlanta, Georgia; Cincinnati, Ohio; Toledo, Ohio; and Detroit, Michigan. Interstate 75 in Ohio is part of High priority corridor 76. The total length of the highway is 1,786 miles and it passes through six states. The length of the highway in each state and the number of sections in each state is summarized in Table 8.

Table 8: Interstate 75 segments.

State	Length (Miles)	Sections			
		Name	Length (Miles)	MP	Description
Florida	471	I-75-FL-1	123	0 to 123	Miami-Dade Co. to Lee Co.
		I75-FL-2	119	123 to 242	Lee Co. to Hillsborough Co.
		I75-FL-3	73	242 to 315	Hillsborough Co. to Sumter Co.
		I75-FL-4	156	315 to 471	Sumter Co. to Georgia border
Georgia	355	I75-GA-1	101	0 to 101	Florida border to Crisp Co.
		I75-GA-2	84	101 to 185	Crisp Co. to Monroe Co.
		I75-GA-3	71	185 to 256	Monroe Co. to Fulton Co.
		I75-GA-4	99	256 to 355	Fulton Co. to Tennessee border
Tennessee	162	I75-TN-1	85	0 to 85	Georgia border to Knox Co.
		I75-TN-2	77	85 to 162	Knox Co. to Kentucky border
Kentucky	192	I75-KY-1	76	0 to 76	Tennessee border to Madison Co.
		I75-KY-2	116	116 to 192	Madison Co. to Ohio border
Ohio	211	I75-OH-1	108	0 to 108	Kentucky border to Shelby Co.
		I75-OH-2	103	108 to 211	Shelby Co. to Michigan border
Michigan	396	I75-MI-1	80	0 to 80	Ohio border to Oakland Co.
		I75-MI-2	89	80 to 169	Oakland Co. to Bay Co.
		I75-MI-3	90	169 to 259	Bay Co. to Crawford Co.
		I75-MI4	137	259 to 396	Crawford Co. to Chippewa Co.

2.3.8 Interstate 80

Interstate 80 (I-80) is a major trans-continental highway running from San Francisco, California to Teaneck, New Jersey. It is the second longest interstate in the United States. Interstate 80 in New Jersey is part of High priority corridor 63 (the Liberty Corridor). The total length of the Interstate is 2,900 miles and it traverses through 11 states. The length of I-80 in each of the states and the number of sections considered for analysis are summarized in Table 9.

2.3.9 Interstate 90

Interstate 90 (I-90) is the longest interstate highway in the United States with a mileage of 3,101. Its western terminus is Seattle, Washington and eastern terminus is Boston, Massachusetts. It connects the major population centers of Madison, Wisconsin; Chicago, Illinois; Rockford, Illinois; Cleveland, Ohio; Toledo, Ohio; Buffalo, New York, Albany, New York; and Springfield, Massachusetts. Interstate 90 in the Seattle metropolitan area is part of High priority corridor 35: FAST Corridor. The interstate traverses through 13 states and Table 10 summarizes the length of interstate in each state and the number of sections considered for analysis.

2.3.10 Interstate 94

Interstate 94 (I-94) is the northern most east-west interstate highway connecting the Great Lakes and Intermountain regions. Interstate 94 has its western terminus in Billings, Montana and its eastern terminus at Blue Water Bridge in Michigan. It is the eighth longest interstate highway in the United States. The total length of this interstate is 1,585 miles and it passes through seven states. The length of interstate in each of the states and the number of sections in each are summarized in Table 11.

Table 9: Interstate 80 segments.

State	Length (Miles)	Sections			
		Name	**Length (Miles)**	**MP**	**Description**
California	199	I-80-CA-1	107	0 to 107	San Francisco Co. to Placer Co.
		I80-CA-2	92	107 to 199	Placer Co. to Nevada border
Nevada	411	I80-NV-1	124	0 to 124	California border to Pershing Co.
		I80-NV-2	88	124 to 212	Pershing Co. to Humboldt Co.
		I80-NV-3	114	212 to 326	Humboldt Co. to Elko Co.
		I80-NV-4	85	326 to 411	Elko Co. to Utah border
Utah	196	I80-UT-1	117	0 to 117	Nevada border to Salt Lake Co.
		I80-UT-2	79	117 to 196	Salt Lake Co. to Wyoming border
Wyoming	403	I80-WY-1	99	0 to 99	Utah border to Sweetwater Co.
		I80-WY-2	91	99 to 190	Sweetwater Co. to Carbon Co.
		I80-WY-3	112	190 to 302	Carbon Co. to Albany Co.
		I80-WY-4	101	302 to 403	Albany Co. to Nebraska border
Nebraska	455	I80-NE-1	108	0 to 108	Wyoming border to Deuel Co.
		I80-NE-2	130	108 to 238	Deuel Co. to Dawson Co.
		I80-NE-3	141	238 to 379	Dawson Co. to Seward Co.
		I80-NE-4	76	379 to 455	Seward Co. to Iowa border
Iowa	303	I80-IA-1	127	0 to 127	Nebraska border to Polk Co.
		I80-IA-2	81	127 to 208	Polk Co. to Iowa Co.
		I80-IA-3	95	208 to 303	Iowa Co. to Illinois border
Illinois	164	I80-IL-1	90	0 to 90	Iowa border to LaSalle Co.
		I80-IL-2	74	90 to 164	LaSalle Co. to Indiana border
Indiana	152	I80-IN-1	88	0 to 88	Illinois border to Elkhart Co.
		I80-IN-2	64	88 to 152	Elkhart Co. to Ohio border
Ohio	237	I80-OH-1	133	0 to 133	Indiana border to Lorain Co.
		I80-OH-2	104	133 to 237	Lorain Co. to Pennsylvania border
Pennsylvania	311	I80-PA-1	81	0 to 81	Ohio border to Jefferson Co.
		I80-PA-2	130	81 to 211	Jefferson Co. to Northumberland Co.
		I80-PA-3	100	211 to 311	Northumb. Co. to New Jersey border
New Jersey	68	I80-NJ-1	68	0 to 68	Pennsylvania border to Bergen Co.

Table 10: Interstate 90 segments.

State	Length (Miles)	Sections			
		Name	Length (Miles)	MP	Description
Washington	297	I90-WA-1	109	0 to 109	King Co. to Kittitas Co.
		I90-WA-2	96	109 to 205	Kittitas Co. to Adams Co.
		I90-WA-3	92	205 to 297	Adams Co. to Idaho border
Idaho	74	I90-ID-1	74	0 to 74	Washington border to Montana
Montana	552	I90-MT-1	132	0 to 132	Idaho border to Missoula Co.
		I90-MT-2	70	132 to 202	Missoula Co. to Deer Lodge Co.
		I90-MT-3	109	202 to 311	Deer Lodge Co. to Gallatin Co.
		I90-MT-4	116	311 to 427	Gallatin Co. to Yellowstone Co.
		I90-MT-5	125	427 to 552	Yellowstone Co. to Wyoming border
Wyoming	209	I90-WY-1	97	0 to 97	Montana border to Campbell Co.
		I90-WY-2	112	97 to 209	Camp. Co. to South Dakota border
South Dakota	413	I90-SD-1	68	0 to 68	Wyoming border to Pennington Co.
		I90-SD-2	125	68 to 193	Pennington Co. to Jones Co.
		I90-SD-3	119	193 to 312	Jones Co. to Davison Co.
		I90-SD-4	101	312 to 413	Davison Co. to Minnesota border
Minnesota	276	I90-MN-1	140	0 to 140	South Dakota border to Freeborn Co.
		I90-MN-2	136	140 to 276	Freeborn Co. to Wisconsin border
Wisconsin	187	I90-WI-1	187	0 to 187	Minnesota border to Illinois border
Illinois	108	I90-IL-1	108	0 to 108	Wisconsin border to Indiana border
Indiana	156	I90-IN-1	156	0 to 156	Illinois border to Ohio border
Ohio	245	I90-OH-1	103	0 to 103	Indiana border to Sandusky Co.
		I90-OH-2	142	103 to 245	Sandusky Co. to Pennsylvania border
Pennsylvania	46	I90-PA-1	46	0 to 46	Ohio border to New York border
New York	385	I90-NY-1	108	0 to 108	Pennsylvania border to Victa
		I90-NY-2	134	108 to 242	Victa to Utica
		I90-NY-3	143	242 to 385	Utica to Massachusetts border
Massachusetts	136	I90-MA-1	136	0 to 136	New York border to Suffolk Co.

Table 11: Interstate 94 segments.

State	Length (Miles)	Sections			
		Name	Length (Miles)	MP	Description
Montana	249	I94-MT-1	119	0 to 119	Yellowstone Co. to Custer Co.
		I94-MT-2	130	119 to 249	Custer Co. to North Dakota border
North Dakota	352	I94-ND-1	128	0 to 128	Montana border to Morton Co.
		I94-ND-2	101	128 to 229	Morton Co. to Stutsman Co.
		I94-ND-3	123	229 to 352	Stutsman Co. to Minnesota border
Minnesota	259	I94-MN-1	115	0 to 115	Minnesota border to Todd Co.
		I94-MN-2	144	115 to 259	Todd Co. to Wisconsin border
Wisconsin	341	I94-WI-1	96	0 to 96	Minnesota border to Jackson Co.
		I94-WI-2	92	96 to 188	Jackson Co. to Sauk Co.
		I94-WI-3	153	188 to 341	Sauk Co. to Illinois border
Illinois	75	I94-IL-1	75	0 to 75	Wisconsin border to Indiana border
Indiana	46	I94-IN-1	46	0 to 46	Illinois border to Michigan border
Michigan	275	I94-MI-1	121	0 to 121	Indiana border to Calhoun Co.
		I94-MI-2	82	121 to 203	Calhoun Co. to Wayne Co.
		I94-MI-3	72	203 to 275	Wayne Co. to Canadian border

2.3.11 Interstate 95

Interstate 95 (I-95) runs along the east coast and serves the area between Florida and New England. It runs through important cities such as Boston, Massachusetts; New York City, New York; Philadelphia, Pennsylvania; Baltimore, Maryland; and Washington DC in the north and Jacksonville and Miami, Florida in the south. I-95 is the longest north south interstate and the sixth longest interstate highway overall and passes through more states than any other interstate (15 states in total). The region served by this interstate has a population density more than three times greater than the US as a whole (US Census 2010). The portion of I-95 in Florida is part of High priority corridor 49: Atlantic Commerce Corridor. Through northern New Jersey, it is part of High Priority Corridor 63: Liberty Corridor. In Connecticut, I-95 is part of High Priority corridor 65: Interstate 95 Connecticut. Finally, a portion of I-95 in Maine is part of High priority corridor 50: East –West corridor from Watertown to Calais. The length of the interstate in all 15 states and the number of sections considered for analysis in those states are summarized in Table 12.

Table 12: Interstate 95 segments.

State	Length (Miles)	Sections			
		Name	Length (Miles)	MP	Description
Florida	382	I95-FL-1	132	0 to 132	Miami-Dade Co. to St. Lucie Co.
		I95-FL-2	131	132 to 263	St. Lucie Co. to Volusia Co.
		I95-FL-3	119	263 to 382	Volusia Co. to Georgia border
Georgia	112	I95-GA-1	112	0 to 112	Florida border to South Car. border
South Carolina	199	I95-SC-1	82	0 to 82	Georgia border to Dorchester Co.
		I95-SC-2	117	82 to 199	Dorchester Co. to North Car. border
North Carolina	182	I95-NC-1	98	0 to 98	South Car. border to Johnston Co.
		I95-NC-2	84	98 to 182	Johnston Co. to Virginia border
Virginia	179	I95-VA-1	98	0 to 98	North Car. border to Hanover Co.
		I95-VA-2	81	98 to 179	Hanover Co. to Maryland border
Maryland, Delaware	110+ 23	I75-MI-1	133	0 to 110, 0 to 23	Virginia border to Penn. border
Pennsylvania	51	I95-PA-1	51	0 to 51	Delaware border to New Jer. border
New Jersey, New York	98+24	I95-NJ-1	122	0 to 98, 0 to 24	Pennsylvania border to Connecticut border
Connecticut	112	I95-CT-1	112	0 to 112	New York border to Rhode I. border
Rhode Island	42	I95-RI-1	42	0 to 42	Connecticut border to Mass. border
Massachusetts, New Hampshire	92+16	I95-MA-1	108	0 to 92, 0 to 16	Rhode I. border to Maine border
Maine	303	I95-ME-1	192	0 to 192	New Hamp. border to Penobscot Co.
		I95-ME-2	111	192 to 303	Penobscot Co. to Canadian border

3.0 SIMULATION PROCESS

3.1 INTRODUCTION

A total of 211 segments were considered for the analysis. For each of these sections, detailed information on the climate, traffic, materials, and structural conditions were obtained from the respective Departments of Transportation. These inputs were then used with the NCHRP 1-37A Mechanistic-Empirical analysis method to predict the performance of the pavement infrastructure under the state of the practice traffic projections. These predicted performance metrics formed the baseline, or control conditions for the current study. Subsequent to these control predictions a second set of predictions were made inclusive of broader economic analysis based freight movement trends. The ratio in performance metrics were then used to identify interstate sections expected to be more sensitive to expected freight trends.

3.2 PAVEMENT PERFORMANCE

When engineers consider pavement performance they generally focus on the overall pavement smoothness as well as the distresses of fatigue cracking, rutting, and thermal cracking. Of these three distresses the first two can be readily associated with load related phenomenon, while the third stems from the pavement response to temperature changes. The process of fatigue cracking occurs through the repeated application of load cycles, which while individually not large enough to cause a structural pavement failure do contribute some incrementally small amount of damage in the pavement system. The distress generally appears first as cracks longitudinal or transverse to the travel direction and isolated to the wheel paths, Figure 6(a). With continued loading these cracks generally coalesce and grow until they reach a regular cracked pattern that resembles the scale pattern of an alligator, Figure 6(b). This pattern leads to the colloquial name for this type of distress: alligator cracking. In most low severity cases fatigue cracking can be mitigated through proper maintenance operations, but if this process does not occur in time then water can infiltrate the pavement system and lead to relatively rapid structural failure.

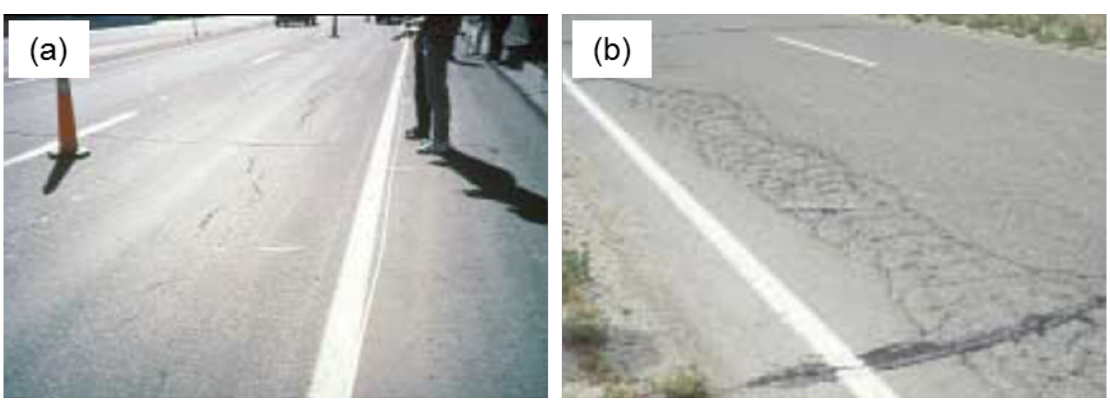


Figure 6: Examples of fatigue cracking in asphalt pavements; (a) low severity and (b) high severity (Miller and Bellinger 2003).

The second load associated distress of principle interest is rutting, which manifest as longitudinal depressions in the pavement surface, Figure 7. Rutting can occur because of extreme deformation in any single pavement layer or due to relatively small accumulation across any of the individual layers. In the case of rutting the major concern is with respect to safety as water can accumulate in these depressions and lead to hydroplaning. In some extreme cases the depressions can be accompanied by large upheavals on either side, which can pose additional safety concerns from lane changes.

Figure 7: Examples of rutting distress in asphalt pavement.

3.3 MECHANISTIC-EMPIRICAL PROCESS

As outlined in the introduction chapter and summarized in Figure 8 below, the NCHRP 1-37A Mechanistic-Empirical analysis method uses a three step approach to predict pavement performance. Step 1 consists of the development of input values for the analysis. During this stage, potential structural options are identified for consideration in Step 2 (analysis). Also in this stage, pavement materials characterization and traffic input data are developed. The enhanced Integrated Climatic Model (EICM), a climatic effects modeling tool, is used to model temperature and moisture within each pavement layer and the sub grade. The climatic model considers hourly climatic data described later on in Section 3.4.2. The pavement layer temperature and moisture predictions from the EICM are calculated hourly over the design period and coupled with secondary effects models to estimate material properties for the foundation and pavement layers as functions of temperature and/or moisture condition. To produce an accurate analysis that considers both daily and monthly variations in temperature, the hourly changes are used to compile five different representative temperature profiles for each month. Subsequent analysis then treats these profiles, referred to as quintiles, as the potential temperature variations for a given month. Step 2 of the design process is the structural/performance analysis. The structural section is analyzed incrementally over time using the pavement response and distress models, and the outputs of the analysis are the accumulated damage and the expected amount of distress and smoothness over time. Step 3 involves the assessment of the structural viability of the pavement based on the damage accumulation and the distress summary of the analysis. In the following paragraphs a brief introduction to the damage and damage modeling process are presented.

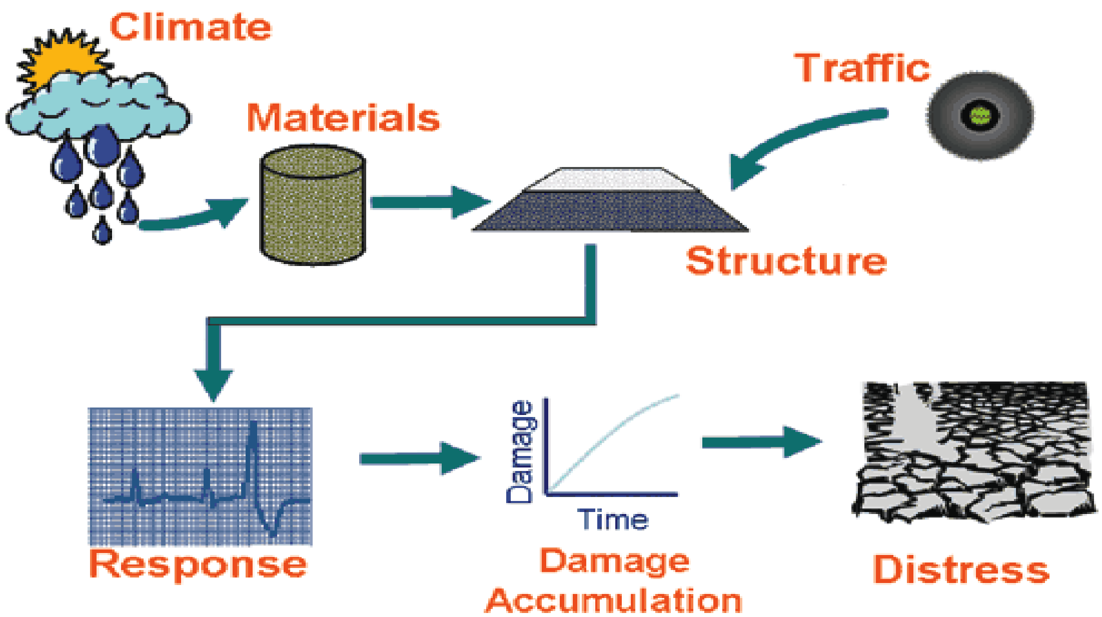


Figure 8: Schematic overview of mechanistic-empirical analysis process.

3.3.1 Pavement Response Modeling

There are many methods that exist for predicting the stress and strains response of flexible pavements to vehicular loading, e.g., layered elastic analysis, layered viscoelastic analysis, elastic and viscoelastic based finite element modeling, etc. Of these, the layered elastic analysis (LEA) technique has been chosen for use in the mechanistic-empirical process because of its overall simplicity, widespread familiarity, general accuracy (if used properly), and (most importantly) computational efficiency. The mathematical details of the LEA process are presented in great detail elsewhere, here the implementation of this method as it relates to the current work are presented.

As the name implies, LEA treats all pavement layers as linear elastic, meaning that the stress and strain are assumed to be perfectly proportional to one another at all levels. This constant of proportionality, the Elastic modulus, forms the primary mechanical property of interest and must be estimated for each and every pavement layer and sub-layer. Other important assumptions in the linear elastic analysis process include:

- The materials are homogeneous and isotropic;
- The applied load has a circular footprint;
- The layers are all perfectly horizontal and extend in infinite directions in the plane perpendicular to the applied load (the x-y plane);
- The mechanical properties are independent of x-y location (but can vary by depth, z);.
- The bottom layer is infinitely thick; and
- All layers/sub-layers are fully bonded.

An important part of any structural analysis process is identifying the important locations where the response should be identified. This facet of structural analysis is also true in the case of pavements, but the process is complicated somewhat because, while the nature of loading is always the same (vertical load to the horizontal pavement surface), the positioning of these loads can change (for example with a single, tandem, tridem, or quad loading axle). The specific implementation of LEA in the mechanistic-empirical analysis used here overcomes this shortcoming by analyzing a pre-determined matrix of x-y locations that allow the results to be generalized to any likely condition. Figure 9 demonstrates the method used, which exploits the linear superposition principle that stems from the use of linear elasticity as the basic mechanical theory in the response modeling.

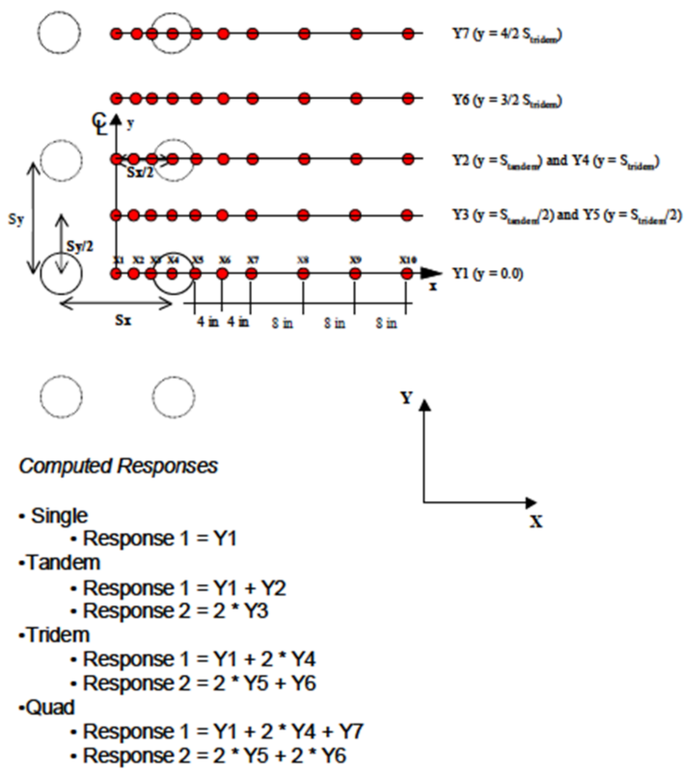


Figure 9: Summary of method used to consider multiple axle configurations in the LEA (ARA 2004).

In addition to coordinates in the x-y plane there are also relevant analysis points at different depths. The depth-wise locations for the response variables are framed with respect to either the fatigue or rutting distresses. In the case of the fatigue cracking phenomenon these depths include the surface of the AC layer, the strain at a depth of 0.5 inches, and at the bottom of the asphalt layer. The first two responses are used to evaluate top-down cracking while the third response is used for the bottom-up cracking prediction. For rutting predictions the relevant strain response depths include the mid-depth of each structural layer/sub-layer, the top of the subgrade, and six inches below the top of the subgrade.

3.3.2 Fatigue Cracking Prediction

Fatigue cracking is predicted based on the cumulative damage concept, e.g., Miner's Law. The damage is calculated as the ratio of predicted number of traffic repetitions to the allowable number of load repetitions (to some failure level) as shown in Equation (1).

$$D = \sum \frac{n_{i,j,k,l,m}}{N_{i,j,k,l,m}} \times 100 \tag{1}$$

Where:

D	=	Cumulative damage;
n	=	Number of load repetitions for condition indicated by subscript combination;
N	=	Number of load repetitions to failure for condition indicated by subscript combination, see Equation (2);
i	=	Month;
j	=	Quintile;
k	=	Axle type;
l	=	Axle load; and
m	=	Traffic path, assuming a normally distributed lateral wheel wander.

The number of load repetitions to failure is estimated using the classic empirical fatigue relationship given by Equation (2). The form of the model is a function of the tensile strain at the bottom of the asphalt pavement layer as well as the modulus of the asphalt layer. This model form is chosen because it directly links with the pavement response model discussed in Section 3.3.1,

$$N_f = Ck_1 \left(\frac{1}{\varepsilon_t}\right)^{k_2} \left(\frac{1}{E}\right)^{k_3} . \tag{2}$$

Where:

N_f	=	Number of repetitions to fatigue cracking;
ε_t	=	Tensile strain at the bottom of the asphalt concrete layer (from the pavement response model);
E	=	Modulus of the asphalt concrete;
k_1,k_2,k_3	=	Calibrated coefficients (0.007566, 3.9492, and 1.281 respectively); and
C	=	Equation (3) with V_a as the air void content and V_b as the asphalt content.

$$C = 10^{4.84\left(\frac{V_b}{V_a + V_b - 0.69}\right)} \tag{3}$$

3.3.3 Rutting Prediction

To predict the cumulative rutting, the permanent deformation in each of the aforementioned sub-layers is first predicted using the model shown in Equation (4) for asphalt concrete and Equation (8) for aggregate base and subgrade. As seen in these equations, the vertical compressive strain from layered elastic analysis is used to link pavement response and pavement performance modeling for the case of rutting. The predicted permanent deformation is converted to rutting depth using the 1-D approximation shown in Equation (15), essentially taking the definition of strain to estimate that the change in geometry is equal to the product of permanent strain and sub-layer depth. Since the subgrade is treated as an infinitely deep layer this expression will not provide a reasonable answer and so an alternative form, shown in Equation (13) is used to estimate the subgrade rutting.

$$\varepsilon_p = \varepsilon_v \left[k_z 10^{K_1} T^{K_2} N^{K_3} \right] \tag{4}$$

$$k_z = \left(C_1 + C_2 z\right) 0.328196^{z} \tag{5}$$

$$C_1 = -0.1039 h_{ac}^2 + 2.4868 h_{ac} - 17.342 \tag{6}$$

$$C_2 = -0.0172 h_{ac}^2 - 1.7331 h_{ac} + 27.428 \tag{7}$$

$$\varepsilon_p = \varepsilon_v \left[\left(\frac{\varepsilon_0}{\varepsilon_r} \right) e^{\left(\frac{\rho}{N}\right)^{\beta}} \right] \beta_{mat} \tag{8}$$

$$\log \beta = -0.61119 - 0.017638 W_c \tag{9}$$

$$\log\left(\frac{\varepsilon_0}{\varepsilon_r} \right) = \frac{\left(0.15 e^{(\rho)^{\beta}}\right) + \left(20 e^{\left(\rho/10^9\right)^{\beta}}\right)}{2} \tag{10}$$

$$\rho = 10^9 \left[\frac{-4.89285}{1-\left(10^9\right)^{\beta}} \right]^{\frac{1}{\beta}} \tag{11}$$

$$W_c = 51.712 \left[\left(\frac{M_r}{2555} \right)^{\frac{1}{0.64}} \right]^{-0.3586 \times GWT^{0.1192}} \tag{12}$$

Where:

ε_p	=	Permanent strain
ε_v	=	Vertical compressive strain at the mid-depth of the given sub-layer (from the pavement response model);
k_z	=	Equation (5);
T	=	Temperature at mid-depth of given sub-layer (°F);
N	=	Number of applied loading cycles;
z	=	Mid-depth at sub-layer of interest (inch);
h_{ac}	=	Overall asphalt pavement thickness (inch);
GWT	=	Depth to water table (feet);
B_{mat}	=	1.673 for aggregate base and 1.35 for subgrade; and

M_r = Soil modulus (psi).

$$RD_{SG} = \int_0^\infty \varepsilon_p(z)\,dz = \frac{1}{k}\varepsilon_{p,z=0} \tag{13}$$

$$k = \frac{1}{6}\ln\left(\frac{\varepsilon_{p,z=0}}{\varepsilon_{p,z=6}}\right) \tag{14}$$

$$RD_{Total} = \sum_{i=1}^{N_{sublayers}} \varepsilon_p^i h^i + RD_{SG} \tag{15}$$

Where:

RD_{SG} = Subgrade rut depth (inch);
$\varepsilon_{p,z=0}$ = Permanent deformation at the top of the subgrade, from Equation (8);
$\varepsilon_{p,z=6}$ = Permanent deformation six inches below the top of the subgrade, from Equation (8);
RD_{Total} = Total pavement rut depth (inch);
$N_{sublayers}$ = Number of sub-layers;
ε_p^i = Total plastic strain in sub-layer i; and
h^i = Thickness of sub-layer i (inch).

The algorithm used to predict rutting over the pavement lifetime is based upon sequential damage accumulation scheme with the amount of accumulated permanent deformation from a given axle load being dependent upon the complete loading history prior to that axle. The process is briefly summarized in Figure 10.

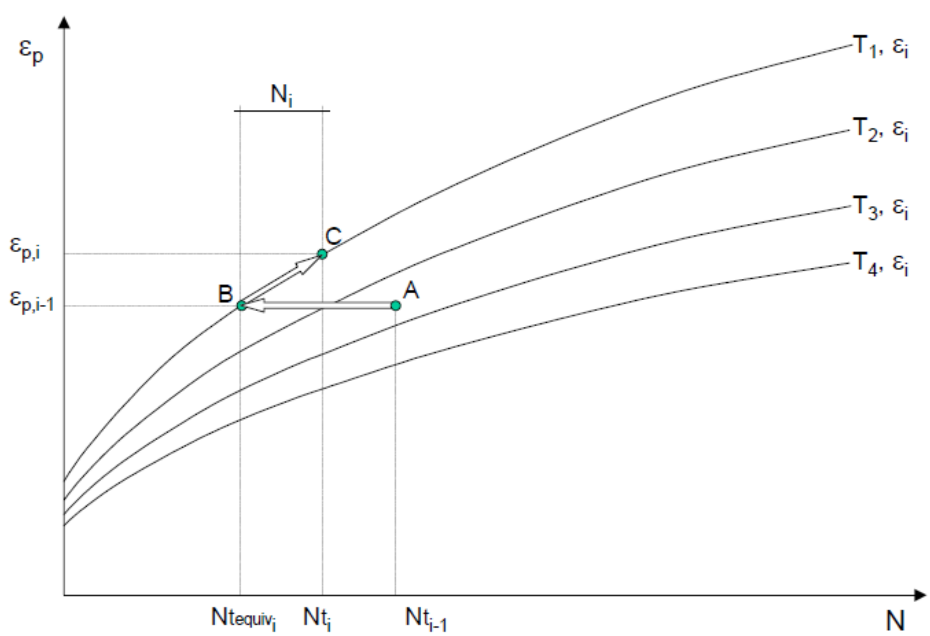


Figure 10: Permanent deformation accumulation.

For the purposes of this figure let $\varepsilon_{p,i\text{-}1}$ represent the permanent strain accumulated in one of the sub-layers at the end of sub-season i-1 (a sub-season here is a combination of month and quintile). Also, let the curve indicated as T_1 represent the value of the permanent deformation function from Equation (4) at the next sub-season, i. Point B is the link between the function that dictated the permanent strain accumulation in sub-season i-1 and the one that will control permanent strain accumulation in sub-season i. Points A and B are at an equivalent permanent strain level because the permanent strain between sub-seasons must be continuous. Finally point C represents the additional increment of permanent strain that would accumulate from the initial loading group in sub-season i. In reality the process is slightly more involved since both the temperature and the applied load level, indicated by the ε_v term in Equation (4), affect the permanent strain accumulation function. In this case careful attention must be given to the order of loading as well as the sub-season.

3.3.4 IRI Prediction

Ride quality is an important measure of functional performance. As shown in Figure 11, it is most often quantified by combining the measured longitudinal pavement profile with a mathematical model that simulates a single wheel on a vehicle, e.g., the International Roughness Index (IRI).

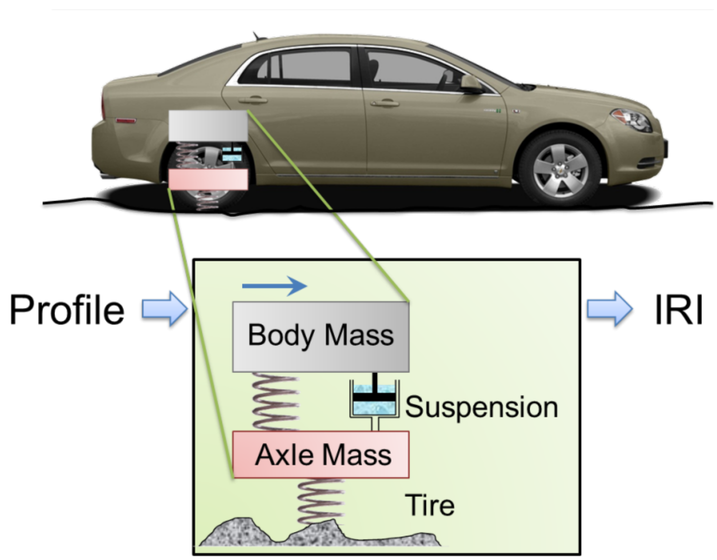


Figure 11: Schematic diagram of IRI parameter.

While the measurement of IRI is fairly straightforward, predicting how it evolves using mechanistic models is not so easy. In the mechanistic-empirical method used for this report, the IRI is estimated over the analysis period by using the distresses (cracking and rutting) predicted from other models. The mathematical model to accomplish this is shown in Equation (16).

$$IRI(t) = IRI_0 + \left(0.4FC + 40RD + 0.008TC + 0.015SF\right) \tag{16}$$

Where:

$IRI(t)$ = Pavement smoothness at a specific time (inch per mile);
IRI_o = Initial smoothness immediately after construction (assumed = 63 in./mi);
FC = Total fatigue cracking (% of lane);
RD = Total pavement rutting (inch);
TC = Total transverse cracking (ft/mi); and
SF = Site factor, Equation (17).

$$SF = Age\left[0.02003\left(PI+1\right)+0.007947\left(Precip+1\right)\right]+0.000636\left(FI+1\right) \tag{17}$$

Where;

Age = Pavement age (year);
PI = Plasticity index of the soil (%);
FI = Average annual freezing index, (°F days); and
$Precip$ = Average annual precipitation, (in.).

3.4 INPUTS

3.4.1 Traffic

For the analysis in this report the initial year traffic volumes, in terms of Average Annual Daily Truck Traffic (AADTT) were obtained from the National Highway Planning Network (FHWA 2015) Traffic was considered using so-called Level 3 analysis, which means that the required input (other than AADTT and traffic growth rates) were obtained from default values provided in the analysis software. These default values were established from a national level analysis of pavement loadings, and since this analysis was national in scope it was decided that such an approach would provide sufficient accuracy to meet the objectives of this study.

Figure 12 shows the map of current traffic in the form of AADTT values for various sections considered. Traffic input values form the basis of this analysis, as level of traffic carried by the section is the predominant factor in determining the various distresses caused and hence the performance of the structure. As expected, the traffic levels are particularly high along;

- Interstates 5, 10, and 15 around Los Angeles, California,
- Interstates 5 and 90 around Seattle, Washington,
- Interstates 35 and 10 around San Antonio, Texas,
- Interstate 10 through Dallas, Texas,
- Interstates 80 and 90 around Chicago, Illinois,
- Interstates 75 and 94 around Detroit, Michigan, and
- Interstate 95 around Miami, Florida and New York City, New York.

It can also be seen from the map that the traffic level is relatively less in the West-North central region and the northern part of the Mountains region.

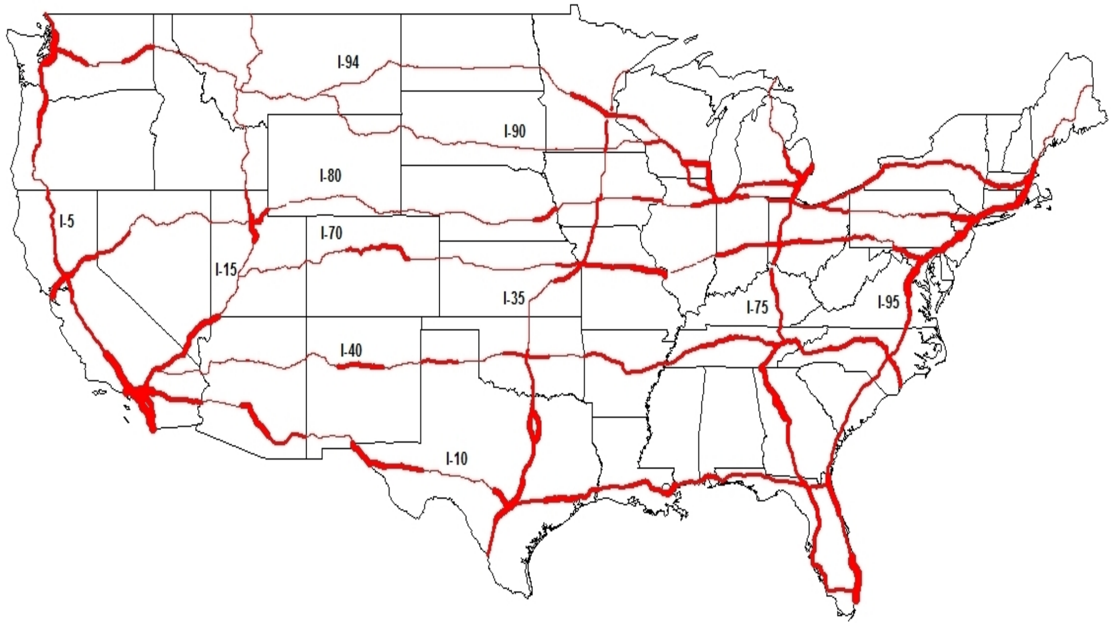


Figure 12: Interstates AADTT map.

Within the default values there are several adjustments that are made to the initial AADTT volumes. The first adjustment is for the vehicle class distribution, which quantifies the percentage of the total AADTT attributed to each class of trucks. By default there are 17 different classifications, referred to as Truck Traffic Classifications or TTC's. These classifications along with the category of roadway that they typically apply to are summarized in Table 13. For the analysis here, TTC 1, which has a predominance of class 9 trucks (74%), has been considered for all cases. The second adjustment factor is the axle load distribution factor, which denotes the percentage of axles of each type (single, tandem, tridem, or quad), month, and vehicle class carrying a given load. It is estimated using Weigh in Motion (WIM) data from various Long Term Pavement Performance (LTPP) sites around the nation. Other traffic factors include corrections for the number of vehicles in the design direction and design lane. These were estimated by considering the pavements to have two lanes in each direction. Hence a directional split of 50 percent and a lane distribution factor of 90% have been used nationally.

Finally each segment was analyzed with respect to the traffic growth values found from the website of each Department of Transportation. These rates are summarized for each analysis section in Appendix B, but in all cases were applied based on compound growth as shown in Equation (18).

$$AADTT_t = AADTT_{BY}\left(1+GR\right)^t \tag{18}$$

Where:

$AADTT_t$	=	AADTT in t years from the base year;
$AADTT_{BY}$	=	AADTT in the base year of analysis;
t	=	Time; and
GR	=	Growth rate as a percentage.

Table 13: Summary of available default TTCs.

TTC	Buses	Multi-Trailer Trucks	General Categories					Description
			I	PA	MA	MjC	MC	
1	(>2%)	(<2%)	X	X				Predominantly single-trailer trucks
2	(>2%)	(<2%)	X	X				Predominantly single-trailer trucks with a low percentage of single-unit trucks
3	(<2%)	(2 - 10%)	X	X				Predominantly single-trailer trucks
4	(>2%)	(<2%)	X	X	X			Predominantly single-trailer trucks with a low to moderate amount of single-unit trucks
5	(<2%)	(>10%)	X					Predominately Single-trailer trucks.
6	(>2%)	(<2%)		X	X	X		Mixed truck traffic with a higher percentage of single-unit trucks
7	(<2%)	(2 - 10%)		X				Mixed truck traffic with a higher percentage of single-trailer trucks
8	(<2%)	(>10%)	X	X	X			High percentage of single-trailer truck with some single-unit trucks.
9	(>2%)	(<2%)		X	X	X	X	Mixed truck traffic with about equal percentages of single-unit and single-trailer trucks
10	(<2%)	(2 - 10%)		X	X			Mixed truck traffic with about equal percentages of single-unit and single-trailer trucks.
11	(<2%)	(>10%)	X	X	X			Mixed truck traffic with a higher percentage of single-trailer trucks
12	(>2%)	(<2%)		X	X	X	X	Mixed truck traffic with a higher percentage of single-unit trucks.
13	(<2%)	(>10%)	X					Mixed truck traffic with about equal percentages of single-unit and single-trailer trucks
14	(>2%)	(<2%)		X		X	X	Predominantly single-unit trucks
15	(<2%)	(2 - 10%)			X	X		Predominantly single-unit trucks.
16	(<2%)	(>10%)		X	X			Predominantly single-unit trucks.
17	(>25%)	(<2%)			X	X	X	Mixed truck traffic with about equal single-unit and single-trailer trucks

[a] I = Interstate, PA = Principle Arterial, MA = Minor Arterial, MjC = Major Collector, MC = Minor Collector

The primary goal of this project is to examine how freight trends are likely to affect the pavement infrastructure and to meet this objective a key component to the work was estimating the impacts of these trends on actual AADTT growth over a typical design period of 20 years. Such a projection is a complex process that includes various factors from the population growth of the individual regions, the predicted inter- and intra-regional economic and employment growth rate, the nation's overall growth rate, and international trade occurring between nations. These types of analysis are typically done on a highly localized scale (Wittwer et al. 2005, Stone et al. 2006, Jones 2007, BITRE 2012, Wheeler et al. 2011), but one such study has examined these trends nationally and the outcomes were used extensively in this work.

The projected freight trends were developed by IHS Global Insight for the American Trucking Association (Costello 2014). The methodology adopted used a bottom-up prediction method that first examined the economic forecast of the nation and states (in terms of GDP), growth in job generation and the growth in the six key drivers of freight movement; manufacturing, mining, non-oil merchandise and merchandise import and export, construction, and farm marketing. The economic assessment as a whole examined the movement of goods and services by rail, roadway, water, air, and pipeline, but the results of primary interest here are the roadway projections. The data gathered for this forecast included industry and government freight data as well as IHS Global's own data on industries and commodities. It should be noted that due to the high fluctuations in the factors governing the economic forecasts, partially accurate predictions can be made for only a period of ten years. In this work it is assumed that these same projections hold for 20 years.

For these freight projections the country is divided into nine regions by grouping together adjacent states. For each region a cumulative projected growth has been estimated. The regions and cumulative rate are summarized in Figure 13 below. This aggregated projection alone is insufficient to project individual interstate traffic trends and so an analysis technique was devised assuming self-similar growth across all sections within a given region. First, the DOT estimated growth rates for the interstates comprising each region were compiled. Then, the growth rates on each section were cumulated by taking the averaging growth rate, $GR_{DOT,i}$, weighted by the base year AADTT of the section, Equation (19). In this equation the subscript i refers to the section and the subscript j indicates that this process was carried out on a regional basis. The third step equated this weighted average to an equivalent overall regional-wise growth rate, $GR_{DOT\,avg,j}$, as shown in Equation (20).

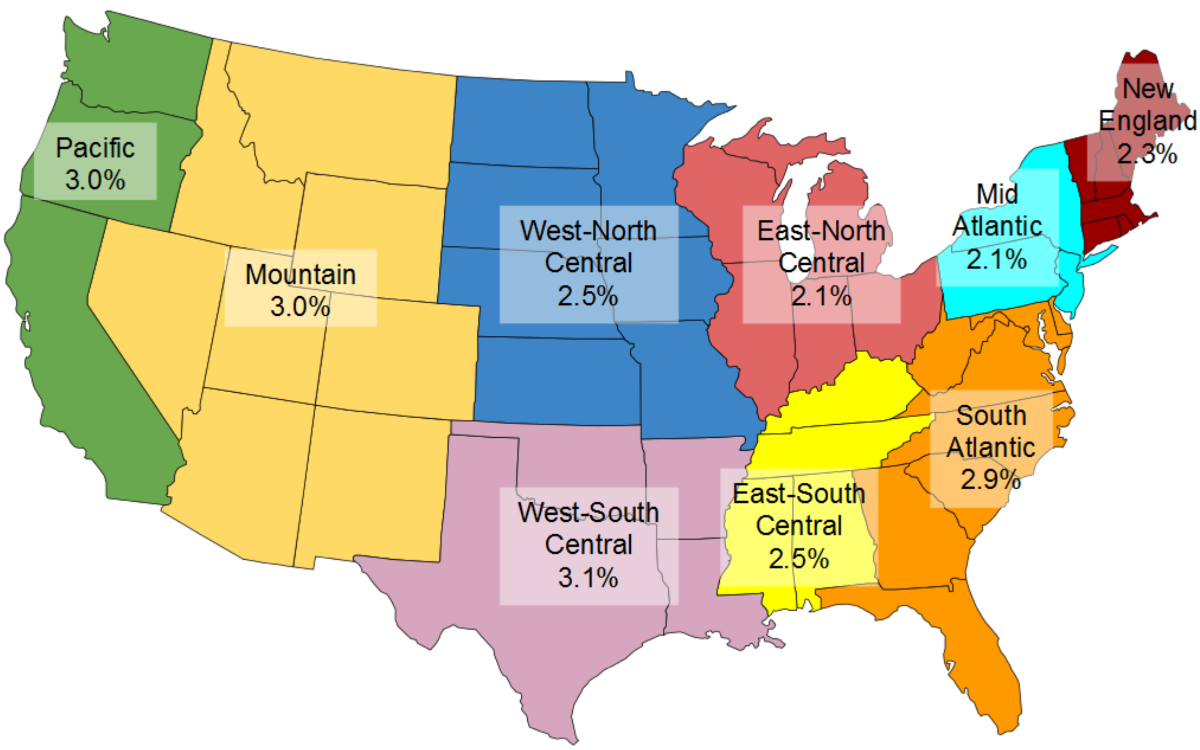


Figure 13: Regional divisions for freight projects and IHS Global projections.

The outcome of these three steps was a current projected average growth rate for each region, which are summarized in Figure 14. Comparing this figure to Figure 13 it can be seen than overall national trends suggest larger movements that currently accounted for in most regions with the exception of New England and West-South Central.

$$\overline{y}_{DOT,j} = \sum_{i=1}^{N} AADTT_{ij}\left(1+\frac{GR_{DOT,ij}}{100}\right) \tag{19}$$

$$GR_{DOT\ avg,j} = \left(\frac{\overline{y}_{DOT,j}}{\sum_{i=1}^{N} AADTT_{ij}} - 1\right)\times 100 \tag{20}$$

To complete the sectional growth rate projections, it was assumed that the IHS Global projections for freight movement would occur across the individual sections in the same proportion that currently exists, e.g., self-similar growth. In this case the ratio of DOT growth rates, denoted as x_{ij} as it is calculated by section and region, Equation (21), was maintained. This ratio was then assumed to hold for the freight projections and used to cast all growth rates, $GR_{Proj,i}$, with respect to an estimated maximum projected growth rate, Equation (22). Thus, estimating the individual section growth rates simplifies to finding only the single maximum projected growth rate. Since the analysis assumes self-similar growth this will be the same section that showed the highest DOT based growth rate.

$$x_{ij} = \frac{GR_{DOT,ij}}{\max\left(GR_{DOT,i}\right)} \tag{21}$$

$$GR_{Proj,ij} = \left(\max\left(GR_{Proj,i}\right)_j\right)\times x_{ij} \tag{22}$$

To estimate the maximum growth rate, the same weighted average calculation procedure used to estimate the DOT based regional average growth rate was applied. Substituting Equation (22) into the basic form of Equation (19) and noting that these calculations are now being performed for projected rates leads to;

$$\overline{y}_{Proj,j} = \sum_{i=1}^{N} AADTT_{ij}\left(1 + x_{ij}\frac{\left(\max\left(GR_{Proj,i}\right)_j\right)}{100}\right). \tag{23}$$

Then following the same principle used with respect to Equation (20), the individual segment growth rates were related to the projected regional average growth rate via

$$GR_{Proj\,avg,j} = \left(\frac{\bar{y}_{Proj,j}}{\sum_{i=1}^{N} AADTT_i} - 1 \right) \times 100 = \left(\frac{\sum_{i=1}^{N} \left(AADTT_{ij} \times x_{ij} \right)}{\sum_{i=1}^{N} AADTT_{ij}} \left(1 + x_{ij} \frac{\left(\max\left(GR_{Proj,i} \right) \right)}{100} \right) \right) \times 100 \quad (24)$$

In this equation, $GR_{Proj\ avg,j}$ was known from the IHS Global estimates and thus the equality could be solved to identify the max($GR_{Proj,i}$) value. Subsequently each section growth rate could be estimated by Equation (22).

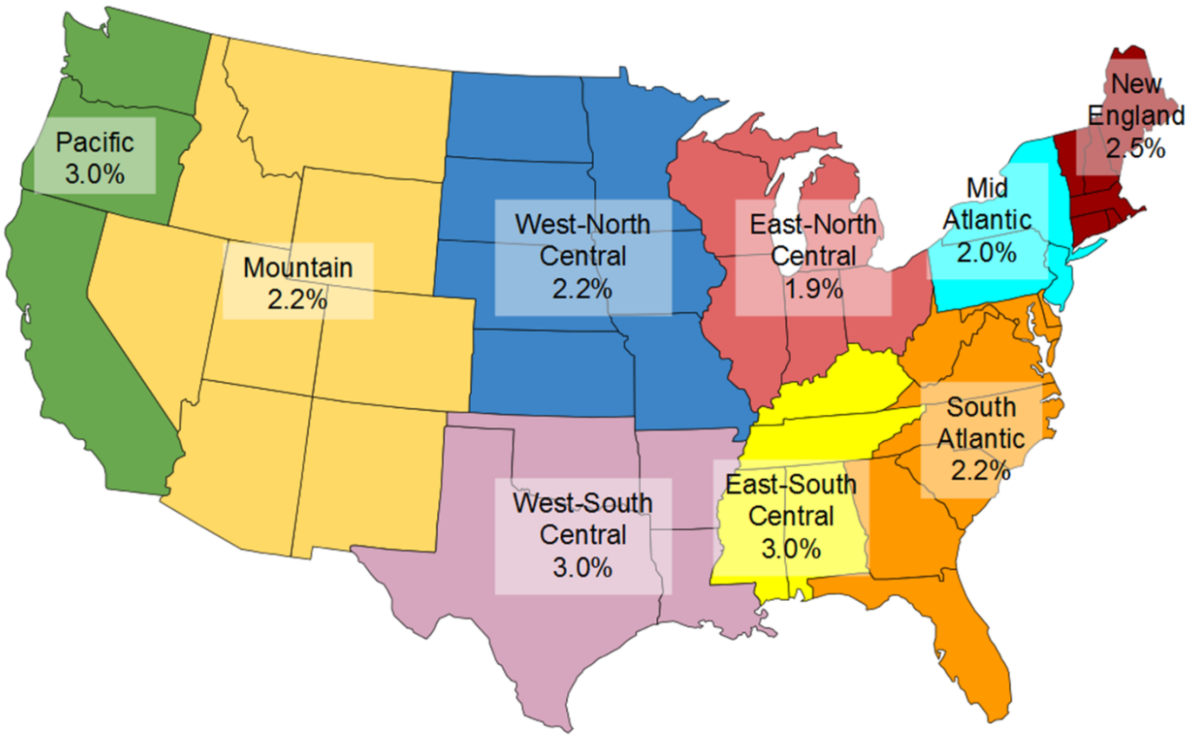


Figure 14: Estimated regional growth rates from DOT projections.

Figure 15 represents the ratio of $GR_{DOT,ij}$ to $GR_{Proj,ij}$ in proportion to the thickness of the plotted line. The map is useful to identify those segments that, based on traffic growth alone, might be likely to experience higher detrimental effects due to high traffic growth in future. The analysis showed some obvious differences in the growth rate of some of the states. It can be seen from the map that the ratio is high for South Atlantic states followed by Mountain states and West-North Central states.

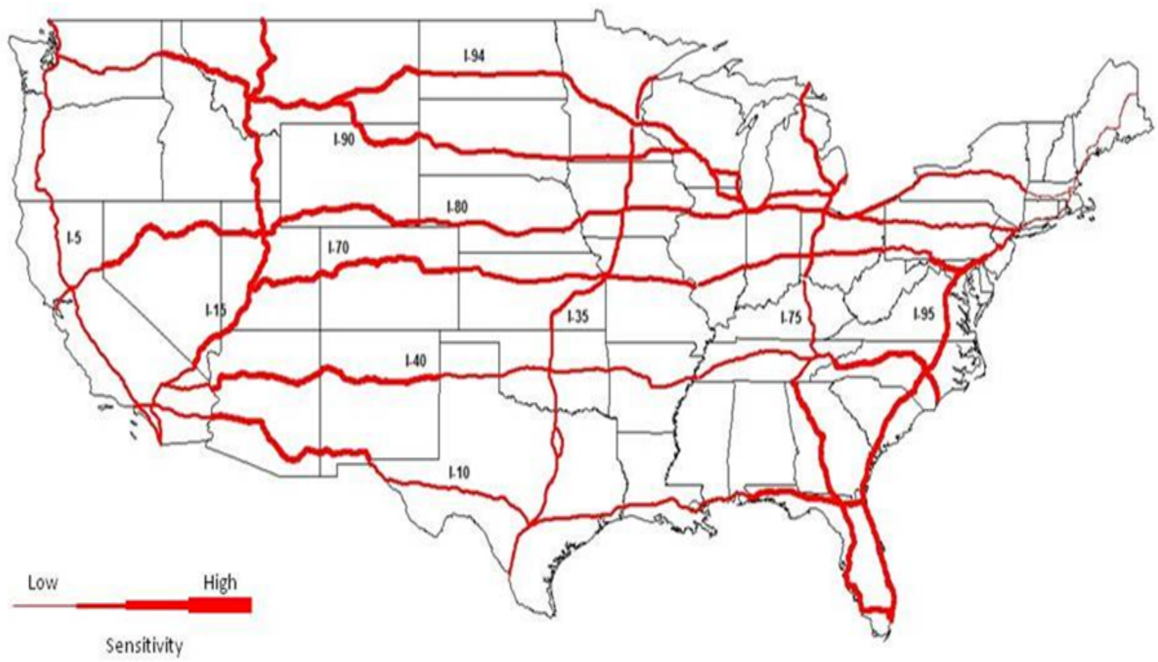


Figure 15: Traffic growth map.

3.4.2 Climate

The local climate affects the material properties by dictating both the pavement temperature and the sub-surface moisture conditions. The relevant parameters include hourly temperature, daily precipitation, average amount of sunshine, wind speed, and latitude and longitude. As demonstrated schematically in Figure 16 each of these variables make contributions to heat and moisture flow in the pavement system. For example, the wind speed contributes to the convection process. As shown in Figure 16 the weather stations used to collect these data were distributed across the United States and provided pre-formatted files that contained a minimum of five years historical data. For each pavement section the weather stations closest to the project were selected. In the case of sections without a close weather station, the closest available stations were chosen and the data interpolated to represent the climate along the entire section length. This approach was deemed acceptable based on the fact that climate was a determining factor in the segmentation process. Appendix C summarizes the relevant weather stations for each section.

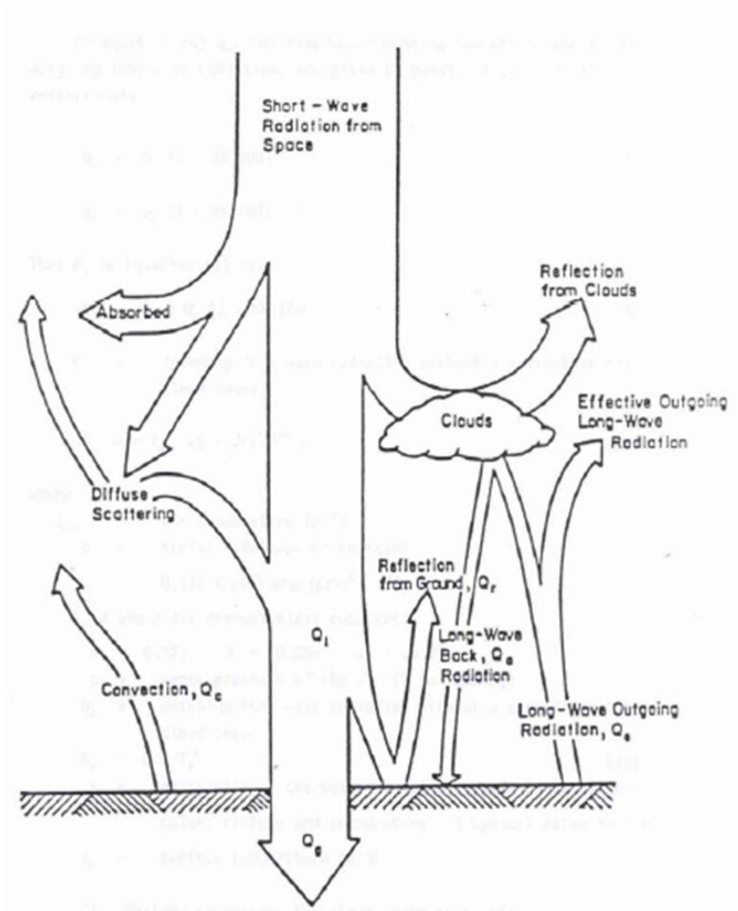


Figure 16: Relevant energy movements in process of heat transfer in pavement system (Lytton et al. 1990).

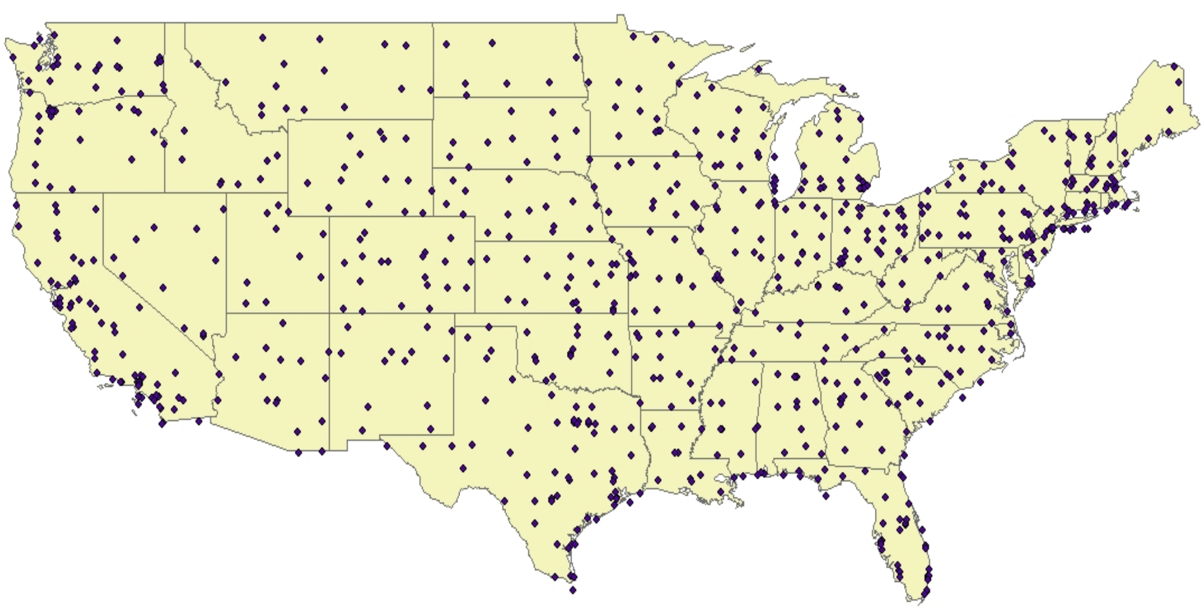


Figure 17: Weather stations across the US.

3.4.3 Materials

The key material properties used for pavement analysis are the moduli values of each paving layer. The moduli values relate stress and strain and are necessary to perform the layered elastic analysis, which as discussed below provides the response variables for performance predictions. In the case of the asphalt concrete the relevant modulus is the temperature and frequency dependent dynamic modulus. For the purposes of this analysis the dynamic modulus was estimated using the Witczak predictive model shown in Equation (25).

$$\log|E^*| = -1.249937 + 0.02923\rho_{200} - 0.001767(\rho_{200})^2 - 0.002841\rho_4 - 0.05809V_a - 0.082208\frac{V_{beff}}{V_{beff}+V_a} + \frac{3.871977 - 0.0021\rho_4 + 0.003958\rho_{3/8} - 0.000017(\rho_{3/8})^2 + 0.00547\rho_{3/4}}{1+e^{(-0.603313-0.313351\log f - 0.393532\log h)}} \tag{25}$$

Where:

ρ_{200}	=	Percentage of aggregate passing #200 sieve;
ρ_4	=	Percentage of aggregate retained in #4 sieve;
$\rho_{3/8}$	=	Percentage of aggregate retained in 3/8 - inch sieve;
$\rho_{3/4}$	=	Percentage of aggregate retained in ¾ - inch sieve;
V_a	=	Percentage of air voids (by volume of mix);
V_{beff}	=	Percentage of effective asphalt content (by volume of mix);
f	=	Loading frequency (Hz); and
η	=	Binder viscosity at temperature of interest (10^6 P).

As shown in this equation the relevant material properties include gradation parameters, binder viscosity, and volumetric properties. The asphalt cement viscosity was estimated from the correlation between viscosity and specification grade of the asphalt binder. The required specification grade of the asphalt used in the pavement was obtained from either the state department of transportation or from the known climatic conditions at the site. The chosen grade is shown in the tables in Appendix D for each segment.

For unbound layers the elastic modulus at the optimum moisture content is first entered and then adjusted internally for the effects of moisture content changes over time. For sections with an aggregate base layer, the initial elastic modulus and Poisson's ratio were taken from the default model inputs for crushed stone as 30,000 psi and 0.35 respectively. In the case of the subgrade a two-step process was adopted. First, the extensive mapping effort completed under the NCHRP 9-23B project was used to determine the representative AASHTO classification for each analysis segment. The soils are denoted as A1, A2, A3, A4, A5, A6, or A7. These data which were earlier collected for the segmentation process was used here as the subgrade input for the MEPDG analysis. In the Level 3 analysis of MEPDG, the data required in the case of subgrade are the modulus, Poisson's ratio, and the coefficient of lateral pressure, k_o. The modulus values were taken to be the default MEPDG values for the corresponding AASHTO class of the soil (see Table 14), the Poisson's ratio was taken as 0.35, and k_o was taken as 0.5. Other required material parameters included the thermal conductivity and heat capacity of the asphalt as well as the gradation, soil water characteristic curve parameters, and Atterberg limits of the unbound layers. The pre-programmed default values were used for all of these parameters.

Table 14: Soil resilient modulus values entered for analysis.

Material Classification	M_r (psi)	Material Classification	M_r (psi)	Material Classification	M_r (psi)
A-1-a	29,500	A-2-6	20,500	A-5	15,500
A-1-b	26,500	A-2-7	16,500	A-6	14,500
A-2-4	21,500	A-3	24,500	A-7-5	13,000
A-2-5	21,000	A-4	16,500	A-7-6	11,500

3.4.4 Structure

After the traffic, climate and materials input, the pavement structure is the fourth and final major input factor. This input requires knowledge of the thickness and layer types used on each interstate. These details were obtained through direct communication and internet surveys of each of the applicable state departments of transportation. In some cases structure details were unavailable and so they were assumed based on the structures from the adjacent and/or close by states. For example the pavement structure details of the state of Virginia have been assumed from the structure details of North Carolina. The details of each section are summarized in Appendix E, where it can be seen that the majority of sections in this analysis had structures that consisted of an asphalt concrete layer, a granular base layer with crushed stone material, and the sub grade.

3.5 OUTPUT

The results from the mechanistic-empirical analysis are summarized in an output file that lists the average predicted distresses along with the reliability estimate of these distresses. An example output summary from the analysis of segment I94-MT-2 is shown in the table and figures below.

Table 15: Distress output summary.

Distress	Distress Predicted	Reliability Predicted
Terminal IRI (in/mi)	119.2	94.81
Alligator Cracking (%)	0.2	99.99
Permanent Deformation (in)	0.46	99.95

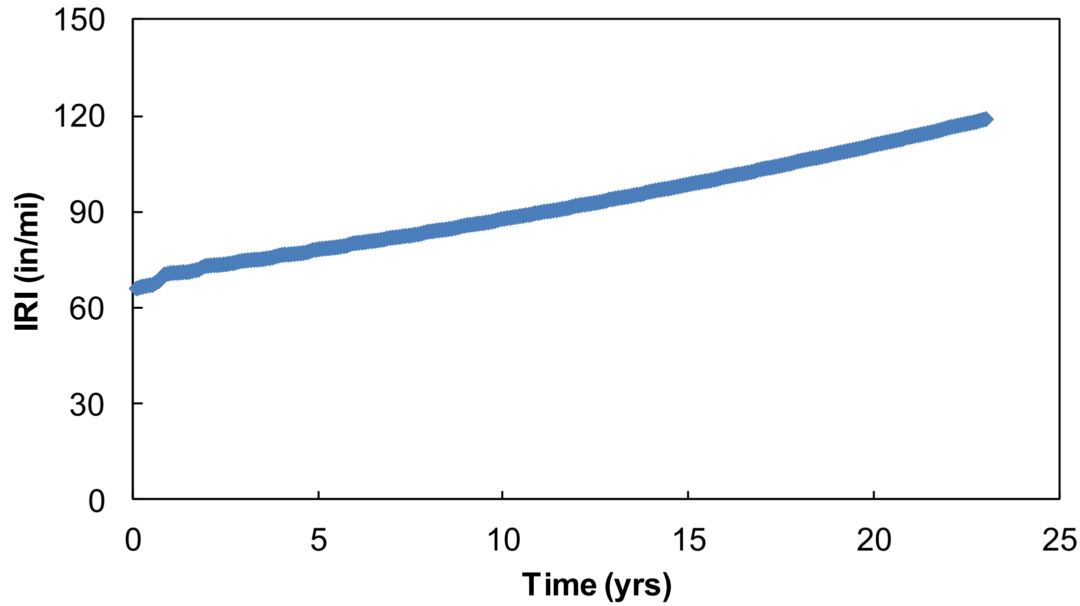


Figure 18: Example IRI results from MEPDG analysis.

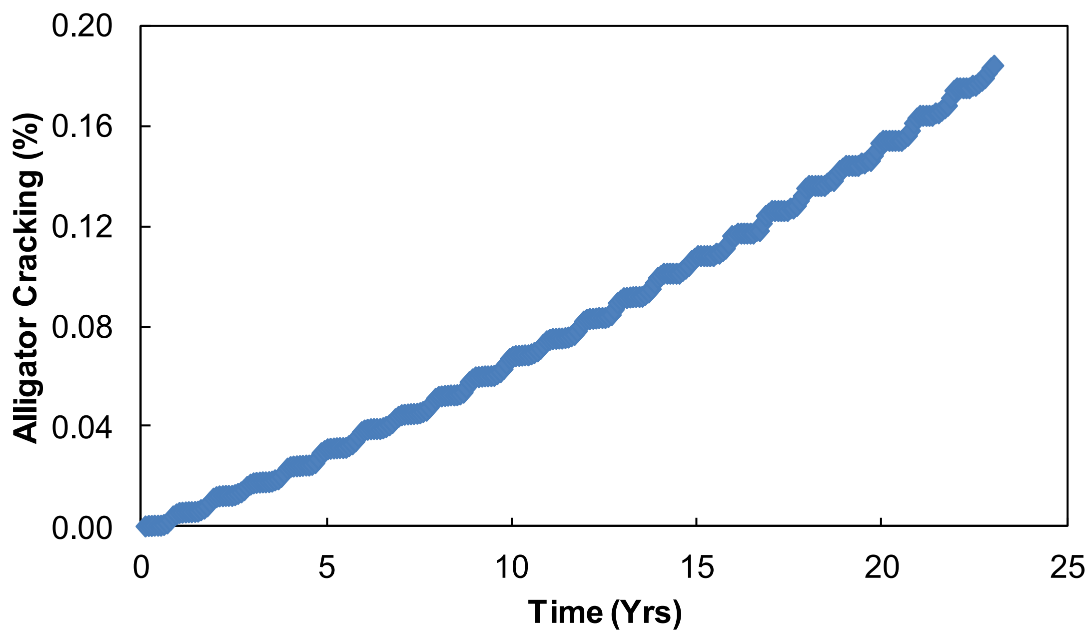


Figure 19: Example alligator cracking results from MEPDG analysis.

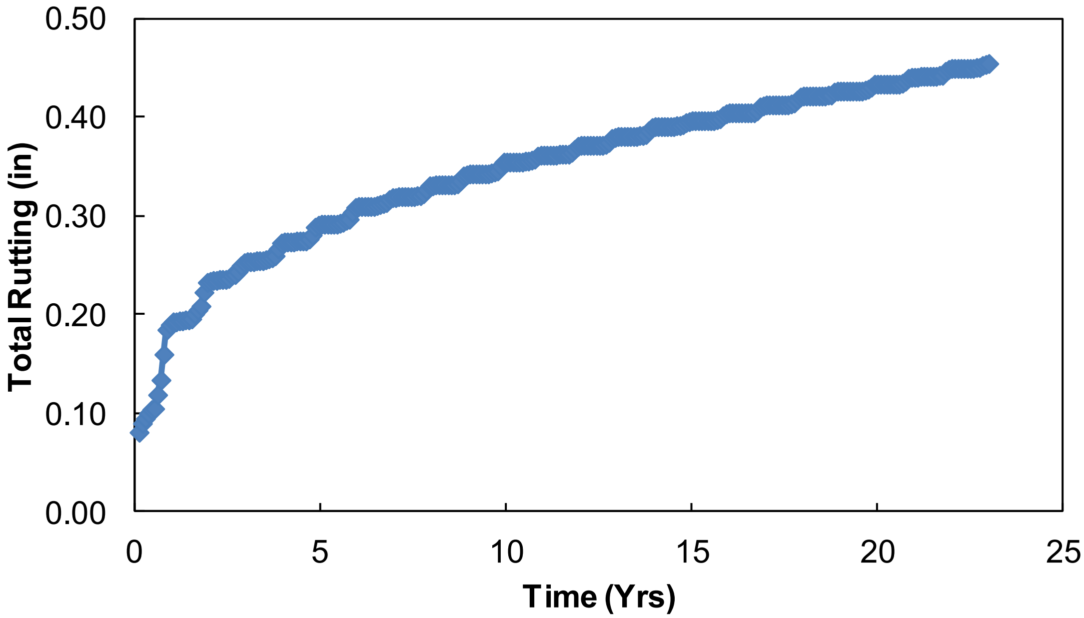


Figure 20: Example rutting results from MEPDG analysis.

4.0 RESULTS

This chapter summarizes the resultant differences in distresses (IRI, rutting, and fatigue cracking) obtained from Mechanistic-Empirical simulations. The results are shown as a series of GIS maps. All the maps represent the 11 major interstates considered for analysis. In each case the distress values are separated into four classes based on the ratio of distress calculated from the DOT based traffic projections and those calculated from the IHS Global derived traffic projections. The classes chosen represent low, medium, high, and very high sensitivity to changes in freight growth projections. The values of these ratios are denoted in the maps by varying the thickness of the line. A thicker line segment denotes a very high value of sensitivity. The results thus obtained are discussed below.

4.1 DISTRESS RESULTS

The distresses map of the US interstates with respect to predicted IRI is shown in Figure 21. The analysis of segments shows a higher value of IRI for segments of Interstate 10 and 15 through Mountain states, the segment of Interstate 90 around Billings, Montana, Interstate 95 in Florida, segments near the I-95 and I-40 interchanges in North Carolina, and segments of Interstate 80 and 90 around Chicago. For the most part these areas correspond to those where the change in growth rate were apparent.

The distress map of US interstates with respect to Fatigue is shown in Figure 22. As the fatigue cracking is directly related to the amount of load carried by the pavement, high fatigue cracking is exhibited by those segments with both a discrepancy in growth rate and that have high baseline traffic levels. Of particular note are the East-West interstates through the Mountains region and the North-South interstates along the South-Atlantic states. The distress map with respect to rutting is shown in Figure 23. Overall the results parallel those of the fatigue except that there is a more consistent level of sensitivity along the whole of the interstate. I-70 for example, shows a different level of sensitivity to fatigue cracking in Colorado and Kansas. However, their sensitivities to rutting in these two states is similar. High rutting sensitivity is also identified in the state of Arizona in the Phoenix-Tucson corridor and the I-75/I-40 interchange area in Knoxville, Tennessee.

Apart from the individual distresses, a cumulative distress index, shown in Equation (26), was also compiled. Figure 24 shows the cumulative distress value in all the interstate segments.

$$R(CD) = R(IRI) + R(Fatigue) + R(Rutting) \tag{26}$$

Where:

$R(CD)$ = Ratio of cumulative distress;
$R(IRI)$ = Ratio of IRI;
$R(Fatigue)$ = Ratio of fatigue cracking; and
$R(Rutting)$ = Ratio of rutting.

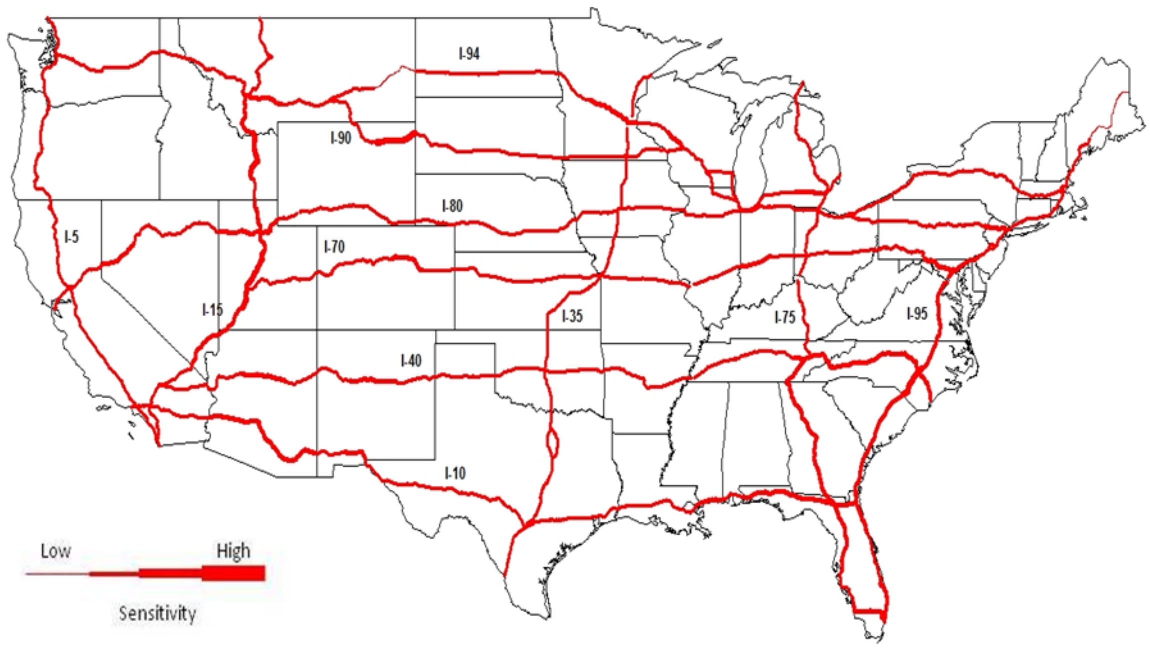


Figure 21: Interstates IRI map.

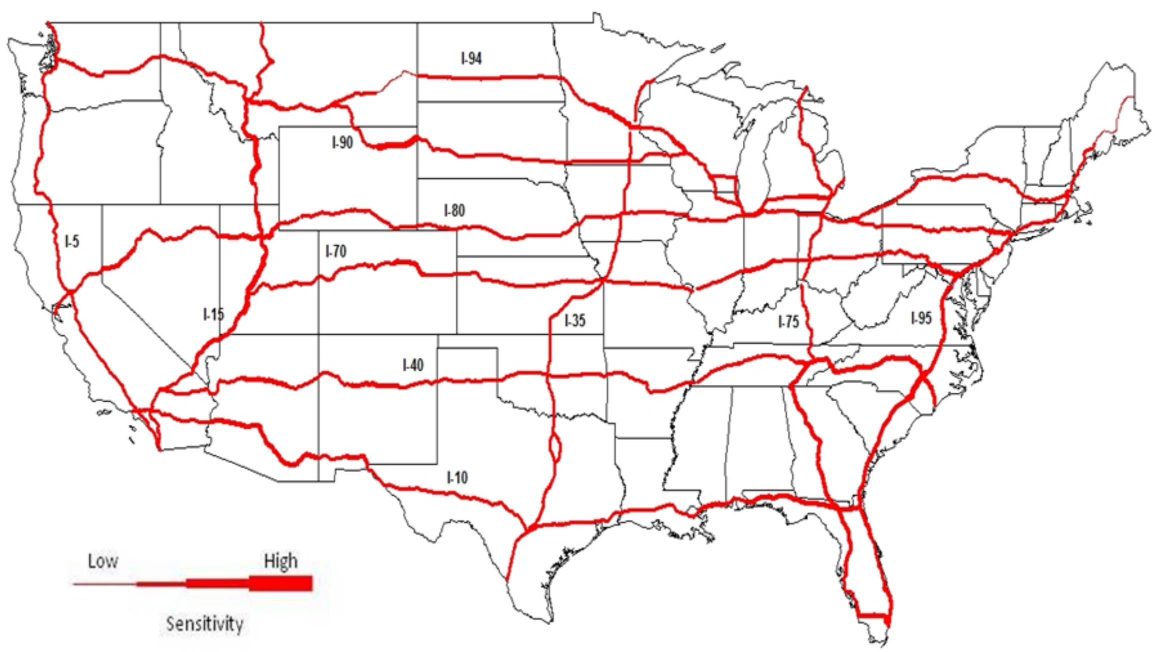


Figure 22: Interstates fatigue map.

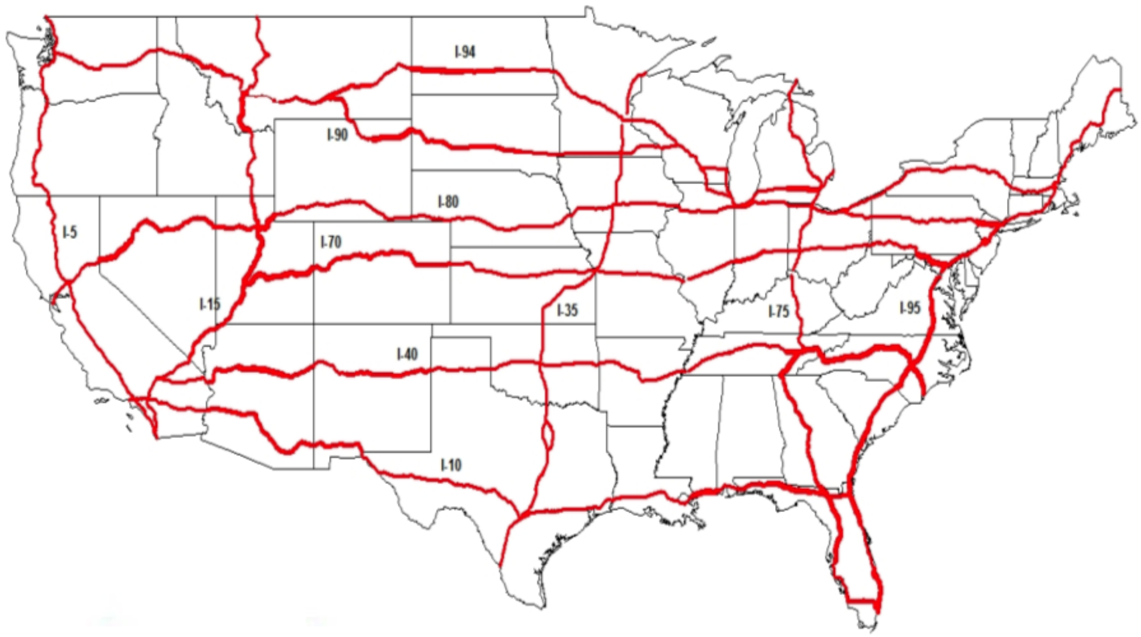


Figure 23: Interstates rutting map.

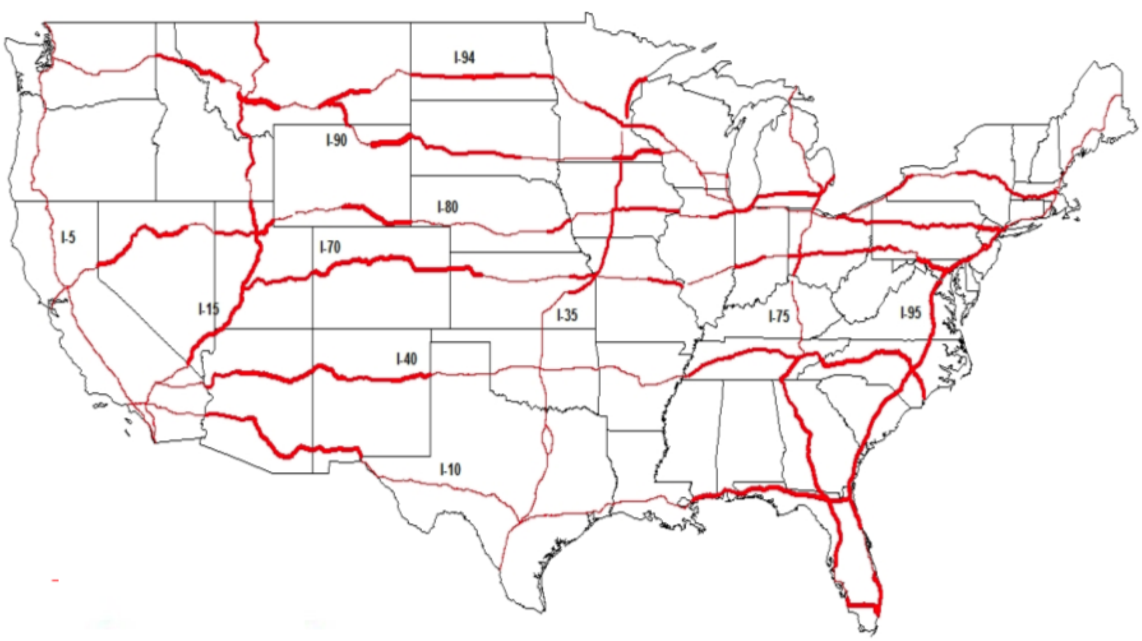


Figure 24: Interstates cumulative distress map.

4.2 DISCUSSION OF RESULTS

It can be seen from the cumulative distress map that it reflects a combination of the baseline traffic levels and the projected traffic levels. The distress values identified in the higher growth ratio states are also high. The distress values are high in the segments of Interstates 75 and 95 in the South Atlantic region states. The two main reasons are the current high level of traffic carried by these segments and the high projected growth rate for the states. Segments of Interstates 10, 15, 40, 70 and 90 in the Mountain states also exhibit predominantly high value of distress ratios. It has to be noted that apart from the high predicted growth rate, the segments in mountain states carry goods from the California ports eastward to the rest of the country. Likewise these regions are subjected to more extreme temperature changes, which all other factors equal would add more sensitivity to any changes in traffic. The average distress ratios for most of the other states are close to one, suggesting that their combination of relatively mild climate, generally consistent freight growth, and designs that appropriately account for the existing baseline traffic have created sufficiently resistant pavement infrastructure. Comparing these maps with those shown in Figure 1 provides a whole new perspective on the impacts of future freight growth. With respect to congestion the areas in the North-East and along the Pacific coast are expected to show significant impacts. However, in terms of pavement performance it is the areas in the middle portion of the country and in the South-Atlantic that may be least prepared, and thus more economically impacted, by the future freight trends. The two most critical corridors appear to be the southern and middle reaches of the I-95 corridor and the I-15 corridor through Utah, which may be doubly impacted by both congestion and an excessively costly pavement infrastructure.

5.0 CHALLENGES, CONCLUSIONS, AND FUTURE RESEARCH

This report analyzes a substantial portion of the interstate system in the United States to evaluate the impact of projected freight trends on the pavement infrastructure. During the course of the research some major challenges were encountered and some simplifications and assumptions were necessary in order to complete the analysis in as meaningful a way as possible. The first challenge for this report was gathering the input data. The pavement simulation tools require a substantial amount of detailed information, which is gathered to a different level of accuracy by different state agencies. Pavement structure characteristics such as layer type and thickness, gradation parameters, binder viscosity, and volumetric properties are not available on a mileage basis for many of the state departments of transportations. Availability of input data on a mileage basis would improve the accuracy of this research.

The report has been developed with Level 3 input values in the analysis software. There have also been discrepancies with respect to the local calibration factors. While some of the states have their own calibration factors, the other states are in the process of developing their calibration factors. National calibration factors with Level 3 inputs have been used in this report. Errors with this approach were accounted for by examining the relative change in performance instead of the predicted performance directly. Future research could be carried on with the identified sections for various distresses, using the locally available calibration and possibly a Level 1 input that could accurately predict the distress values in each of the segments.

Though a weather station can be selected near the analysis section under consideration, some of the weather stations have some missing data. In that case another climatic station, which is close to analysis segment, is used for interpolation. In some cases, e.g., the I10-AZ-3 in Arizona, Tucson is the nearest climatic station available, but Tucson has missing climatic data and hence the data of nearby stations are also taken. Such interpolation of climatic data over a long distance may lead to differences in the segment under analysis.

Interstate segments were also constructed using the rigid and composite pavements, which were not considered here in this analysis. The pavement structure and the materials were taken to be the state suggested or the default MEPDG values, which were considered uniformly throughout the state.

Freight traffic has been predicted for 2035 in this report. Most of the literature on economic and freight prediction does not normally extend more than 10 years because of the uncertainties in such long-term projections. For example, in the freight prediction surveys for 2015 carried out in 2005, the recession which affected the global markets in 2009 (an extreme case) was not predicted. In this report, the freight traffic growth rate predicted by the American Trucking Association for 2025 has been used with corrections for 2035. Though a lot of factors (global economy, population and employment growth rate, growth rate of ports among others) have been considered for analysis, there may be fluctuation in the predicted future truck traffic.

Despite these challenges, the results provide a different, and (in the authors opinions) important perspective concerning the impacts of freight movement along United States highways. The various traffic and the distress maps generated provide a bird's eye view of corridors and states that may be most affected. It also provides an initial look that may be useful for the planning programs of the various state and the national agencies, specifically towards a more efficient pavement preservation program. The primary conclusion from this research is that pavement impacts from freight projections do not mirror congestion impacts. In fact, it is found that corridors, which are not congested, but instead feed into congested areas, are more prone to pavement impacts. Whether this correlation is due to specific design and engineering practices inherent with areas not experiencing congestion or was due to secondary factors (climate for example) was not discovered. More importantly, this research provides a first glimpse of a component of the freight question that heretofore has not been examined at a gross national level. There are many important secondary questions to answer, particularly with respect to the economic and environmental cost of these sensitivities.

6.0 REFERENCES

Alam, M., Fekpe, E., and Mohammed, M. (2007) *FAF*^{2} *freight traffic analysis*, Report Number S7, Federal Highway Administration: Office of Operations.

American Association of State Highway Transportation Officials (AASHTO). (2007) America's freight challenge. [Online] Available from <ftp://ftp.mdt.mt.gov/research/library/TIF3-1-FREIGHT_CHALLENGE-AASHTO.PDF>. [Accessed April 2015].

Applied Research Associates (ARA). (2004) Guide for Mechanistic-Empirical design of new and reconstructed flexible pavements: Part 3 Design Analysis. Final Report. *National Cooperative Highway Research Program.* Transportation Research Board, National Research Council, Washington, D.C.

Blanchard, O.J. and Leigh, D. (2013) Growth forecast errors and fiscal multipliers. NBER Working Paper No. 18779. *National Bureau of Economic Research*.

Bureau of Infrastructure, Transport, and Regional Economics (BITRE). (2012) *Traffic growth: modeling a global phenomenon*. Report 128, Department of Infrastructure and Transport, Canberra AU.

Costello, B. (2014) US freight transportation forecast to 2025. *American Trucking Association*.

Facanha, C. and Horvath, A. (2007) Evaluation of life-cycle air emission factors of freight transportation. *Environmental Science & Technology* 41(20), pp.7138-7144.

Federal Highway Administration (FHWA). (2013) Freight facts and figures 2013. [Online] Available from: <http://ops.fhwa.dot.gov/Freight/freight_analysis/nat_freight_stats/docs/13facts figures/index.htm>. [Accessed December 2014].

Gillespie, T.D. and Karamihas, S.M. (1994) Heavy truck properties significant to pavement damage. ASTM Special Technical Publication, 1225, pp. 52-62.

Hensher, D.A. and Puckett, S.M. (2005) Refocusing the modeling of freight distribution: Development of an economic-based framework to evaluate supply chain behavior in response to congestion charging. *Transportation* 32(6), pp. 573-602.

Jones, C. (2007) Perspective on freight congestion. *Public Roads* 71(1). Available from < http://www.fhwa.dot.gov/publications/publicroads/07july/06.cfm>. [Accessed October 2014].

Kveiborg, O. and Fosgerau, M. (2007) Decomposing the decoupling of Danish road freight traffic growth and economic growth. *Transport policy* 14(1), pp. 39-48.

Li, Q. Xiao, D.X., Wang, K.C., Hall, K.D. and Qiu, Y. (2011) Mechanistic-Empirical Pavement Design Guide (MEPDG): a bird's-eye view. *Journal of Modern Transportation* 19(2), pp. 114-133.

Lytton, R.L., Pufahl, D.E., Michalak, C.H., Liang, H.S., and Dempsey, B.J. (1993) An integrated model of the climatic effects on pavement. Final Report: FHWA-RD-90-033). *Federal Highway Administration*.

Mani, A. and Prozzi, J. (2004) State-of-the practice in freight data: a review of available freight data in the U.S (No. 0-4713-P2). *Center for Transportation Research*, The University of Texas at Austin.

McKinnon, A. (1999) The effect of traffic congestion on the efficiency of logistical operations. *International Journal of Logistics: Research and Applications* 2(2), pp. 111-128.

Miller, J.S., and Bellinger, W.Y. (2003) Distress identification manual for the long term pavement performance program. Report: FHWA-RD-03-031. *Federal Highway Administration*. Washington, DC.

Moving Ahead for Progress in the 21st Century Act (MAP 21). (2012) Public Law 112-141, Title I Federal-Aid Highways, Subtitles A, B, D, and F.

NCDC. (2010) NOAA's 1981-2010 climate normals. [Online] Available from <http://www.ncdc.noaa.gov/oa/climate/normals/usnormals.html>. [Accessed: December 2014].

Piecyk, M.I. and McKinnon, A.C. (2010) Forecasting the carbon footprint of road freight transport in 2020. *International Journal of Production Economics* 128(1), pp. 31-42.

Reifschneider, D. and Tulip, P. (2007) Gauging the uncertainty of the economic outlook from historical forecasting errors. *Finance and Economic Discussion Series, Federal Reserve Board, Washington, D.C*.

Salama, H.K., Chatti, K., and Lyles, R.W. (2006) Effect of heavy multiple axle trucks on flexible pavement damage using in-service pavement performance data. *Journal of Transportation Engineering* 132(10), pp. 763-770.

Sankaran, J.K. Gore, A and Coldwell, B. (2005) The impact of road traffic congestion on supply chains: insights from Auckland, New Zealand. *International Journal of Logistics: Research and Applications* 8(2), pp. 159-180.

United States Census Bureau. (2010) 2010 US Census Data [Online] Available from < http://www.census.gov/2010census/data/>. [Accessed: March 2015].

Wheeler, N. and Figliozzi, M. (2011) Multi criteria trucking freeway performance measures in congested corridors. *Transportation Research Board Annual Meeting.*

Witter, E., Adams, T., Gordon,T., Kawamura, K., Lindquist, P., Vonderembse, M., Kawamura, K., and McNeil, S. (2005) Upper Midwest freight corridor study. Final Report: FHWA/OH 2005-1). *Ohio Department of Transportation*. Columbus OH.

Zeitsman, J., Rilett, L.R. and Kim, S.J. (2006) Transportation corridor decision-making with multi-attribute utility theory. *International Journal of Management and Decision Making* 7(2), pp. 254-266.

7.0 APPENDICES

APPENDIX A

DETAILED DESCRIPTION OF ANALYSIS SEGMENTS

Interstate 5

California

Interstate 5 runs for a length of 797 miles in the state of California. The interstate has been divided into five segments for the sake of analysis. The first segment runs from the Mexico – United States border in San Diego County northward to Orange County. The average AADTT value for this segment is 35,733. The overall average annual precipitation is 10 to 15 inches and the region is made up of AASHTO A4 type of soil. The second segment runs from Orange County to Kern County for a length of 189 miles and has heavy traffic. The average AADTT value for this segment was 42,920. The average annual precipitation value was approximately 10 inches and the region is made up of A4 soil. The third segment travels from Kern County to San Joaquin County. The average AADTT value for this segment was 8,051, the annual average precipitation was 20 inches, and the soil type was AASHTO A6. The fourth segment runs from San Joaquin to Glenn County and has a total length of 132 miles. The average AADTT value for this segment was 17,280, the annual average precipitation was 30 inches, and the soil type was A4. The fifth and final segment starts at Glenn County and ends at the Oregon state boundary. The traffic volume is relatively small in the entire segment due to low commercial activities and a hilly terrain. The average AADTT value was found to be 5,905, the average annual precipitation was 40 inches, and the soil was an A4 type.

Oregon

Interstate 5 travels 308 miles in Oregon and has been divided into four segments The first segment spans from the California boundary to Josephine County with a total mileage of 55. The average AADTT value for this segment was found to be 5,658. The average annual precipitation in this segment was 30-60 inches and the soil was considered as A4. The second segment starts just beyond Josephine County and goes to Douglas County. The traffic is relatively low with an average AADTT value of 3,268. Apart from traffic, the average annual precipitation values and the soil types are relatively similar to that of the first section. This segment has a length of about 64 miles. The third segment starts beyond Douglas County and goes up to Linn County. The average AADTT value for this segment is 7,825. The total length of this segment is 115 miles and the terrain is generally mountainous in this region. The precipitation is between 30 and 60 inches per year, the soil was considered as A4. The fourth and the final segment start from Linn County and finishes at the Washington state boundary. The terrain of this segment is generally hilly to plain, with heavy traffic. The average AADTT value for this segment is 19,421, average annual precipitation is between 30 and 60 inches and the soil type is was considered as A4.

Washington

Interstate 5 travels 277 miles in the state of Washington. The terrain and the climate of its entire stretch is quiet similar. Based on the factors discussed above, the interstate has been divided into three segments for the purpose of analysis. The first segment starts from the Oregon state boundary and goes north to Thurston County. The total length of this segment is 112 miles. The average AADTT in this segment is 15,328, the precipitation level is generally higher in this segment and varies from 60 to 100 inches, and the more prevalent soil type is A2. The second segment runs from Thurston County to Snohomish County. The traffic is higher than on the first segment with an average AADTT value of 37,881. The section predominantly has A4 soil type with the annual average precipitation value ranges between 30 and 60 inches. The third and final segment runs from Snohomish County to the international border with Canada. The segment carries less overall traffic than others with an average AADTT of 9,708, the average annual precipitation value is in the range of 30 to 60 inches, and is made of A4 soil type.

Interstate 10

California

Interstate 10 runs for 251 miles in the state of California from the west terminus in Santa Monica and up to the Arizona state line. It runs through three counties Los Angeles, San Bernardino, and Riverside. The peak traffic occurs on the San Bernardino freeway, and is comparatively less near the boundaries (44,339 AADTT on the western side and 11,594 AADTT on the eastern side). The soil is comparatively weaker in the Santa Monica area with type A5 and it gets courser to type A2 as it approaches Arizona. The rainfall is between 15-30 inches in the Los Angeles area and it reduces to 10 inches in the counties of San Bernardino and Riverside.

Arizona

I-10 travels 393 miles in the state of Arizona. From the California boundary it passes through the cities of Phoenix and then Tucson. In this state the interstate has been divided into three segments. The first segment runs from the California boundary to Maricopa County (a length of 126 miles) and has an average AADTT value of 3,796. The average annual rainfall in this region is 10 inches and the soil type is A4. The second segment runs from Maricopa County to Pima County (also a length of 126 miles) and has an average AADTT value of 22,696. The average annual rainfall in this region is 10 inches and the soil type is A4. The last segment, from Pima County to the New Mexico border has a length of 141 miles. The average annual rainfall in this region is 10 inches and the soil type is A4.

New Mexico

The interstate travels 164 miles in New Mexico and has been divided into two segments. The first segment runs from the Arizona state line to the Luna County. The total length of this segment is 85 miles. The average AADTT in this segment is 3,520. The average annual rainfall in this region is 15 inches and the soil type is considered as A4 .The second segment runs from Luna County and to the Texas state line. The total length of this segment is 79 miles. The average AADTT in this segment is 5,284. The average annual rainfall in this region is 10 inch and the soil type is A4.

Texas

Interstate 10 travels 881 miles in Texas and has been divided into eight segments for analysis. The first section runs from the New Mexico state line in El Paso County to the Hudspeth County for a length of 136 miles. The average AADTT value for this segment is 22,000. The average annual rainfall in this region is 15 inches and the soil type is A4. The second segment runs from Hudspeth County to Pecos County. It has a length of about 124 miles. The average AADTT value for this segment is 12,954. The average annual rainfall in this region is 18 inch and the soil type is A4. The third section runs from Pecos County to Sutton County. The average AADTT value for this portion of the interstate is only 1,137. The average annual rainfall is 20 inches and the soil type is A4. The fourth section runs from Sutton County to Kerr County. The traffic volume is similar to the previous section with an AADTT value of 1,706. The average annual rainfall in this region is 25 inches and the soil type is A4. The fifth section runs from Kerr County to the Bexar County. The average AADTT value for this segment is 17,429. The average annual rainfall in this region is 30 inches and the soil type is A4. The sixth segment runs from Bexar to Colorado County and it has an average AADTT value of 5,767. The average annual rainfall in this region is 35 inches and the soil type is A4. The seventh segment runs from Colorado County and goes up to Chambers County. The average AADTT in this portion of the interstate is the highest in Interstate 10 in Texas with a value of 27,279. The average annual rainfall in this region is 40 inches and the soil type is A4. The final segment runs from Chambers County to the Louisiana state boundary. It has an average AADTT value of 12,536. The average annual rainfall in this region is 40 inches and the soil type is considered A4.

Louisiana

Interstate I5 travels 274 mile in the state of Louisiana. The interstate has been divided into three segments for the purpose of analysis. The first segment starts at the Texas state border and goes to Lafayette County. The total length of this segment is 94 miles. The average AADTT is 8,905, the average annual precipitation level is 50 inches, and the most prevalent soil type is A4. The second segment runs from Lafayette County to Jefferson County. The traffic is higher than on the first segment with an average AADTT value of 11,195. The section predominantly has A4 soil type with the annual average precipitation value of 60 inches. The third and final segment runs from Jefferson County to St. Tammany County. The segment has an average AADTT of 19,973, the average annual precipitation value 60 inches, and is made of A4 soil type.

Mississippi

The interstate runs for a length of 77 miles in the state of Mississippi and it has been considered as one segment. It starts at the Hancock County and ends at the Alabama boundary in Baldwin County. This segment has an average AADTT of 10,569. The average annual rainfall in this region is 60 inches and the soil type is A4.

Alabama

Interstate 10 covers a very short distance of 66 miles in the state of Alabama. It has been considered as one segment for analysis. The segment begins at the border with Mississippi and ends at the Florida state border in Baldwin County. The average AADTT value for this segment is 12,400. The average annual rainfall in this region is 60 inches and the soil type is A4.

Florida

Interstate 10 travels a total length of 362 miles in Florida and has been divided into three segments for analysis. The first segment starts at the Alabama border and goes until Washington County for a length of about 103 miles. This section has an average AADTT value of 6,754 and the soil type is A4. The average annual rainfall in this region is 60 inches. The second segment starts at Washington County and goes until Madison County. This section of the interstate has an average AADTT value of 5,797. The average annual rainfall in this region is 50 inches and the soil type is considered A4. The third and the last segment run from Madison County until the end of I-10 at Jacksonville. This portion of the interstate has a slightly higher AADTT value of 8,504. The average annual rainfall in this region is 40 inches and the soil type is considered A4.

Interstate 15

California

The Interstate 15 runs for a length of 287 miles in the state of California and it has been divided into two segments. The first segment starts from San Diego and goes up to San Bernardino County. This section runs for a length of 119 miles and has an average AADTT value of 29,374. The average annual rainfall in this region is 15 inches and the soil type is A4. The second segment runs from San Bernardino County and goes to the Nevada state line. It has a total length of 168 miles and has an average AADTT value of 11,577. The average annual rainfall in this region is 10 inches and the soil type is A5.

Nevada and Arizona

The interstate runs for a length of 123 miles in the state of Nevada and for 30 miles in the state of Arizona. It has been considered as one segment for the analysis. The average AADTT value for this segment is 23,196. The average annual rainfall in this region is 15 inches and the soil type is A6.

Utah

Interstate 15 travels 401 miles in the state of Utah. Based on the factors discussed above, the interstate has been divided into four segments for the purpose of analysis. The first segment starts from the Nevada state border and goes to Iron County. The total length of this segment is 77 miles. The average AADTT in this segment is 4,996, the average annual precipitation is 15 inches, and the more prevalent soil type is A4. The second segment runs from Iron County to Utah County. The average AADTT value is 3,197. The section predominantly has A4 soil type with the annual average precipitation value of 10 inches. The third segment runs from Utah County to the Idaho state border. The segment carries an average AADTT of 27,321, the average annual precipitation value is 15 inches, and is made of A4 soil type.

Idaho

Interstate 15 travels 196 miles in the state of Idaho. The interstate has been divided into two segments for the purpose of analysis. The first segment starts at the Utah state border and goes up to Bingham County. The total length of this segment is 75 miles. The average AADTT in this segment is 3,256, the average annual precipitation level is 15 inches, and the most prevalent soil type is A4. The second segment runs from Bingham County to the Montana state border. The segment has an average AADTT value of 2,201. The section predominantly has A4 soil type with the annual average precipitation value of 10 inches.

Montana

Interstate 15 travels 396 miles in the state of Montana. The interstate has been divided into three segments for the purpose of analysis. The first segment runs from the Idaho state border to Jefferson County. The total length of this segment is 134 miles. It has an average AADTT of 1,401, an average annual precipitation of 20 inches, and an A4 soil. The second segment runs from Jefferson County to Cascade County. The segment has an average AADTT value of 1,272. The soil type is A4 with the annual average precipitation value of 15 inches. The third and final segment runs from Cascade County to the Canadian international border. The segment has an average AADTT of 1,044, the average annual precipitation value 15 inches, and has an A4 soil type.

Interstate 35

Texas

Interstate 35 runs for a length of 686 miles in Texas and it has been divided into four sections for the purpose of analysis. The first section runs from the Mexican international border at the city of Laredo to Frio County for a length of 102 miles and has an AADTT value of 7,319. The average annual rainfall in this region is 20 inches and the soil type is considered A4. The second section runs from Frio County to Travis County. It has a length of 146 miles and has a relatively high AADTT value of 21,716. The average annual rainfall in this region is 25 inches with A4 soil type. The third section runs from Travis County to McLennan County for a length of 81 miles and has an AADTT value of 13,657. The average annual rainfall in this region is 30 inches and the soil type is considered A4. The fourth section goes until the Oklahoma state boundary in Cooke County and has an AADTT value of 12,513. The average annual rainfall in this region is 30 inches with A4 soil type. There are two split sections in I-35 near Dallas. They are designated as I35E and I35W. The split sections were needed because I-35 splits into two separate branches while crossing Hill County. The traffic values for these separate routes were available and due to their high and differing AADTT values they were considered separately in order to achieve a more accurate analysis. I35E has a length of 97 miles and I35W has a length of 85 miles. The AADTT values in these segments are 23,824 and 17,635 respectively. The average annual rainfall in this region is 30 inches with A4 soil type.

Oklahoma

Interstate 35 runs for a length of 236 miles in the state of Oklahoma and it passes through Oklahoma City. The interstate has been divided into two segments for the purpose of analysis. The first segment runs from the Texas state border to Oklahoma County, a distance of 151 miles. It has an average AADTT value of 10,530. The average annual rainfall in this region is 30 inches and the soil type in this region is A6. The second segment runs from Oklahoma County to the Kansas state border. It has a total length of 85 miles and has an average AADTT of 4,782. The average annual rainfall in this region is 30 inches and the soil type is A4.

Kansas

Interstate 35 travels 236 miles in the state of Kansas. The interstate has been divided into two segments for the purpose of analysis. The first segment starts from Oklahoma state border and goes up to Lyon County. The total length of this segment is 141 miles. The average AADTT in this segment is 2,946, the average annual precipitation level is 25 inches, and the most prevalent soil type is A4. The second segment runs from Lyon County to the Missouri state border. The segment has an average AADTT value of 13,602. The section predominantly has A6 soil type with the annual average precipitation value of 35 inches.

Missouri

Interstate 35 travels 115 miles in the state of Missouri and it has been considered as a single segment for the purpose of analysis. The segment has an average AADTT value of 8,991. The average annual precipitation in this region is 35 inches and the soil type is A6.

Iowa

Interstate 35 travels 218 miles in the state of Iowa. The interstate has been divided into two segments for the purpose of analysis. The first segment starts from at the Missouri state border and goes up to Story County. The total length of this segment is 102 miles. The average AADTT in this segment is 9,526, the average annual precipitation level is 35 inches, and the soil type is A6. The second segment runs from Story County to the Minnesota state border. The segment has an average AADTT value of 4,052. The section predominantly has A6 soil type with the annual average precipitation value of 30 inches.

Minnesota

Interstate 35 travels 260 miles in the state of Minnesota, and has been divided into two segments for the purpose of analysis. The first segment starts at the Iowa state border and goes up to Dakota County. The total length of this segment is 97 miles. The average AADTT in this segment is 7,334, the average annual precipitation level is 30 inches, and the soil type is A4. The second segment runs from Dakota County to the end of the interstate at the city of Duluth. The segment has an average AADTT value of 5,606. The section predominantly has A3 soil type with the annual average precipitation value of 25 inches.

Interstate 40

California

Interstate 40 travels 155 mile in the state of California, and has been divided into two segments for the purpose of analysis. The first segment starts at Barstow County and goes to Ludlow County. The total length of this segment is 79 miles. The average AADTT is 3,035, the average annual precipitation level is 10 inches, and the soil type is A6. The second segment runs from Ludlow County to the Arizona state border. The segment has an average AADTT value of 2,750. The section predominantly has A4 soil type with the annual average precipitation value of 10 inches.

Arizona

I-40 travels 359 miles in the state of Arizona. In this state the interstate has been divided into three segments. The first segment runs from the California state border to Yavapai County (a length of 122 miles) and has an average AADTT value of 2,656. The average annual rainfall in this region is 10 inches and the soil type is A6. The second segment runs from Yavapai County to Navajo County (a length of 135 miles) and has an average AADTT value of 2,750. The average annual rainfall in this region is 20 inches and the soil type is A6. The last segment, from Navajo County to the New Mexico state border has a length of 102 miles. The average annual rainfall in this region is 15 inches and the soil type is A5.

New Mexico

In the state of New Mexico, I-40 runs for a length of 373 miles and it has been divided into three segments for the purpose of analysis. The segments break at mileage length of 114 and 256 at Cibola County and Guadalupe County. The three sections have an average AADTT value of 4,195, 15,263, and 3,229 respectively. The average annual rainfall in the first two segments is 15 inches and that in the second segment is 20 inches. The soil type in all three segments is considered as A4.

Texas

Interstate 40 runs for a short length of 177 miles in the northern most part of Texas. It has been divided into two sections for analysis. The first section runs from the New Mexico state border to Gray County and has an AADTT value of 8,515. The average annual rainfall in this region is 15 inches with A4 soil type. The second section runs from Gray County to the Oklahoma state border (a length of 63 miles). It has an average AADTT value of 2,528. The average annual rainfall in this region is 20 inches and the soil type is A4.

Oklahoma

I-40 travels 332 miles in the state of Oklahoma. In this state the interstate has been divided into three segments. The first segment runs from the Texas state border to Custer County for a length of 83 miles, and has an average AADTT value of 3,643. The average annual rainfall in this region is 25 inches and the soil type is A4. The second segment runs from Custer County to Okfuskee County for a length of 138 miles and has an average AADTT value of 10,623. The average annual rainfall in this region is 30 inches and the soil type is A5. The last segment, from Okfuskee County to the Arkansas state border, has an average AADTT value of 3,862 for a length of 111 miles. The average annual rainfall in this region is 40 inches and the soil type is A4.

Arkansas

Interstate 40 travels 285 miles in the state of Arkansas. The interstate has been divided into two segments for the purpose of analysis. The first segment starts at the Oklahoma state border and goes to Faulkner County. The total length of this segment is 136 miles. The average AADTT in this segment is 6,408, the average annual precipitation level is 45 inches, and the most prevalent soil type is A4. The second segment runs from Faulkner County to the Tennessee state border. The segment has an average AADTT value of 10,087. The section predominantly has A4 soil type with the annual average precipitation value of 50 inches.

Tennessee

Interstate 40 travels 455 miles in Tennessee and has been divided into four segments. The first segment spans from the Arkansas state border to Henderson County (a total of 100 miles). The average AADTT value for this segment was found to be 10,214. The average annual precipitation in this segment is 50 inches and the soil type is A4. The second segment starts just beyond Henderson County and goes to Wilson County. The traffic is relatively high with an average AADTT value of 14,700. Apart from traffic, the soil type is relatively similar to that of the first section. This segment has a length of about 123 miles and an average annual precipitation of 55 inches. The third segment starts beyond Wilson County and goes up to

Cumberland County. The average AADTT value for this segment is 8,490. The total length of this segment is 98 miles. The average annual precipitation is 55 inches per year, the soil is type A4. The fourth and the final segment start from Cumberland County and finishes at the North Carolina state boundary. The average AADTT value for this segment is 13,256, average annual precipitation is 45 inches and the soil type is A4.

North Carolina

I-40 travels 419 miles in the state of North Carolina. In this state the interstate has been divided into three segments. The first segment runs from the Tennessee state border to Burke County (a length of 104 miles) and has an average AADTT value of 8,306. The average annual rainfall in this region is 50 inches and the soil type is A4. The second segment runs from Burke County to Orange County (a length of 140 miles) and has an average AADTT value of 14,430. The average annual rainfall in this region is 45 inches and the soil type is A4. The last segment, from Orange County to the end of I-40 in New Hanover County (a length of 102 miles) has an average AADTT value of 13,936. The average annual rainfall in this region is 50 inches and the soil type is A5.

Interstate 70

Utah

Interstate 70 travels 232 miles in the state of Utah. The interstate has been divided into two segments for the purpose of analysis. The first segment starts from Millard County and goes to Emery County. The total length of this segment is 93 miles. The average AADTT in this segment is 1,385, the average annual precipitation level is 10 inches, and the most prevalent soil type is A4. The second segment runs from Emery County to the Colorado state border. The segment has an average AADTT value of 1,213. The section predominantly has A4 soil type with the annual average precipitation value of 10 inches.

Colorado

Interstate 70 travels 452 miles in Colorado and has been divided into four segments. The first segment spans from the state border with Utah to Eagle County with a total mileage of 142. The average AADTT value for this segment was found to be 3,600. The average annual precipitation in this segment was 10 inches and the soil type was A6. The second segment starts just beyond Eagle County and goes to Jefferson County. The segment has an average AADTT value of 6,295. The soil type is A4. This segment has a length of about 112 miles and an average annual precipitation of 20 inches. The third segment starts beyond Jefferson County and goes up to Lincoln County. The traffic is relatively high with an average AADTT value for this segment is 17,100. The total length of this segment is 112 miles. The average annual precipitation is 20 inches per year, the soil is type A4. The fourth and final segment starts at Lincoln County and ends at the state border with Kansas. The average AADTT value for this segment is 2,084, the average annual precipitation is 10 inches, and the soil type is A4.

Kansas

In Kansas I-70 travels 424 miles and has been divided into four segments The first segment spans from the Colorado state border to Gove County with a total mileage of 96. The average

AADTT value for this segment was 1,738. The average annual precipitation was 20 inches and the soil type was A4. The second segment starts just beyond Gove County and goes to Ellsworth County. The segment has an average AADTT value of 2,090. The soil type is A4. This segment has a length of about 121 miles and an average annual precipitation of 25 inches. The third segment starts beyond Ellsworth County and goes up to Shawnee County. The average AADTT value for this segment is 3,374. The total length of this segment is 127 miles. The average annual precipitation is 30 inches per year, the soil is type A6. The fourth and final segment starts from Shawnee County and finishes at the border with Missouri. The average AADTT value for this segment is 8,316, average annual precipitation is 40 inches, and the soil type is A5.

Missouri

Interstate 70 travels 250 miles in the state of Missouri. The interstate has been divided into two segments for the purpose of this analysis. The first segment starts from the state border with Kansas and goes up Callaway County. The total length of this segment is 148 miles. The average AADTT in this segment is 13,654, the average annual precipitation level is 40 inches, and the soil type is A6. The second segment runs from Callaway County to the border with Illinois. The segment has an average AADTT value of 21,481, a predominantly A4 soil type, and an annual average precipitation value of 40 inches.

Illinois

Interstate 70 runs for a length of 138 miles in the state of Illinois and has been considered as a single segment for the analysis. This segment has an average AADTT value of 4,205. The average annual rainfall in this region is 40 inches and the soil type found in this region is A4.

Indiana

Interstate 70 runs for a length of 157 miles in the state of Indiana and has been divided into two segments. The first segment runs from the Illinois state border to Hancock County for a length of 92 miles and has an average AADTT value of 14,017. The average annual rainfall in this region is 40 inches and the soil type is A4. The second segment runs from Hancock County to the border with Ohio in Wayne County and has a length of 65 miles. It has an average AADTT value of 6,955. The average annual rainfall in this region is 35 inches and the soil type is A4.

Ohio and West Virginia

Interstate 70 runs for a length of 226 miles in Ohio and for 14 miles in West Virginia. These two states have been combined into two segments. The first segment, which is 129 miles, is wholly contained in in Ohio and runs from the Indiana border to Licking County. The average AADTT value in this segment is 12,056. The average annual rainfall in this region is 40 inches and the soil type is A4. The second segment lies in both states, but is predominantly in Ohio (97 of the 111 miles). It starts at Licking County and meets the Pennsylvania state boundary at Westmoreland County. The average AADTT value in the second segment is 7,332. The average annual rainfall in this region is 10 inches and the soil type is A6.

Pennsylvania

Interstate 70 travels 169 miles in the state of Pennsylvania, and has been divided into two segments. The first segment starts from the border with West Virginia and includes the route until Westmoreland County (a total length of 82 miles). The average AADTT in this segment is 7,681, the average annual precipitation level is 40 inches, and the soil type is A4. The second segment runs from Westmoreland County to the Maryland border. The segment has an average AADTT value of 3,136. The section predominantly has A4 soil type with the annual average precipitation value of 35 inches.

Maryland

Interstate 70 runs for a length of 94 miles in the state of Maryland and has been considered as a single segment for the purpose of analysis. The section runs from Washington to Baltimore counties and has an average AADTT value of 12,870. The average annual rainfall in this region is 40 inches and the soil type is considered A4.

Interstate 75

Florida

Interstate 75 travels 471 miles in Florida and has been divided into four segments. The first segment spans from the Miami-Dade County to Lee County with a total of 123 miles. The average AADTT value for this segment was found to be 9,904. The average annual precipitation was 60 inches and the soil type is A4. The second segment starts just beyond Eagle County and goes to Jefferson County. The segment has an average AADTT value of 6,295. The soil type is A4. This segment has a length of about 112 miles and an average annual precipitation of 20 inches. The third segment starts beyond Jefferson County and goes north to Lincoln County. The traffic is relatively high with an average AADTT value for this segment is 17,100. The total length of this segment is 112 miles. The average annual precipitation is 20 inches per year, the soil is type A4. The fourth and the final segment start from Lincoln County and finishes at the Georgia state border. The average AADTT value for this segment is 2,084, average annual precipitation is 10 inches and the soil type is A4.

Georgia

Interstate 75 travels 355 miles in Georgia and has been divided into four segments. The first segment spans from the Florida state border to Crisp County with a total mileage of 101. The average AADTT value for this segment was found to be 8,539. The average annual precipitation in this segment was 50 inches and the soil type was A5. The second segment starts just beyond Crisp County and goes to Monroe County. The segment has an average AADTT value of 11,589. The soil type is A5. This segment has a length of about 84 miles and an average annual precipitation of 45 inches. The third segment starts beyond Monroe County and goes up to Fulton County. The average AADTT value for this segment is 33,132. The total length of this segment is 71 miles. The average annual precipitation is 50 inches per year, the soil is type A4. The fourth and final segment starts from Fulton County and finishes at the Tennessee state border. The average AADTT value for this segment is 23,290, average annual precipitation is 50 inches and the soil type is A4.

Tennessee

Interstate 75 runs for a length of 162 miles in the state of Tennessee and has been divided into two segments. The first segment runs from the border with Georgia to Knox County for a length of 85 miles and has an average AADTT value of 12,025. The average annual rainfall in this region is 55 inches and the soil type is A6. The second segment runs from Knox County to the Kentucky border and has a length of 77 miles. It has an average AADTT value of 9,688. The average annual rainfall in this region is 50 inches and the soil type is A4.

Kentucky

Interstate 75 runs for a length of 192 miles in the state of Kentucky and has been divided into two segments. The first segment runs from the Tennessee border to Madison County for a length of 76 miles and has an average AADTT value of 6,763. The average annual rainfall in this region is 50 inches and the soil type is A4. The second segment runs from Madison County to the border with Ohio. It has a total length of 116 miles, an average AADTT value of 11,338, an average annual rainfall of 45 inches, and the soil type is A6.

Ohio

In Ohio, I-75 travels 211 miles and has been divided into two segments. The first segment is 108 miles, and travels from the border with Kentucky to Shelby County. It has an AADTT value of 17,178. The average annual rainfall in this region is 40 inches and the soil type is A4. The second segment of 103 miles runs from the Shelby County to the Michigan state border. It has an AADTT value of 9,942, an average annual rainfall of 35 inches, and A6 soil.

Michigan

Interstate I75 travels 396 miles in Michigan and has been divided into four segments. The first segment spans from the Ohio state border to Oakland County with a total mileage of 80. The average AADTT value for this segment was found to be 21,131. The average annual precipitation was 34 inches and the soil type was A6. The second segment starts from Oakland County and goes to Bay County. The segment has an average AADTT value of 12,479. The soil type is A6. This segment has a length of about 89 miles and an average annual precipitation of 32 inches. The third segment starts beyond Bay County and goes up to Crawford County. The average AADTT value for this segment is 2,839. The total length of this segment is 90 miles. The average annual precipitation is 30 inches per year, the soil is type A6. The fourth and final segment starts from Crawford County and finishes at Chippewa County. The average AADTT value for this segment is 1,722, average annual precipitation is 30 inches, and the soil type is A2.

Interstate 80

California

Interstate 80 runs for a length of 199 miles in the state of California. It has been divided into two sections with the first segment running from the San Francisco County to the Placer County for a length of 107 miles. It has an average AADTT value of 27,970. The average annual rainfall in this region is 30 inches. The soil type found in this region is A6. The second segment runs from Placer County to the Nevada state boundary at Truckee County for a length of 92 miles. The average AADTT value in this segment is 15,957. The average annual rainfall in this region is 40 inches, and the soil is A5.

Nevada

Interstate 80 travels 411 miles in Nevada and has been divided into four segments. The first segment spans from the California border to Pershing County (124 miles). The average AADTT value for this segment was found to be 9,810. The average annual precipitation in this segment was 10 inches and the soil type was A5. The second segment starts at Pershing County and goes to Humboldt County. The segment has an average AADTT value of 1,490. The soil type is A5. This segment has a length of about 88 miles and an average annual precipitation of 10 inches. The third segment starts beyond Humboldt County and goes to Elko County. The average AADTT value for this segment is 1,725. The total length of this segment is 114 miles. The average annual precipitation is 10 inches per year, the soil is type A5. The fourth and final segment starts from Elko County and finishes at the Utah state border. The average AADTT value for this segment is 1,120, average annual precipitation is 10 inches, and the soil type is A2.

Utah

Interstate 80 travels 196 miles in Utah and has been divided into two segments. The first segment spans from the Nevada state border to Salt Lake County for a length of 117 miles. The segment has an average AADTT value of 5,292. The average annual rainfall in this region is 10 inches and the soil type is A6. The second segment starts from Salt Lake County and ends at the border with Wyoming. The total length of the segment is 79 miles and it has an average AADTT value of 12,865. The average annual rainfall in this region is 15 inches and the soil type is A4.

Wyoming

Interstate 80 travels 403 miles in Wyoming and has been divided into 4 segments. The first segment spans from the Utah state border to Sweetwater County for a total of 99 miles. The average AADTT value for this segment was found to be 1,953. The average annual precipitation in this segment was 10 inches and the soil type was considered A4. The second segment starts from Sweetwater County and goes to Carbon County. The segment has an average AADTT value of 2,450. The soil type is A4. This segment has a length of about 91 miles and an average annual precipitation of 10 inches. The third segment starts beyond Carbon County and goes up to Albany County. The average AADTT value for this segment is 2,456. The total length of this segment is 112 miles. The average annual precipitation is 10 inches per year, the soil is type A4. The fourth and final segment starts from Albany County and finishes at the Nebraska state boundary at Laramie County. The average AADTT value for this segment is 2,572, average annual precipitation is 15 inches, and the soil type is considered A4.

Nebraska

Interstate 80 runs for a length of 455 miles in the state of Nebraska and has been divided into four segments. The first segment starts at the Wyoming border and ends at Deuel County after a length of 108 miles. It has an AADTT value of 1,750. The average annual rainfall in this region is 15 inches and the soil type is considered A4. The second segment starts at the Deuel County and ends at Dawson County after a length of 130 miles. It has an average AADTT value of 3,110. The average annual rainfall in this region is 15 inches with A4 soil type. The third segment in Nebraska ends at Seward County and has a length of 141 miles, an AADTT value of 4,237, and an A4 soil type. The average annual rainfall in this region is 20 inches. The fourth segment ends at the Iowa state border after a length of 76 miles. It has an AADTT value of 15,277. The average annual rainfall in this region is 30 inches and the soil type is considered A4.

Iowa

Interstate 80 travels 303 miles in the state of Iowa. In this state the interstate has been divided into three segments. The first segment runs from the border with Nebraska to Polk County (a length of 127 miles) and has an average AADTT value of 5,542. The average annual rainfall in this region is 30 inches and the soil type is A6. The second segment runs from Polk County to Iowa County (a length of 81 miles) and has an average AADTT value of 5,725. The average annual rainfall in this region is 35 inches and the soil type is A6. The last segment, from Iowa County to the Illinois state border has a length of 95 miles, an average AADTT value of 7,142, an average annual rainfall of 35 inches, and an A4 soil type.

Illinois

Interstate 80 travels 164 miles in Illinois and has been divided into two segments. The first segment spans from the Iowa state line to La Salle County for a length of 90 miles. The segment has an average AADTT value of 4,234. The average annual rainfall in this region is 10 inches and the soil type is A6. The second segment starts from La Salle County and ends at the state border of Indiana. The total length of the segment is 74 miles and it has an average AADTT value of 14,188. The average annual rainfall in this region is 35 inches and the soil type is A6.

Indiana

Interstate 80 runs for a length of 152 miles in the state of Indiana and has been divided into two segments at Elkhart County. The first segment has a length of 88 miles and an AADTT value of 12,666. The average annual rainfall in this region is 40 inches and the soil type is considered A4. The second segment has a length of 64 miles and an AADTT value of 4,762. The average annual rainfall in this region is 35 inches and the soil is of type A4.

Ohio

Interstate 80 travels 237 miles in Ohio and has been divided into two segments. The first segment spans from the Indiana border to Loraine County for a length of 133 miles. The average AADTT value for this segment is 6,388. The average annual rainfall in this region is 35 inches and the soil type is A6. The second segment runs from Loraine County to Mahoning County (at the Pennsylvania state border) for a length of 104 miles. The average AADTT value for this segment is 7,043. The average annual rainfall in this region is 40 inches and the soil type is A4.

Pennsylvania

In Pennsylvania, I-80 travels 311 miles and has been divided into three segments. The first segment spans from the Ohio state border to Jefferson County for a length of 81 miles and has an average AADTT value of 5,272. The average annual rainfall in this region is 40 inches and the soil type is A4. The second segment spans from Jefferson County to Northumberland County and has an average AADTT value of 4,802. The average annual rainfall in this region is 45 inches and the soil type is A4.The third and final segment from Northumberland County meets the New Jersey state line at Monroe County after traversing a length of 100 miles. It has an average AADTT value of 7,636, average annual rainfall of 45 inches, and an A4 soil type.

New Jersey

Interstate 80 spans a length of 68 miles in the New Jersey and has been considered as a single segment. It starts at the Pennsylvania state border and ends at the Bergen County. The segment has an average AADTT value of 23,413. The average annual rainfall in this region is 45 inches and the soil type is A4.

Interstate 90

Washington

Interstate 90 travels 297 miles in Washington and has been divided into three segments. The first segment spans from King County to Kittitas County for a length of 109 miles and has an average AADTT value of 13,157. The average annual rainfall in this region is in the range of 90-120 inches and the soil type is A6. The second segment spans from Kittitas County to Adams County and has an average AADTT value of 2,508. The segment spans a length of 96 miles. The average annual rainfall in this region is in the range of 60-90 inches and the soil type is A4.The third and final segment from Adams County meets the Idaho state border at Spokane County after traversing a length of 92 miles. It has an average AADTT value of 11,068. The average annual rainfall in this region is 30 inch and the soil type is A4.

Idaho

Interstate 90 spans 74 miles in Idaho and has been considered as a single segment for the purpose of analysis. The average AADTT value for this segment is 3,938 and the soil type is predominantly A4. The average rainfall over this region is approximately 30 inches.

Montana

Interstate 90 spans 552 miles in Montana and has been divided into five segments. The first section runs from the Idaho state border to Missoula County for a length of 132 miles. The average AADTT value for this segment is 2,973, the average rainfall over the section is around 30-50 inches and the soil type is considered A4. The second segment runs from Missoula County to Deer Lodge County for a length of about 70 miles. The annual rainfall in this segment is similar to the first segment with a value of 30-50 inches and the soil type is considered A4. The third segment runs from Deer Lodge County to Gallatin County for a length of about 109 mile. The average AADTT value for this segment is equal to 2,621 and the average annual rainfall is about 10 inches with A4 soil type. The fourth segment runs from Gallatin County to Yellowstone County and it covers a length of about 116 miles. The average AADTT value for this segment is 2,426 and this region has an average annual rainfall of about 10 inches with A4 soil type. The fifth and final segment of I-90 in Montana runs from Yellowstone County to the Wyoming border for a length of about 97 miles. The average AADTT value for this segment is 2,792 and it has a rainfall of about 10 inches average annually and the soil type is considered A4.

Wyoming

Interstate 90 runs for a length of about 209 miles in the state of Wyoming. It has been divided into two segments. The first segment runs from the Montana border to Campbell County for a length of about 97 miles. The average AADTT value for this segment is equal to 1,178. The average annual rainfall for this segment of the region is around 20 inches and the soil type is considered A4. The second segment runs from Campbell to the South Dakota border and it covers a length of about 112 miles. The average AADTT value for this segment is 1,295 and it receives rainfall of less than 20 inches per year. The soil type is considered A4.

South Dakota

Interstate 90 travels 413 miles in South Dakota and has been divided into four segments. The first segment spans from the Wyoming state border to Pennington County (a total distance of 68 miles). The average AADTT value for this segment was found to be 3,482. The average annual precipitation in this segment was 20 inches and the soil type was A4. The second segment starts from Pennington County and goes to Jones County. The segment has an average AADTT value of 1,220. The soil type is A6. This segment has a length of about 125 miles and an average annual precipitation of 15 inches. The third segment starts beyond Jones County and goes to Davison County. The average AADTT value for this segment is 1,392. The total length of this segment is 119 miles. The average annual precipitation is 20 inches per year and the soil is type A5. The fourth and final segment starts from Davison County and finishes at the Minnesota state border. The average AADTT value for this segment is 2,479, average annual precipitation is 25 inches, and the soil type is A6.

Minnesota

Interstate 90 covers a length of 276 miles in Minnesota and has been divided into two segments. The first segment runs from the South Dakota border Freeborn County covering a length of 140 miles and has an average AADTT value of 1,713. The average annual precipitation in this segment is 25-30 inches and the soil type is A6. The second segment runs from Freeborn County to the Wisconsin border and has a total length of 136 miles, an average AADTT value of 2,462, an average annual precipitation of 30-35 inches, and A6 soil.

Wisconsin

Interstate 90 spans 187 miles in Wisconsin and has been considered as one segment for the purpose of analysis. The segment has an average AADTT value of 8,107, an average annual precipitation of 30 inches, and type A6 soil.

Illinois

Interstate 90 spans 108 miles in Illinois and has been considered as a single segment. The segment has an average AADTT value of 8,100, an average annual precipitation of 40 inches, and a type A4 soil.

Indiana

Interstate 90 runs for a length of 156 miles in the state of Indiana and it has been considered as a single segment. The segment has an average AADTT value of about 12,168, an average annual precipitation of 35 inches, and a type A4 soil.

Ohio

In Ohio, I-90 covers a length of 245 miles and has been divided into two segments. The first segment runs from the state border with Indiana to Sandusky County covering a length of 103 miles. It has an average AADTT value of 6,903, an average precipitation of 35 inches, and type

A5 soil. The second segment runs from Sandusky County to the Pennsylvania border (142 miles). It has an AADTT value of 13,658, average annual precipitation of 35 inches, soil of type A6.

Pennsylvania

Interstate 90 spans 46 miles in Pennsylvania and has been considered as a single segment. The segment runs from the border with Ohio to that with New York. The average AADTT value is 6,020, the average annual precipitation is 40 inches, and the soil type is A4.

New York

Interstate 90 runs for a length of 385 miles in the state of New York and has been divided into three segments for the purpose of analysis. The first segment runs from the Pennyslvania border to Victa and it covers a length of 108 miles. It has an average AADTT value of 13,500. The average precipitation value for this segment is around 40 inches and the soil type is considered A4. The second segment runs from Victa to Utica and it covers a length of 134 miles. It has an average AADTT value of 7,224. The average precipitation value for this segment is around 35 inches with soil type A4. The third segment runs from Utica to Massachusetts and it covers a length of 143 miles. It has an average AADTT value of 8,085. The average precipitation value for this segment is around 30 inches and the soil type is considered A4.

Massachusetts

In Massachusetts, I-90 runs for a length of 136 miles and has been considered as one segment for the purpose of analysis. The segment has an average AADTT value of about 15,015, an average annual precipitation of 35 inches, and the soil type is considered A4.

Interstate 94

Montana

Interstate 94 runs for a length of 249 miles in the state of Montana and has been divided into two segments. The first segment runs from Yellowstone County to Custer County for a length of 119 miles and has an average AADTT value of 888. The average annual rainfall in this region is 10 inches and the soil type is A4. The second segment starts from Custer County and meets the North Dakota state boundary at the Wibaux County after a length of 130 miles. This segment has an average AADTT value of 721. The average annual rainfall in this region is 15 inches with A4 soil type.

North Dakota

Interstate 94 travels 352 miles in North Dakota and has been divided into three segments. The first segment spans from the Montana state border to Morton County for a length of 128 miles and with an average AADTT value of 945. The average annual rainfall in this region is 15 inches and the soil type is A6. The second segment spans from Morton County to Stutsman County and has an average AADTT value of 2,844. The segment spans a length of 101 miles. The average annual rainfall in this region is 17 inches and the soil type is A6.The third and final segment travels from Stutsman County to the Minnesota state line after a distance of 123 miles. It has an average AADTT value of 3,507. The average annual rainfall in this region is 20 inches and the soil type is A7.

Minnesota

Interstate 94 spans 259 miles in Minnesota and has been divided into two segments. The first segment starts at the North Dakota border and ends at the Todd County covering a length of 115 miles. It has an average AADTT value of 8,834. The average annual rainfall in this region is 22 inches and the soil type is A7. The second segment starts at Todd County and goes to Washington County for a length of 144 miles. It has an average AADTT value of 12,975. The average annual rainfall in this region is 28 inches and the soil type is A4.

Wisconsin

In Wisconsin, I-94 travels 341 miles and has been divided into three segments. The first segment spans from the Minnesota border to Jackson County for a length of 96 miles and has an average AADTT value of 10,903. The average annual rainfall in this region is 30 inches and the soil type is A4. The second segment spans from Jackson County to Sauk County and has an average AADTT value of 5,070. The segment spans a length of 92 miles. The average annual rainfall in this region is 35 inches and the soil type is A4.The third and final segment from Sauk County to the Illinois state border has a length of 153 miles. It also has an average AADTT value of 18,271, an average annual rainfall of 30 inches, and an A4 soil.

Illinois

Interstate 94 spans 75 miles as a single section across Illinois. The average AADTT value in this segment is 26,349. The average annual rainfall in this region is 35 inches and the soil type is A4.

Indiana

Interstate 94 spans 46 miles in Indiana and has been considered as a single section in the analysis. The average AADTT value in this segment is 9,338. The average annual rainfall in this region is 35 inches and the soil type is A6.

Michigan

Interstate 94 covers a length of 275 miles in the Michigan. It has been divided into three segments for the purpose of analysis. The first segment runs from the state border with Indiana to Calhoun County for a length of 121 miles. It has an average AADTT value of 8,834. The average annual rainfall in this region is 34 inches and the soil type is A3.The second segment starts at Calhoun County and ends at Wayne County covering a length of 82 miles. The average AADTT value in this segment is 12,975. The average annual rainfall in this region is 30 inches and the soil type is A3. The third segment ends at St. Clair County and has an average AADTT value of 22,956. The average annual rainfall in this region is 28 inches and the soil type is A3.

Interstate 95

Florida

Interstate 95 runs for a length of 382 miles in the state of Florida and it has been divided into three segments. The first segment is located in southern Florida and includes the Miami area. It is subjected to high traffic, average AADTT value of 32,226, a large average annual rainfall of 60 inches, and is built upon an A4 subgrade. The second segment begins at St. Lucie County and ends in Volusia County. This segment has an average AADTT value of 10,289. The average annual rainfall in this region is 54 inches with A4 soil. The third and final segment runs from Volusia County to the Georgia state border. This segment has an average AADTT value of 19,975, an average annual rainfall of less than 50 inches, and an A4 soil.

Georgia

There are a total of 112 miles of I-95 in the state of Georgia, and all of this is considered as one segment. The traffic is moderate with an average AADTT value of 10,922. The average annual rainfall in this region is 48 inches and the soil type is A6.

South Carolina

Interstate 95 travels a total of 199 miles in the state of South Carolina and it is divided into two sections. The first segment runs from the Georgia border to Dorchester County (a length of 82 miles). The average AADTT value for this segment is 8,479, the average annual rainfall is 50 inches, and the soil type is A5. The second segment runs from Dorchester County to the North Carolina border. It has a total length of about 117 miles. The average AADTT value for this segment is 6,765. The average annual rainfall in this region is 45 inches and the soil type is A4.

North Carolina

Interstate 95 traverses 182 miles in the state of North Carolina, and is divided into two segments. The first segment runs from the border with South Carolina to Johnston County (a length of 98 miles). The average AADTT value for this segment is 7,971, the average annual rainfall is 48 inches, and the soil type is A4. The second segment runs from Johnston County to the Virginia border. It has a total length of about 84 miles. The average AADTT value for this segment is 6,582. The average annual rainfall in this region is 42 inches and the soil type is A5.

Virginia

Interstate 95 traverses 179 miles in the state of Virginia, and is divided into two segments. The first segment runs from the North Carolina border to Hanover County for a length of 98 miles. The average AADTT value for this segment is 14,571, the average annual rainfall is 40 inches, and the soil type is A4. The second segment runs from Hanover County to the Maryland border. It has a total length of about 81 miles. The average AADTT value for this segment is 32,610. The average annual rainfall in this region is 35 inches and the soil type is A4.

Maryland and Delaware

Interstate 95 covers 110 miles in Maryland and 23 miles in the state of Delaware. Hence the entire length of 133 miles has been taken as a single segment for analysis. The average AADTT value for this segment is 25,329. This segment runs from the border with Virginia in the south to the border with Pennsylvania in the north. The average annual rainfall in this region is 40 inches. The soil type is A4.

Pennsylvania

Interstate 95 covers 51 miles in the state of Pennsylvania. This segment starts at the Delaware border and runs to the New Jersey state boundary in Mercer County. The average AADTT value for this segment is 22,727. The average annual rainfall in this region is 40 inches and the soil type is A4.

New Jersey and New York

Interstate 95 covers 98 miles in the state of New Jersey and 24 miles in the state of New York. It has been considered as a single segment for analysis. The total 122 miles of this segment has an average AADTT value of 23,074. The average annual rainfall in this region is 45 inches and the soil type is A4.

Connecticut

Interstate 95 spans 112 miles in the state of Connecticut. It runs from the New York border to the Rhode Island border in New London County. The average AADTT value for this segment is 19,296. The average annual rainfall in this region is 40 inches and the soil type is A4.

Rhode Island

In Rhode Island, I-95 only travels 42 miles. It starts at the Connecticut border in Washington County and ends at the Massachusetts border in Providence County. The average AADTT value for this segment is 30,403. The average annual rainfall in this region is 46 inches and the soil type is considered A4.

Massachusetts and New Hampshire

Interstate 95 runs for a length of 92 miles in the state of Massachusetts and for a length of 16 miles in the state of New Hampshire. It has been considered as a single segment for the purpose of analysis. It starts at the Rhode Island border and ends at the Maine-New Hampshire border. The average AADTT value for this segment is equal to 22,344. The average annual rainfall in this region is 45 inches and the soil type is considered A4.

Maine

Interstate 95 spans 303 miles in the state of Maine and it has been divided into two segments. The first segment runs from York County (New Hampshire border) to Penobscot County for a length of 192 miles. The segment has an average AADTT value of 5,014. The average annual rainfall in this region is 40 inches and the soil type is A4.The second segment runs from Penobscot County to the Canadian border in Aroostook County (111 miles), it has an average AADTT value of 3,429, an average annual rainfall of 40 inches, a type A4 soil

APPENDIX B

TRAFFIC GROWTH RATES BY SECTION

Table B.1 : Summary of traffic values for each analysis section.

Route	State	Name	Length (Miles)	Initial Year AADTT	Baseline Growth Rate	Freight Trend Analysis Growth Rate
I-5	CA	I5-CA-1	85	35733	3	3
		I5-CA-2	189	42920	3	3
		I5-CA-3	194	8051	3	3
		I5-CA-4	132	17280	3	3
		I5-CA-5	197	5905	3	3
	OR	I5-OR-1	55	5658	4	3
		I5-OR-2	64	3268	4	3
		I5-OR-3	115	7825	4	3
		I5-OR-4	74	19421	4	3
	WA	I5-WA-1	112	15328	4	3
		I5-WA-2	99	37881	4	3
		I5-WA-3	66	9708	4	3
I-10	CA	I10-CA-1	86	44339	3	3
		I10-CA-2	165	11594	3	3
	AZ	I10-AZ-1	126	3796	2	3
		I10-AZ-2	126	22696	2	3
		I10-AZ -3	141	8691	2	3
	NM	I10-NM-1	85	3520	2	3
		I10-NM-2	79	5284	2	3
	TX	I10-TX-1	136	22000	4	3.1
		I10-TX-2	124	12954	4	3.1
		I10-TX-3	125	1137	4	3.1
		I10-TX-4	125	1706	4	3.1
		I10-TX-5	80	17429	4	3.1
		I10-TX-6	110	5767	4	3.1
		I10-TX-7	105	27279	4	3.1
		I10-TX-8	76	12536	4	3.1
	LA	I10-LA-1	94	8905	3	3.1
		I10-LA-2	127	11195	3	3.1
		I10-LA-3	53	19973	3	3.1
	MS	I10-MS-1	77	10569	3	2.5
	AL	I10-AL-1	66	12400	4	2.9
	FL	I10-FL-1	103	6754	3	2.9
		I10-FL-2	138	5797	3	2.9
		I10-FL-2	121	8504	3	3
I-15	CA	I15-CA-1	119	29374	3	3
		I15-CA-2	168	11577	3	3
	AZ, NV	I15-NV-1	154	23196	2	3
	UT	I15-UT-1	77	4996	2	3
		I15-UT-2	170	3197	2	3
		I15-UT-3	80	27321	2	3
		I15-UT-4	74	10615	2	3
	ID	I15-ID-1	75	3256	3	3
		I15-ID-2	121	2201	3	3
	MT	I15-MT-1	134	1401	3	3
		I15-MT-2	140	1272	3	3
		I15-MT-3	122	1044	3	3

Table B.1: Summary of traffic values for each analysis section (continued).

Route	State	Name	Length (Miles)	Initial Year AADTT	Baseline Growth Rate	Freight Trend Analysis Growth Rate
I-35	TX	I35-TX-1	102	7319	4	3.1
		I35-TX-2	146	21716	4	3.1
		I35-TX-3	81	13657	4	3.1
		I35-TX-4	175	12513	4	3.1
		I35E-TX	97	23824	4	3.1
		I35W-TX	85	17635	4	3.1
	OK	I35-OK-1	151	10530	4	3.1
		I35-OK-2	85	4782	4	3.1
	KS	I35-KS-1	141	2946	4	2.5
		I35-KS-2	95	13602	4	2.5
	MO	I35-MO-1	115	8991	4	2.5
	IA	I35-IA-1	102	9526	3	2.5
		I35-IA-2	116	4052	3	2.5
	MN	I35-MN-1	97	7334	3	2.5
		I35-MN-2	163	5606	3	2.5
I-40	CA	I40-CA-1	79	3035	3	3
		I40-CA-2	76	2750	3	3
	AZ	I40-AZ-1	122	2656	2	3
		I40-AZ-2	135	2758	2	3
		I40-AZ-3	102	2182	2	3
	NM	I40-NM-1	114	4195	2	3
		I40-NM-2	142	15263	2	3
		I40-NM-3	117	3229	2	3
	TX	I40-TX-1	114	8515	4	3.1
		I40-TX-2	63	2528	4	3.1
	OK	I40-OK-1	83	3643	4	3.1
		I40-OK-2	138	10623	4	3.1
		I40-OK-3	111	3862	4	3.1
	AR	I40-AR-1	136	6408	4	3.1
		I40-AR-2	149	10087	4	3.1
	TN	I40-TN-1	100	10214	4	2.5
		I40-TN-2	123	14700	4	2.5
		I40-TN-3	98	8490	4	2.5
		I40-TN-4	134	13256	4	2.5
	NC	I40-NC-1	104	8306	3	2.9
		I40-NC-2	140	14430	3	2.9
		I40-NC-3	175	13936	3	2.9
I-70	UT	I70-UT-1	93	1385	2	3
		I70-UT-2	139	1213	2	3
	CO	I70-CO-1	142	3600	3	3
		I70-CO-2	112	6295	3	3
		I70-CO-3	110	17100	3	3
		I70-CO-4	88	2084	3	3
	KS	I70-KS-1	96	1738	4	2.5
		I70-KS-2	121	2090	4	2.5
		I70-KS-3	127	3374	4	2.5
		I70-KS-4	80	8316	4	2.5
	MO	I70-MO-1	148	13654	4	2.5
		I70-MO-2	102	21481	4	2.5

Table B.1: Summary of traffic values for each analysis section (continued).

Route	State	Name	Length (Miles)	Initial Year AADTT	Baseline Growth Rate	Freight Trend Analysis Growth Rate
I-70	IL	I70-IL-1	138	4205	3	2.1
	IN	I70-IN-1	92	14017	3	2.1
		I70-IN-2	65	6955	3	2.1
	OH, WV	I70-OH-1	129	12056	2	2.1
		I70-OH-2	111	7332	2	2.1
	PA	I70-PA-1	82	7681	2	2.3
		I70-PA-2	87	3136	2	2.3
	MD	I70-MD-1	94	12870	3	2.9
I-75	FL	I75-FL-1	123	9904	3	2.9
		I75-FL-2	119	14791	3	2.9
		I75-FL-3	73	16764	3	2.9
		I75-FL-4	156	11551	3	2.9
	GA	I75-GA-1	101	8539	4	2.9
		I75-GA-2	84	11589	4	2.9
		I75-GA-3	71	33132	4	2.9
		I75-GA-4	99	23290	4	2.9
	TN	I75-TN-1	85	12025	4	2.5
		I75-TN-2	77	9688	4	2.5
	KY	I75-KY-1	76	6763	4	2.5
		I75-KY-2	116	11338	4	2.5
	OH	I75-OH-1	108	17178	2	2.1
		I75-OH-2	103	9942	2	2.1
	MI	I75-MI-1	80	21131	3	2.1
		I75-MI-2	89	12479	3	2.1
		I75-MI-3	90	2839	3	2.1
		I75-MI-4	137	1722	3	2.1
I-80	CA	I80-CA-1	107	27970	3	3
		I80-CA-2	92	15957	3	3
	NV	I80-NV-1	124	9810	3	3
		I80-NV-2	88	1490	3	3
		I80-NV-3	114	1725	3	3
		I80-NV-4	85	1120	3	3
	UT	I80-UT-1	117	5292	2	3
		I80-UT-2	79	12865	2	3
	WY	I80-WY-1	99	1953	3	3
		I80-WY-2	91	2450	3	3
		I80-WY-3	112	2456	3	3
		I80-WY-4	101	2572	3	3
	NE	I80-NE-1	108	1750	3	2.5
		I80-NE-2	130	3110	3	2.5
		I80-NE-3	141	4237	3	2.5
		I80-NE-4	76	15277	3	2.5
	IA	I80-IA-1	127	5542	3	2.5
		I80-IA-2	81	5725	3	2.5
		I80-IA-3	95	7142	3	2.5
	IL	I80-IL-1	90	4234	3	2.1
		I80-IL-2	74	14188	3	2.1
	IN	I80-IN-1	88	12666	3	2.1
		I80-IN-2	64	4762	3	2.1

Table B.1: Summary of traffic values for each analysis section (continued)

Route	State	Name	Length (Miles)	Initial Year AADTT	Baseline Growth Rate	Freight Trend Analysis Growth Rate
I-80	OH	I80-OH-1	133	6388	2	2.1
		I80-OH-2	104	7043	2	2.1
	PA	I80-PA-1	81	5272	2	2.1
		I80-PA-2	130	4802	2	2.1
	NJ	I80-NJ-1	68	23413	4	2.1
I-90	WA	I90-WA-1	109	13157	4	3
		I90-WA-2	96	2508	4	3
		I90-WA-3	92	11068	4	3
	ID	I90-ID-1	74	3938	3	3
	MT	I90-MT-1	132	2973	3	3
		I90-MT-2	70	1612	3	3
		I90-MT-3	109	2621	3	3
		I90-MT-4	116	2426	3	3
		I90-MT-5	125	2792	3	3
	WY	I90-WY-1	97	1178	3	3
		I90-WY-2	112	1295	3	3
	SD	I90-SD-1	68	3482	3	2.5
		I90-SD-2	125	1220	3	2.5
		I90-SD-3	119	1392	3	2.5
		I90-SD-4	101	2479	3	2.5
	MN	I90-MN-1	140	1713	3	2.5
		I90-MN-2	136	2462	3	2.5
	WI	I90-WI-1	187	8107	3	2.1
	IL	I90-IL-1	108	8100	3	2.1
	IN	I90-IN-1	156	12168	3	2.1
	OH	I90-OH-1	103	6903	2	2.1
		I90-OH-2	142	13658	2	2.1
	PA	I90-PA-1	46	6020	2	2.1
	NY	I90-NY-1	108	13500	3	2.1
		I90-NY-2	134	7224	3	2.1
		I90-NY-3	143	8085	3	2.1
	MA	I90-MA-1	136	15015	3	2.3
I-94	MT	I94-MT-1	119	888	2	3
		I94-MT-2	130	721	2	3
	ND	I94-ND-1	128	945	3	2.5
		I94-ND-2	101	2844	3	2.5
		I94-ND-3	123	3507	3	2.5
	MN	I94-MN-1	115	3253	3	2.5
		I94-MN-2	144	13506	3	2.5
	WI	I94-WI-1	96	10903	3	2.1
		I94-WI-2	92	5070	3	2.1
		I94-WI-3	153	18271	3	2.1
	IL	I94-IL-1	75	26349	3	2.1
	IN	I94-IN-1	46	9338	3	2.1
	MI	I94-MI-1	121	8834	3	2.1
		I94-MI-2	82	12975	3	2.1
		I94-MI-3	72	22956	3	2.1

Table B.1: Summary of traffic values for each analysis section (continued).

Route	State	Name	Length (Miles)	Initial Year AADTT	Baseline Growth Rate	Freight Trend Analysis Growth Rate
I-95	FL	I95-FL-1	132	32226	3	2.9
		I95-FL-2	131	10289	3	2.9
		I95-FL-3	119	19975	3	2.9
	GA	I95-GA-1	112	10922	4	2.9
	SC	I95-SC-1	82	8479	3	2.9
		I95-SC-2	117	6765	3	2.9
	NC	I95-NC-1	98	7971	3	2.9
		I95-NC-2	84	6582	3	2.9
	VA	I95-VA-1	98	14571	3	2.9
		I95-VA-2	81	32610	3	2.9
	MD, DE	I95-MD-1	133	25329	3	2.9
	PA	I95-PA-1	51	22727	2	2.1
	NJ, NY	I95-NJ-1	122	23074	4	2.1
	CT	I95-CT-1	112	19296	3	2.3
	RI	I95-RI-1	42	30403	3	2.3
	MA, NH	I95-MA-1	108	22344	3	2.3
	ME	I95-ME-1	192	5014	3	2.3
		I95-ME-2	111	3429	3	2.3

APPENDIX C

CLIMATE STATIONS BY SECTION

Table C.1: Summary of climate files chosen by analysis section.

Route	State	Name	Length (Miles)	Climate Station
I-5	CA	I5-CA-1	85	San Diego
		I5-CA-2	189	Los Angeles
		I5-CA-3	194	Stockton
		I5-CA-4	132	Sacramento
		I5-CA-5	197	Redding
	OR	I5-OR-1	55	Medford
		I5-OR-2	64	Roseburg, Sexton summit, Montague, Klamath Falls, Mount Shasta
		I5-OR-3	115	Salem
		I5-OR-4	74	Portland
	WA	I5-WA-1	112	Portland
		I5-WA-2	99	Tacoma
		I5-WA-3	66	Seattle
I-10	CA	I10-CA-1	86	Los Angeles
		I10-CA-2	165	Blythe
	AZ	I10-AZ-1	126	Phoenix
		I10-AZ-2	126	Phoenix
		I10-AZ -3	141	Tucson, Nogales, Safford, Douglas Bisbee, Phoenix
	NM	I10-NM-1	85	Deming
		I10-NM-2	79	Deming
	TX	I10-TX-1	136	El Paso
		I10-TX-2	124	El Paso
		I10-TX-3	125	Fort Stockton
		I10-TX-4	125	Fort Stockton
		I10-TX-5	80	San Antonio
		I10-TX-6	110	San Antonio
		I10-TX-7	105	Houston
		I10-TX-8	76	Houston
	LA	I10-LA-1	94	Lake Charles
		I10-LA-2	127	Baton Rouge
		I10-LA-3	53	Baton Rouge
	MS	I10-MS-1	77	Gulfport
	AL	I10-AL-1	66	Mobile
	FL	I10-FL-1	103	Crestview, Destin
		I10-FL-2	138	Panama City, Destin
		I10-FL-3	121	Jacksonville
I-15	CA	I15-CA-1	119	San Diego
		I15-CA-2	168	Las Vegas
	AZ, NV	I15-NV-1	154	Las Vegas
	UT	I15-UT-1	77	Cedar City
		I15-UT-2	170	Cedar City
		I15-UT-3	80	Salt Lake City
		I15-UT-4	74	Salt Lake City
	ID	I15-ID-1	75	Pocatello
		I15-ID-2	121	Idaho Falls
	MT	I15-MT-1	134	Butte
		I15-MT-2	140	Great Falls
		I15-MT-3	122	Great Falls

Table C.1: Summary of climate files chosen by analysis section (continued).

Route	State	Name	Length (Miles)	Climate Station(s)
I-35	TX	I35-TX-1	102	Cotulla
		I35-TX-2	146	San Antonio
		I35-TX-3	81	Fort Worth
		I35-TX-4	175	Dallas
		I35E-TX	97	Dallas
		I35W-TX	85	Dallas
	OK	I35-OK-1	151	Oklahoma City
		I35-OK-2	85	Oklahoma City
	KS	I35-KS-1	141	Wichita
		I35-KS-2	95	Olathe
	MO	I35-MO-1	115	Kansas City
	IA	I35-IA-1	102	Des Moines
		I35-IA-2	116	Des Moines
	MN	I35-MN-1	97	Minneapolis
		I35-MN-2	163	Duluth
I-40	CA	I40-CA-1	79	Bakersfield, Sandberg
		I40-CA-2	76	Needles
	AZ	I40-AZ-1	122	Kingman, Needles, Las Vegas
		I40-AZ-2	135	Flagstaff
		I40-AZ-3	102	Winslow, Flagstaff
	NM	I40-NM-1	114	Gallup
		I40-NM-2	142	Albuquerque
		I40-NM-3	117	Albuquerque
	TX	I40-TX-1	114	Amarillo
		I40-TX-2	63	Amarillo
	OK	I40-OK-1	83	Oklahoma City
		I40-OK-2	138	Oklahoma City
		I40-OK-3	111	Muskogee
	AR	I40-AR-1	136	Fort Smith
		I40-AR-2	149	Little Rock
	TN	I40-TN-1	100	Memphis
		I40-TN-2	123	Nashville
		I40-TN-3	98	Knoxville, Oak Ridge, Crossville, Asheville,
		I40-TN-4	134	Knoxville, Oak Ridge, Crossville, Asheville
	NC	I40-NC-1	104	Asheville
		I40-NC-2	140	Winston Salem
		I40-NC-3	175	Raleigh/Durham
I-70	UT	I70-UT-1	93	Price
		I70-UT-2	139	Price
	CO	I70-CO-1	142	Grand Junction
		I70-CO-2	112	Denver
		I70-CO-3	110	Denver
		I70-CO-4	88	Burlington
	KS	I70-KS-1	96	Goodland
		I70-KS-2	121	Russell
		I70-KS-3	127	Salina
		I70-KS-4	80	Topeka
	MO	I70-MO-1	148	Kansas City
		I70-MO-2	102	Columbia

Table C.1: Summary of traffic values for each analysis section (continued).

Route	State	Name	Length (Miles)	Climate Station(s)
I-70	IL	I70-IL-1	138	Springfield, Decatur, Peoria
	IN	I70-IN-1	92	Terre Haute
		I70-IN-2	65	Indianapolis
	OH, WV	I70-OH-1	129	Columbus
		I70-OH-2	111	Columbus
	PA	I70-PA-1	82	Harrisburg
		I70-PA-2	87	Harrisburg
	MD	I70-MD-1	94	Baltimore, Washington DC
I-75	FL	I75-FL-1	123	Miami
		I75-FL-2	119	Naples
		I75-FL-3	73	Gainesville
		I75-FL-4	156	Jacksonville
	GA	I75-GA-1	101	Valdosta, Alma
		I75-GA-2	84	Macon
		I75-GA-3	71	Atlanta
		I75-GA-4	99	Atlanta
	TN	I75-TN-1	85	Chattanooga
		I75-TN-2	77	Bristol, Asheville
	KY	I75-KY-1	76	London
		I75-KY-2	116	Lexington
	OH	I75-OH-1	108	Cincinnati
		I75-OH-2	103	Toledo
	MI	I75-MI-1	80	Detroit
		I75-MI-2	89	Pontiac
		I75-MI-3	90	Saginaw, Flint
		I75-MI-4	137	Gaylord
I-80	CA	I80-CA-1	107	San Francisco
		I80-CA-2	92	Sacramento
	NV	I80-NV-1	124	Reno
		I80-NV-2	88	Lovelock
		I80-NV-3	114	Elko
		I80-NV-4	85	Elko
	UT	I80-UT-1	117	Salt Lake city
		I80-UT-2	79	Salt Lake City
	WY	I80-WY-1	99	Buffalo
		I80-WY-2	91	Rock Spring
		I80-WY-3	112	Rawlins
		I80-WY-4	101	Cheyenne
	NE	I80-NE-1	108	Akron
		I80-NE-2	130	Akron
		I80-NE-3	141	Topeka
		I80-NE-4	76	Topeka
	IA	I80-IA-1	127	Des Moines
		I80-IA-2	81	Iowa City
		I80-IA-3	95	Iowa City
	IL	I80-IL-1	90	Moline
		I80-IL-2	74	Chicago
	IN	I80-IN-1	88	South Bend
		I80-IN-2	64	South Bend

Table C.1: Summary of traffic values for each analysis section (continued).

Route	State	Name	Length (Miles)	Climate Station(s)
I-80	OH	I80-OH-1	133	Toledo
		I80-OH-2	104	Cleveland
	PA	I80-PA-1	81	Harrisburg
		I80-PA-2	130	Harrisburg
		I80-PA-3	100	Mount Pocono
	NJ	I80-NJ-1	68	Newark
I-90	WA	I90-WA-1	109	Seattle
		I90-WA-2	96	Ellensburg, Wenatchee, Yakima, Stampede-Pass
		I90-WA-3	92	Spokane
	ID	I90-ID-1	74	Lewiston
	MT	I90-MT-1	132	Missoula
		I90-MT-2	70	Butte
		I90-MT-3	109	Billings
		I90-MT-4	116	Billings
		I90-MT-5	125	Miles City
	WY	I90-WY-1	97	Buffalo
		I90-WY-2	112	Gillette
	SD	I90-SD-1	68	Rapid City
		I90-SD-2	125	Pierre
		I90-SD-3	119	Mitchell
		I90-SD-4	101	Sioux Falls
	MN	I90-MN-1	140	Minneapolis
		I90-MN-2	136	Minneapolis
	WI	I90-WI-1	187	La Crosse
	IL	I90-IL-1	108	Chicago
	IN	I90-IN-1	156	South Bend
	OH	I90-OH-1	103	Toledo
		I90-OH-2	142	Cleveland
	PA	I90-PA-1	46	Erie
	NY	I90-NY-1	108	Buffalo
		I90-NY-2	134	Syracuse
		I90-NY-3	143	Albany
	MA	I90-MA-1	136	Boston
I-94	MT	I94-MT-1	119	Miles City
		I94-MT-2	130	Miles City
	ND	I94-ND-1	128	Dickinson
		I94-ND-2	101	Bismarck
		I94-ND-3	123	Fargo
	MN	I94-MN-1	115	Minneapolis
		I94-MN-2	144	Minneapolis
	WI	I94-WI-1	96	Eau Claire
		I94-WI-2	92	Madison
		I94-WI-3	153	Milwaukee
	IL	I94-IL-1	75	Chicago
	IN	I94-IN-1	46	South Bend
	MI	I94-MI-1	121	Kalamazoo
		I94-MI-2	82	Jackson, Adrian
		I94-MI-3	72	Detroit

Table C.1: Summary of traffic values for each analysis section (continued).

Route	State	Name	Length (Miles)	Climate Station(s)
I-95	FL	I95-FL-1	132	Miami
		I95-FL-2	131	Daytona Beach
		I95-FL-3	119	Jacksonville
	GA	I95-GA-1	112	Savannah
	SC	I95-SC-1	82	Charleston
		I95-SC-2	117	Florence
	NC	I95-NC-1	98	Fayetteville
		I95-NC-2	84	Raleigh/Durham
	VA	I95-VA-1	98	Richmond
		I95-VA-2	81	Richmond
	MD, DE	I95-MD-1	133	Baltimore, Washington DC
	PA	I95-PA-1	51	Philadelphia
	NJ, NY	I95-NJ-1	122	Newark
	CT	I95-CT-1	112	Bridgeport
	RI	I95-RI-1	42	Providence
	MA, NH	I95-MA-1	108	Boston
	ME	I95-ME-1	192	Portland
		I95-ME-2	111	Bangor

APPENDIX D

ASPHALT BINDER GRADE BY SECTION

Table D.1: Summary of asphalt grade used for each analysis section.

Route	State	Name	Length (Miles)	Asphalt Grade
I-5	CA	I5-CA-1	85	76-22
		I5-CA-2	189	76-22
		I5-CA-3	194	76-22
		I5-CA-4	132	76-22
		I5-CA-5	197	76-22
	OR	I5-OR-1	55	70-22
		I5-OR-2	64	70-22
		I5-OR-3	115	70-22
		I5-OR-4	74	70-22
	WA	I5-WA-1	112	64-22
		I5-WA-2	99	64-22
		I5-WA-3	66	64-22
I-10	CA	I10-CA-1	86	76-22
		I10-CA-2	165	76-22
	AZ	I10-AZ-1	126	76-16
		I10-AZ-2	126	76-16
		I10-AZ -3	141	76-16
	NM	I10-NM-1	85	76-22
		I10-NM-2	79	76-22
	TX	I10-TX-1	136	64-22
		I10-TX-2	124	64-22
		I10-TX-3	125	64-22
		I10-TX-4	125	64-22
		I10-TX-5	80	64-22
		I10-TX-6	110	64-22
		I10-TX-7	105	64-22
		I10-TX-8	76	64-22
	LA	I10-LA-1	94	64-22
		I10-LA-2	127	64-22
		I10-LA-3	53	64-22
	MS	I10-MS-1	77	64-22
	AL	I10-AL-1	66	64-22
	FL	I10-FL-1	103	70-22
		I10-FL-2	138	70-22
		I10-FL-3	121	70-22
I-15	CA	I15-CA-1	119	76-22
		I15-CA-2	168	76-22
	AZ, NV	I15-NV-1	154	70-22
	UT	I15-UT-1	77	70-22
		I15-UT-2	170	70-22
		I15-UT-3	80	70-22
		I15-UT-4	74	70-22
	ID	I15-ID-1	75	64-22
		I15-ID-2	121	64-22
	MT	I15-MT-1	134	64-22
		I15-MT-2	140	64-22
		I15-MT-3	122	64-22

Table D.1: Summary of asphalt grade used for each analysis section (continued).

Route	State	Name	Length (Miles)	Asphalt Grade
I-35	TX	I35-TX-1	102	64-22
		I35-TX-2	146	64-22
		I35-TX-3	81	64-22
		I35-TX-4	175	64-22
		I35E-TX	97	64-22
		I35W-TX	85	64-22
	OK	I35-OK-1	151	64-22
		I35-OK-2	85	64-22
	KS	I35-KS-1	141	64-22
		I35-KS-2	95	64-22
	MO	I35-MO-1	115	64-22
	IA	I35-IA-1	102	64-22
		I35-IA-2	116	64-22
	MN	I35-MN-1	97	64-22
		I35-MN-2	163	64-22
I-40	CA	I40-CA-1	79	76-22
		I40-CA-2	76	76-22
	AZ	I40-AZ-1	122	70-22
		I40-AZ-2	135	70-22
		I40-AZ-3	102	70-22
	NM	I40-NM-1	114	76-22
		I40-NM-2	142	76-22
		I40-NM-3	117	76-22
	TX	I40-TX-1	114	64-22
		I40-TX-2	63	64-22
	OK	I40-OK-1	83	64-22
		I40-OK-2	138	64-22
		I40-OK-3	111	64-22
	AR	I40-AR-1	136	64-22
		I40-AR-2	149	64-22
	TN	I40-TN-1	100	64-22
		I40-TN-2	123	64-22
		I40-TN-3	98	64-22
		I40-TN-4	134	64-22
	NC	I40-NC-1	104	64-22
		I40-NC-2	140	64-22
		I40-NC-3	175	64-22
I-70	UT	I70-UT-1	93	70-22
		I70-UT-2	139	70-22
	CO	I70-CO-1	142	70-22
		I70-CO-2	112	70-22
		I70-CO-3	110	70-22
		I70-CO-4	88	70-22
	KS	I70-KS-1	96	64-22
		I70-KS-2	121	64-22
		I70-KS-3	127	64-22
		I70-KS-4	80	64-22
	MO	I70-MO-1	148	64-22
		I70-MO-2	102	64-22

Table D.1: Summary of asphalt grade used for each analysis section (continued).

Route	State	Name	Length (Miles)	Asphalt Grade
I-70	IL	I70-IL-1	138	64-22
	IN	I70-IN-1	92	64-22
		I70-IN-2	65	64-22
	OH, WV	I70-OH-1	129	64-22
		I70-OH-2	111	64-22
	PA	I70-PA-1	82	64-22
		I70-PA-2	87	64-22
	MD	I70-MD-1	94	70-22
I-75	FL	I75-FL-1	123	70-22
		I75-FL-2	119	70-22
		I75-FL-3	73	70-22
		I75-FL-4	156	70-22
	GA	I75-GA-1	101	64-22
		I75-GA-2	84	64-22
		I75-GA-3	71	64-22
		I75-GA-4	99	64-22
	TN	I75-TN-1	85	64-22
		I75-TN-2	77	64-22
	KY	I75-KY-1	76	64-22
		I75-KY-2	116	64-22
	OH	I75-OH-1	108	64-22
		I75-OH-2	103	64-22
	MI	I75-MI-1	80	64-22
		I75-MI-2	89	64-22
		I75-MI-3	90	64-22
		I75-MI-4	137	64-22
I-80	CA	I80-CA-1	107	76-22
		I80-CA-2	92	76-22
	NV	I80-NV-1	124	70-22
		I80-NV-2	88	70-22
		I80-NV-3	114	70-22
		I80-NV-4	85	70-22
	UT	I80-UT-1	117	70-22
		I80-UT-2	79	70-22
	WY	I80-WY-1	99	64-22
		I80-WY-2	91	64-22
		I80-WY-3	112	64-22
		I80-WY-4	101	64-22
	NE	I80-NE-1	108	64-22
		I80-NE-2	130	64-22
		I80-NE-3	141	64-22
		I80-NE-4	76	64-22
	IA	I80-IA-1	127	64-22
		I80-IA-2	81	64-22
		I80-IA-3	95	64-22
	IL	I80-IL-1	90	64-22
		I80-IL-2	74	64-22
	IN	I80-IN-1	88	64-22
		I80-IN-2	64	64-22

Table D.1: Summary of asphalt grade used for each analysis section (continued).

Route	State	Name	Length (Miles)	Asphalt Grade
I-80	OH	I80-OH-1	133	64-22
		I80-OH-2	104	64-22
	PA	I80-PA-1	81	64-22
		I80-PA-2	130	64-22
		I80-PA-3	100	64-22
	NJ	I80-NJ-1	68	64-22
I-90	WA	I90-WA-1	109	76-22
		I90-WA-2	96	76-22
		I90-WA-3	92	76-22
	ID	I90-ID-1	74	64-22
	MT	I90-MT-1	132	64-22
		I90-MT-2	70	64-22
		I90-MT-3	109	64-22
		I90-MT-4	116	64-22
		I90-MT-5	125	64-22
	WY	I90-WY-1	97	64-22
		I90-WY-2	112	64-22
	SD	I90-SD-1	68	64-22
		I90-SD-2	125	64-22
		I90-SD-3	119	64-22
		I90-SD-4	101	64-22
	MN	I90-MN-1	140	64-22
		I90-MN-2	136	64-22
	WI	I90-WI-1	187	64-22
	IL	I90-IL-1	108	64-22
	IN	I90-IN-1	156	64-22
	OH	I90-OH-1	103	64-22
		I90-OH-2	142	64-22
	PA	I90-PA-1	46	64-22
	NY	I90-NY-1	108	64-22
		I90-NY-2	134	64-22
		I90-NY-3	143	64-22
	MA	I90-MA-1	136	64-22
I-94	MT	I94-MT-1	119	64-22
		I94-MT-2	130	64-22
	ND	I94-ND-1	128	64-22
		I94-ND-2	101	64-22
		I94-ND-3	123	64-22
	MN	I94-MN-1	115	64-22
		I94-MN-2	144	64-22
	WI	I94-WI-1	96	64-22
		I94-WI-2	92	64-22
		I94-WI-3	153	64-22
	IL	I94-IL-1	75	64-22
	IN	I94-IN-1	46	64-22
	MI	I94-MI-1	121	64-22
		I94-MI-2	82	64-22
		I94-MI-3	72	64-22

Table D.1: Summary of asphalt grade used for each analysis section (continued).

Route	State	Name	Length (Miles)	Asphalt Grade
I-95	FL	I95-FL-1	132	70-22
		I95-FL-2	131	70-22
		I95-FL-3	119	70-22
	GA	I95-GA-1	112	64-22
	SC	I95-SC-1	82	64-22
		I95-SC-2	117	64-22
	NC	I95-NC-1	98	64-22
		I95-NC-2	84	64-22
	VA	I95-VA-1	98	64-22
		I95-VA-2	81	64-22
	MD, DE	I95-MD-1	133	64-22
	PA	I95-PA-1	51	64-22
	NJ, NY	I95-NJ-1	122	64-22
	CT	I95-CT-1	112	64-22
	RI	I95-RI-1	42	64-22
	MA, NH	I95-MA-1	108	64-22
	ME	I95-ME-1	192	64-22
		I95-ME-2	111	64-22

APPENDIX E

PAVEMENT STRUCTURE BY SECTION

Table E.1: Summary of structure used for each analysis section.

Route	State	Name	Length (Miles)	Structural Section
I-5	CA	I5-CA-1	85	AC-7.5″, Crushed Stone 12″, Crushed stone 16″
		I5-CA-2	189	AC-7.5″, Crushed Stone 12″, Crushed stone 16″
		I5-CA-3	194	AC-7.5″, Crushed Stone 12″, Crushed stone 16″
		I5-CA-4	132	AC-7.5″, Crushed Stone 12″, Crushed stone 16″
		I5-CA-5	197	AC-7.5″, Crushed Stone 12″, Crushed stone 16″
	OR	I5-OR-1	55	AC-10″, Crushed Stone 14″
		I5-OR-2	64	AC-10″, Crushed Stone 14″
		I5-OR-3	115	AC-10″, Crushed Stone 14″
		I5-OR-4	74	AC-10″, Crushed Stone 14″
	WA	I5-WA-1	112	AC-10″, Crushed Stone 14″
		I5-WA-2	99	AC-10″, Crushed Stone 14″
		I5-WA-3	66	AC-10″, Crushed Stone 14″
I-10	CA	I10-CA-1	86	AC-7.5″, Crushed Stone 12″, Crushed stone 16″
		I10-CA-2	165	AC-7.5″, Crushed Stone 12″, Crushed stone 16″
	AR	I10-AZ-1	126	AC-10″, Crushed Stone 14″
		I10-AZ-2	126	AC-10″, Crushed Stone 14″
		I10-AZ -3	141	AC-10″, Crushed Stone 14″
	NM	I10-NM-1	85	AC-10″, Crushed Stone 10″
		I10-NM-2	79	AC-10″, Crushed Stone 10″
	TX	I10-TX-1	136	AC-10″, Crushed Stone 14″
		I10-TX-2	124	AC-10″, Crushed Stone 14″
		I10-TX-3	125	AC-10″, Crushed Stone 14″
		I10-TX-4	125	AC-10″, Crushed Stone 14″
		I10-TX-5	80	AC-10″, Crushed Stone 14″
		I10-TX-6	110	AC-10″, Crushed Stone 14″
		I10-TX-7	105	AC-10″, Crushed Stone 14″
		I10-TX-8	76	AC-10″, Crushed Stone 14″
	LA	I10-LA-1	94	AC-10″, Crushed Stone 12″
		I10-LA-2	127	AC-10″, Crushed Stone 12″
		I10-LA-3	53	AC-10″, Crushed Stone 12″
	MS	I10-MS-1	77	AC-10″, Crushed Stone 12″
	AL	I10-AL-1	66	AC-10″, Crushed Stone 12″
	FL	I10-FL-1	103	AC-10″, Crushed Stone 12″
		I10-FL-2	138	AC-10″, Crushed Stone 12″
		I10-FL-3	121	AC-10″, Crushed Stone 12″
I-15	CA	I15-CA-1	119	AC-7.5″, Crushed Stone 12″, Crushed stone 16″
		I15-CA-2	168	AC-7.5″, Crushed Stone 12″, Crushed stone 16″
	AZ, NV	I15-NV-1	154	AC-10″, Crushed Stone 14″
	UT	I15-UT-1	77	AC-10″, Crushed Stone 12″
		I15-UT-2	170	AC-10″, Crushed Stone 12″
		I15-UT-3	80	AC-10″, Crushed Stone 12″
		I15-UT-4	74	AC-10″, Crushed Stone 12″
	ID	I15-ID-1	75	AC-10″, Crushed Stone 14″
		I15-ID-2	121	AC-10”, Crushed Stone 14″
	MT	I15-MT-1	134	AC-10″, Crushed Stone 12″
		I15-MT-2	140	AC-10″, Crushed Stone 12″
		I15-MT-3	122	AC-10″, Crushed Stone 12″

Table E.1: Summary of structure used for each analysis section (continued).

Route	State	Name	Length (Miles)	Structural Section
I-35	TX	I35-TX-1	102	AC-10″, Crushed Stone 14″
		I35-TX-2	146	AC-10″, Crushed Stone 14″
		I35-TX-3	81	AC-10″, Crushed Stone 14″
		I35-TX-4	175	AC-10″, Crushed Stone 14″
		I35E-TX	97	AC-10″, Crushed Stone 14″
		I35W-TX	85	AC-10″, Crushed Stone 14″
	OK	I35-OK-1	151	AC-10″, Crushed Stone 12″
		I35-OK-2	85	AC-10″, Crushed Stone 12″
	KS	I35-KS-1	141	AC-10″, Crushed Stone 12″
		I35-KS-2	95	AC-10″, Crushed Stone 12″
	MO	I35-MO-1	115	AC-10″, Crushed Stone 12″
	IA	I35-IA-1	102	AC-10″, Crushed Stone 12″
		I35-IA-2	116	AC-10″, Crushed Stone 12″
	MN	I35-MN-1	97	AC-10″, Crushed Stone 12″
		I35-MN-2	163	AC-10″, Crushed Stone 12″
I-40	CA	I40-CA-1	79	AC-7.5″, Crushed Stone 12″, Crushed stone 16″
		I40-CA-2	76	AC-7.5″, Crushed Stone 12″, Crushed stone 16″
	AZ	I40-AZ-1	122	AC-10″, Crushed Stone 14″
		I40-AZ-2	135	AC-10″, Crushed Stone 14″
		I40-AZ-3	102	AC-10″, Crushed Stone 14″
	NM	I40-NM-1	114	AC-10″, Crushed Stone 8″
		I40-NM-2	142	AC-10″, Crushed Stone 8″
		I40-NM-3	117	AC-10″, Crushed Stone 10″
	TX	I40-TX-1	114	AC-10″, Crushed Stone 14″
		I40-TX-2	63	AC-10″, Crushed Stone 14″
	OK	I40-OK-1	83	AC-10″, Crushed Stone 12″
		I40-OK-2	138	AC-10″, Crushed Stone 12″
		I40-OK-3	111	AC-10″, Crushed Stone 12″
	AR	I40-AR-1	136	AC-10″, Crushed Stone 12″
		I40-AR-2	149	AC-10″, Crushed Stone 12″
	TN	I40-TN-1	100	AC-10″, Crushed Stone 12″
		I40-TN-2	123	AC-10″, Crushed Stone 12″
		I40-TN-3	98	AC-10″, Crushed Stone 12″
		I40-TN-4	134	AC-10″, Crushed Stone 12″
	NC	I40-NC-1	104	AC-10″, Crushed Stone-12″
		I40-NC-2	140	AC-10″, Crushed Stone 12″
		I40-NC-3	175	AC-10″, Crushed Stone 12″
I-70	UT	I70-UT-1	93	AC-10″, Crushed Stone 12″
		I70-UT-2	139	AC-10″, Crushed Stone 12″
	CO	I70-CO-1	142	AC-10″, Crushed Stone 12″
		I70-CO-2	112	AC-10″, Crushed Stone 12″
		I70-CO-3	110	AC-10″, Crushed Stone 12″
		I70-CO-4	88	AC-10″, Crushed Stone 12″
	KS	I70-KS-1	96	AC-10″, Crushed Stone 12″
		I70-KS-2	121	AC-10″, Crushed Stone 12″
		I70-KS-3	127	AC-10″, Crushed Stone 12″
		I70-KS-4	80	AC-10″, Crushed Stone 12″
	MO	I70-MO-1	148	AC-10″, Crushed Stone 12″
		I70-MO-2	102	AC-10″, Crushed Stone 12″

Table E.1: Summary of structure used for each analysis section (continued).

Route	State	Name	Length (Miles)	Structural Section
I-70	IL	I70-IL-1	138	AC-10″, Crushed Stone 12″
	IN	I70-IN-1	92	AC-10″, Crushed Stone 12″
		I70-IN-2	65	AC-10″, Crushed Stone 12″
	OH, WV	I70-OH-1	129	AC-10″, Crushed Stone 12″
		I70-OH-2	111	AC-10″, Crushed Stone 12″
	PA	I70-PA-1	82	AC-10″, Crushed Stone 12″
		I70-PA-2	87	AC-10″, Crushed Stone 12″
	MD	I70-MD-1	94	AC-10″, Crushed Stone 14″
I-75	FL	I75-FL-1	123	AC-10″, Crushed Stone 12″
		I75-FL-2	119	AC-10″, Crushed Stone 12″
		I75-FL-3	73	AC-10″, Crushed Stone 12″
		I75-FL-4	156	AC-10″, Crushed Stone 12″
	GA	I75-GA-1	101	AC-10″, Crushed Stone 14″
		I75-GA-2	84	AC-10″, Crushed Stone 14″
		I75-GA-3	71	AC-10″, Crushed Stone 14″
		I75-GA-4	99	AC-10″, Crushed Stone 14″
	TN	I75-TN-1	85	AC-10″, Crushed Stone 12″
		I75-TN-2	77	AC-10″, Crushed Stone 12″
	KY	I75-KY-1	76	AC-10″, Crushed Stone 14″
		I75-KY-2	116	AC-10″, Crushed Stone 14″
	OH	I75-OH-1	108	AC-10″, Crushed Stone 12″
		I75-OH-2	103	AC-10″, Crushed Stone 12″
	MI	I75-MI-1	80	AC-10″, Crushed Stone 12″
		I75-MI-2	89	AC-10″, Crushed Stone 12″
		I75-MI-3	90	AC-10″, Crushed Stone 12″
		I75-MI-4	137	AC-10″, Crushed Stone 12″
I-80	CA	I80-CA-1	107	AC-7.5″, Crushed Stone 12″, Crushed stone 16″
		I80-CA-2	92	AC-7.5″, Crushed Stone 12″, Crushed stone 16″
	NV	I80-NV-1	124	AC-10″, Crushed Stone 12″
		I80-NV-2	88	AC-10″, Crushed Stone 12″
		I80-NV-3	114	AC-10″, Crushed Stone 12″
		I80-NV-4	85	AC-10″, Crushed Stone 12″
	UT	I80-UT-1	117	AC-10″, Crushed Stone 12″
		I80-UT-2	79	AC-10″, Crushed Stone 12″
	WY	I80-WY-1	99	AC-10″, Crushed Stone 12″
		I80-WY-2	91	AC-10″, Crushed Stone 12″
		I80-WY-3	112	AC-10″, Crushed Stone 12″
		I80-WY-4	101	AC-10″, Crushed Stone 12″
	NE	I80-NE-1	108	AC-10″, Crushed Stone 12″
		I80-NE-2	130	AC-10″, Crushed Stone 12″
		I80-NE-3	141	AC-10″, Crushed Stone 12″
		I80-NE-4	76	AC-10″, Crushed Stone 12″
	IA	I80-IA-1	127	AC-10″, Crushed Stone 12″
		I80-IA-2	81	AC-10″, Crushed Stone 12″
		I80-IA-3	95	AC-10″, Crushed Stone 12″
	IL	I80-IL-1	90	AC-10″, Crushed Stone 12″
		I80-IL-2	74	AC-10″, Crushed Stone 12″
	IN	I80-IN-1	88	AC-10″, Crushed Stone 12″
		I80-IN-2	64	AC-10″, Crushed Stone 12″

Table E.1: Summary of structure used for each analysis section (continued).

Route	State	Name	Length (Miles)	Structural Section
I-80	OH	I80-OH-1	133	AC-10″, Crushed Stone 12″
		I80-OH-2	104	AC-10″, Crushed Stone 12″
	PA	I80-PA-1	81	AC-10″, Crushed Stone 12″
		I80-PA-2	130	AC-10″, Crushed Stone 12″
		I80-PA-3	100	AC-10″, Crushed Stone 12″
	NJ	I80-NJ-1	68	AC-10″, Crushed Stone 12″
I-90	WA	I90-WA-1	109	AC-10″, Crushed Stone 14″
		I90-WA-2	96	AC-10″, Crushed Stone 14″
		I90-WA-3	92	AC-10″, Crushed Stone 14″
	ID	I90-ID-1	74	AC-10″, Crushed Stone 14″
	MT	I90-MT-1	132	AC-10″, Crushed Stone 12″
		I90-MT-2	70	AC-10″, Crushed Stone 12″
		I90-MT-3	109	AC-10″, Crushed Stone 12″
		I90-MT-4	116	AC-10″, Crushed Stone 12″
		I90-MT-5	125	AC-10″, Crushed Stone 12″
	WY	I90-WY-1	97	AC-10″, Crushed Stone 12″
		I90-WY-2	112	AC-10″, Crushed Stone 12″
	SD	I90-SD-1	68	AC-10″, Crushed Stone 12″
		I90-SD-2	125	AC-10″, Crushed Stone 12″
		I90-SD-3	119	AC-10″, Crushed Stone 12″
		I90-SD-4	101	AC-10″, Crushed Stone 12″
	MN	I90-MN-1	140	AC-10″, Crushed Stone 12″
		I90-MN-2	136	AC-10″, Crushed Stone 12″
	WI	I90-WI-1	187	AC-10″, Crushed Stone 12″
	IL	I90-IL-1	108	AC-10″, Crushed Stone 12″
	IN	I90-IN-1	156	AC-10″, Crushed Stone 12″
	OH	I90-OH-1	103	AC-10″, Crushed Stone 12″
		I90-OH-2	142	AC-10″, Crushed Stone 12″
	PA	I90-PA-1	46	AC-10″, Crushed Stone 12″
	NY	I90-NY-1	108	AC-10″, Crushed Stone 12″
		I90-NY-2	134	AC-10″, Crushed Stone 12″
		I90-NY-3	143	AC-10″, Crushed Stone 12″
	MA	I90-MA-1	136	AC-10″, Crushed Stone 12″
I-94	MT	I94-MT-1	119	AC-10″, Crushed Stone 12″
		I94-MT-2	130	AC-10″, Crushed Stone 12″
	ND	I94-ND-1	128	AC-10″, Crushed Stone 12″
		I94-ND-2	101	AC-10″, Crushed Stone 12″
		I94-ND-3	123	AC-10″, Crushed Stone 12″
	MN	I94-MN-1	115	AC-10″, Crushed Stone 12″
		I94-MN-2	144	AC-10″, Crushed Stone 12″
	WI	I94-WI-1	96	AC-10″, Crushed Stone 12″
		I94-WI-2	92	AC-10″, Crushed Stone 12″
		I94-WI-3	153	AC-10″, Crushed Stone 12″
	IL	I94-IL-1	75	AC-10″, Crushed Stone 12″
	IN	I94-IN-1	46	AC-10″, Crushed Stone 12″
	MI	I94-MI-1	121	AC-10″, Crushed Stone 12″
		I94-MI-2	82	AC-10″, Crushed Stone 12″
		I94-MI-3	72	AC-10″, Crushed Stone 12″

Table E.1: Summary of structure used for each analysis section (continued).

Route	State	Name	Length (Miles)	Structural Section
I-95	FL	I95-FL-1	132	AC-10″, Crushed Stone 12″
		I95-FL-2	131	AC-10″, Crushed Stone 12″
		I95-FL-3	119	AC-10″, Crushed Stone 12″
	GA	I95-GA-1	112	AC-10″, Crushed Stone 14″
	SC	I95-SC-1	82	AC-10″, Crushed Stone 12″
		I95-SC-2	117	AC-10″, Crushed Stone 12″
	NC	I95-NC-1	98	AC-10″, Crushed Stone 12″
		I95-NC-2	84	AC-10″, Crushed Stone 12″
	VA	I95-VA-1	98	AC-10″, Crushed Stone 12″
		I95-VA-2	81	AC-10″, Crushed Stone 12″
	MD, DE	I95-MD-1	133	AC-10″, Crushed Stone 14″
	PA	I95-PA-1	51	AC-10″, Crushed Stone 12″
	NJ, NY	I95-NJ-1	122	AC-10″, Crushed Stone 12″
	CT	I95-CT-1	112	AC-10″, Crushed Stone 12″
	RI	I95-RI-1	42	AC-10″, Crushed Stone 12″
	MA, NH	I95-MA-1	108	AC-10″, Crushed Stone 12″
	ME	I95-ME-1	192	AC-10″, Crushed Stone 12″
		I95-ME-2	111	AC-10″, Crushed Stone 12″