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PAVEMENT DAMAGE AND ROAD PRICING

by

SAJJAD HUSSAIN

A dissertation submitted to the Graduate Faculty in Engineering in partial fulfillment of
the requirements for the degree of Doctor of Philosophy,
The City University of New York.
2005

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Abstract
PAVEMENT DAMAGE AND ROAD PRICING

Sajjad Hussain

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The number and weight of the vehicles that use a road significantly influences the pavement damage and cost of the construction and maintenance. Road damage increases much more than proportionately with vehicle weight on a road surface. The studies conducted by Federal government and various state governments conclude that heavy vehicles typically do not pay their share of road damage costs, while lighter vehicles tend to be taxed for more than their share. The objective of this thesis is to quantify the pavement damage caused by different classes of vehicles, and to find an efficient pricing mechanism to regulate demand for highway services.

Road deterioration is broadly a function of the original design, material types, quality, traffic volume, axle load characteristics, speed, tire pressure, road geometry, environmental conditions, age of pavement, and the pursued maintenance policy. Several models were reviewed and KENLAYER was selected for the purposes of this analysis because of its ability to use actual axle load applied to the pavement, and thereby, eliminating the need for a traditional ESAL approach; and to incorporate effects of load distribution, tire pressure and speed on viscoelastic materials.

The analyses show that a 4-axle truck causes more pavement damage, as compared to a 5-axle truck, when carrying the same amount of the load. When fitting a curve to the data set, the compressive strain curve follows the AASHTO 4th power curve more closely,

while the tensile strain follows a 3rd-power curve. At heavier loads, the damage inflicted becomes increasingly more costly to repair, as the pavement starts to fail at the top of the subgrade instead the bottom of the surface course. The model demonstrates that the same truck can cause different damage depending on load, whether empty, partially loaded or fully loaded; and how that load is distributed over the axles. A damage simulation exhibited that an equal load distribution over the axles yields the least pavement damage. The spread between two consecutive axles in a tandem- or tridem-axle group also affects pavement life or performance. Lower speeds and congestion significantly reduces the design life of the flexible pavements. Higher tire pressure results in more damage due to the increase in load per-unit area. Adding more axles to each class of vehicle reduces the pavement damage and increases its life.

The best way to economize on maintaining and using an existing road is to apply a user charge equal to the damage each vehicle inflicts on pavements, based on the damaging power of their axle loads; time of the day they travel (congestion and speed), and tire pressure. The current tax structures do a poor job of capturing the pavement damage. Charging taxes by the number of axles or imposing fuel taxes creates an incentive to use fewer axles to conserve fuel by minimizing friction; but it also increases road damage by increasing the weight per axle. Implementation of a real-time weight-mile tax based on actual weight, speed and tire pressure promotes two distinct objectives: one is to apportion the cost of road construction and repair in an equitable manner among users, according to their fair share of damage; second is to discourage the use of heavy axle-loads and thus, reduce the wear on the road system.

Weigh-in-motion technology has the capability of measuring the weight on each axle and the spacing between those axles, in addition to the total weight. Moreover, electronic toll collection (ETC) technology makes it convenient to impose varying tolls based on per axle weight and time of the day vehicles travel (congestion). Establishing a pavement damage tax based on speed will encourage the trucking industry to shift their time of travel towards off-peak hours, which would ultimately reduce congestion in typical peak hours, as well as pavement damage. It could be concluded that the weight-mile tax is a road management device as well as a revenue source.

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I would like to thank all the members of my supervisory committee, Professor Robert Paaswell, Professor Claire McKnight, Professor Kaan Ozbay, and Professor Kyriacos Mouskos, for their mentorship in helping me to complete this dissertation. I would like to express my particular gratitude to my advisor, Professor Neville Parker, who was unfailing in giving both step-by-step technical guidance, thoughtful encouragement, and stimulating feedback. I am also grateful to Professor Claire McKnight, for both her technical advice and her generosity of spirit. I also would like to acknowledge my special thanks to Professor Mumtaz Kasir for his valuable suggestions throughout my time in the Ph.D. Program.

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CHAPTER 1

INTRODUCTION

1.1 Objective

The objective of this thesis is to quantify pavement damage caused by different classes of vehicles, and to find an efficient pricing mechanism to regulate demand for highway services. This can be achieved by imposing pavement deterioration taxes on heavy trucks; depending on real-time axle loads, operating speed (congestion) and tire pressure. The interaction of operating speed (duration of load) and congestion play an important role in contributing to pavement damage and determining pricing policy. An indirect goal of the pricing policy would be to reduce the heaviest axle weights by spreading the load over all axles, thus minimizing pavement damage and the total public and private costs of providing them.

1.2 Background And Motivation

Road user charges and optimal investment were often treated as two separate issues. But in fact have the same objective, that is, to minimize the total costs of building, maintaining, and using a highway system. Massive public spending is required each year for construction and maintenance of the nation's highway system, which consists of 3.95 million miles of federal, state, county and local roads carrying 2.767 trillion vehicle-miles each year⁽¹⁾. Of the 3.95 million miles, only 22% are in urban areas, with the rest (78%) in rural areas. The system consists of 2.504 million miles of paved roads and 1.446 million miles of unpaved roads. Since 1990, total miles have increased by only 2.1%, while travel has increased 28.9%⁽²⁾.

Total highway funding by all units of government reached \$128.5 billion in 2000 – a 222.5% increase compared to 1980 ⁽¹⁾. At 63.0%, highway user fees make up the largest share of revenue used to fund highways. The user fees include motor fuel tax, truck and trailer tax, heavy vehicle use tax, tire tax and tolls. For the year 2001, federal-aid projects that affected 24,606 miles of roadway were conducted. Of those 24,606 miles, 85% was for system preservation, 12% for capacity addition and only 3% for construction of new routes, as shown in Figure 1-1 below ⁽³⁾.

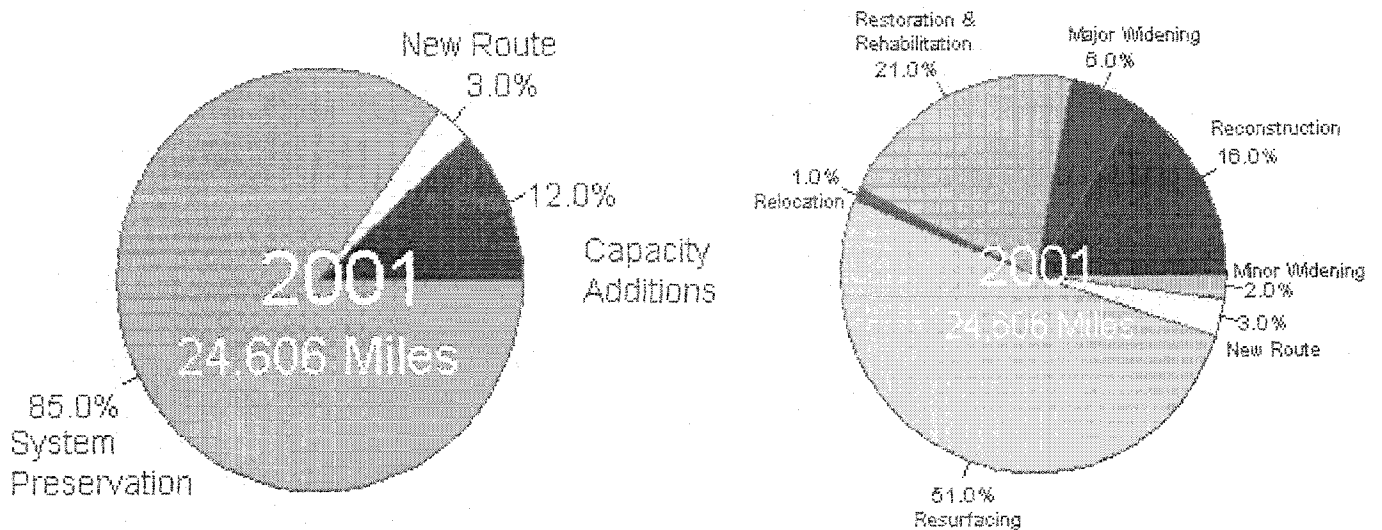


Figure 1-1: Miles of Federal-Aid Projects Underway by Improvement Types

System preservation improvements included some reconstruction, minor widening, restoration and rehabilitation, resurfacing, and reconstruction with no added capacity. Capacity addition improvements include relocation, some reconstruction, major widening, and reconstruction-added capacity. In 2000, federal, state and local government spent \$19.574 billion of their general revenue, \$6.115 billion of their

property taxes, and \$ 7.389 billion in other resources to help cover shortfall in user taxes and tolls ⁽³⁾. Capital expenditures currently account for 51.0% of total highway expenditures; maintenance accounts for 24.4%; administration, highway patrol and bond interest account for 20.1%, and debt retirement accounts for 4.5% ⁽¹⁾.

Despite its extent and cost, the nation's road system is deficient. According to the Federal Highway Administration (FHWA) statistics, in year 2000, about 16% of rural roads were reported in poor or mediocre condition, and only 42% in fair condition. In urban areas, the condition is worse. Twenty-nine percent were reported in poor or mediocre condition, 38% in fair condition and only 33% in good or very good condition ⁽²⁾ as shown in Figure 1-2 (a) and (b)*.

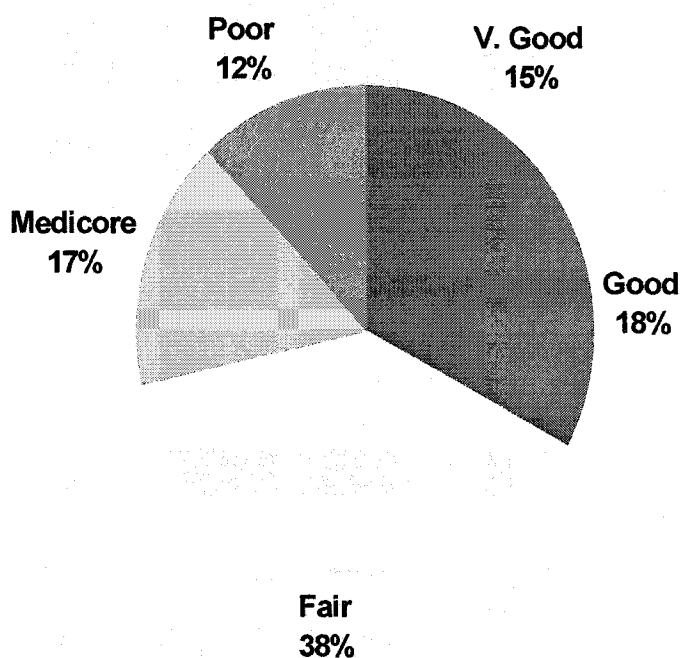


Figure 1-2(a): Urban Pavement Conditions, 2000

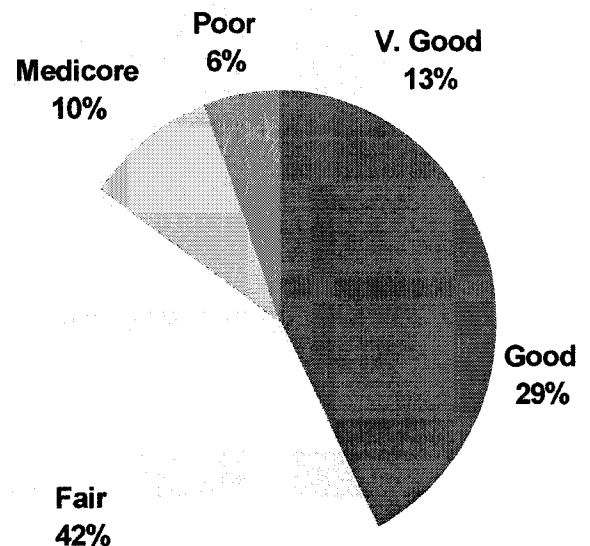


Figure1-2(b): Rural Pavement Conditions, 2000

* The data was reported as "Present Serviceability Rating" (PSR) by functional system. It is a subjective, primarily ride-based system adapted from the "AASHO ROAD TESTS" conducted in the late 1950's and early 1960's. The PSR values range from 0.1 to 5.0; higher PSR values represent smoother riding roadways. The figure shows the weighted average of all functional systems for rural and urban settings

The pavements rated as being in “good” or “fair” condition may suffer a rapid drop in serviceability, to mediocre or poor condition levels, if not maintained in a timely fashion. Refer to Figure 1-3. If a M&R is performed during the early stages of deterioration, over 0% of pavement repair cost can be avoided ⁽³⁸⁾. A pavement may cost four to five times more if repaired in poor condition as compared to “good” condition. Poorly maintained roads may cause high costs in vehicle damage and additional fuel expenditures each year. Therefore, it is crucial to generate sufficient revenue to preserve the nation’s highway system in a timely fashion.

PAVEMENT CONDITION RATING

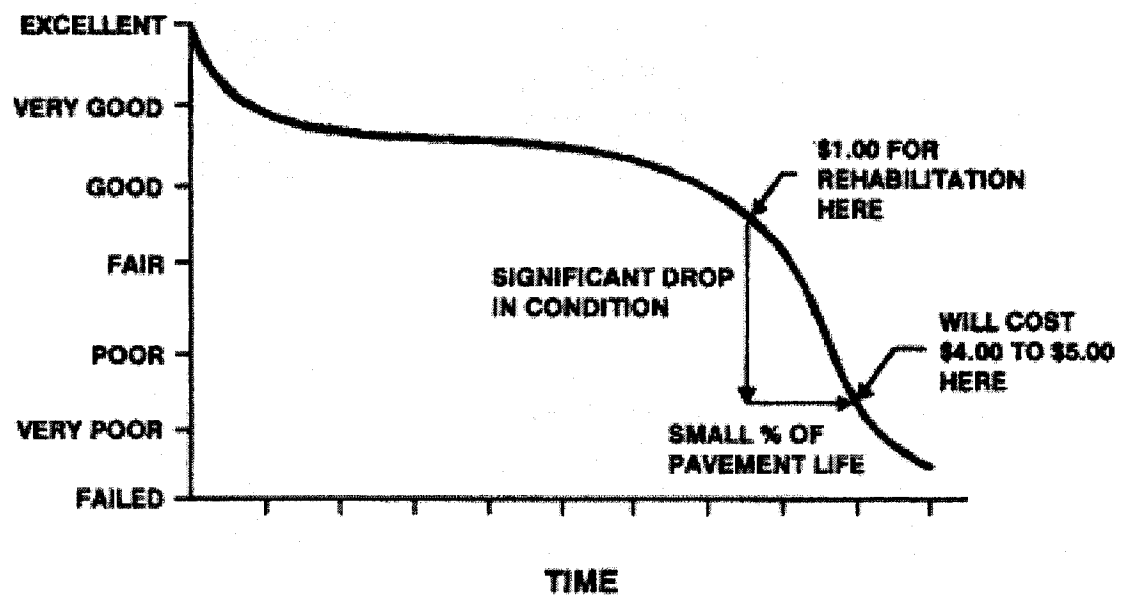


Figure 1-3: Conceptual illustration of life cycle pavement condition [source: Shahin, 1994]

1.3 Problem Statement and Dissertation Approach

When a vehicle travels on a road it causes some damage to the surface and advances the date at which the pavement needs to be repaired, rehabilitated or reconstructed. The

damage vehicles do to the pavement depends on the characteristic of the vehicle, type of the pavement, axle load, tire pressure/contact area and duration of load/congestion (speed). Vehicle operating cost depends on the quality of the road as measured by its roughness, and also on road geometry, which remains constant. Consequently, when a vehicle damages the road surface and increases its roughness, it thereby increases the vehicle operating costs of subsequent vehicles, and creates road damage externalities. None of the charges in current use capture the damage each vehicle causes to the pavement, nor do most versions of the weight-distance taxes levied in various states.

The best way to economize on maintaining and using an existing road is to apply a user charge equal to the actual cost each user imposes on society through his contribution to pavement damage and congestion. This cost can be termed as a marginal cost that can be defined as *the change in the total social cost of travel on existing roads, including cost of maintenance and cost incurred by all its users, brought about by adding one vehicle of a particular type and weight at a particular place and time*. The pavement damage costs to be taken into account in road pricing include maintenance costs incurred by the agency responsible for the road, and user costs incurred by operators of both cars and trucks, which includes repair, vehicle depreciation, fuel, and their value of time. It should be noted that congestion has a strong interaction with pavement damage in terms of slower speeds and longer duration of load on the pavement.

Most of the current taxes rely on fuel tax, which is a function of VMT (vehicle mile traveled). Charging vehicles by VMT does not address the pavement damage issue. Some states levy a weight-distance tax on heavy vehicles depending on gross weight or

number of axles. The current tax structures do a poor job of capturing the pavement damage. Charging by gross weight or number of axles instead of per axle load encourages hauling heavy loads on too few axles. On the other hand, charging per axle instead of by total load would not only reduce the heaviest axle weights, by encouraging trucking companies to distribute the load more evenly, but also hold vehicles accountable for their true share of the pavement damage.

Since the pavement damage depends on design of pavement structure, maintenance cost of the pavement, and real time congestion (speed of vehicle travel), it is essential to use mechanistic tools and intelligent technologies to predict accurately the pavement deterioration and real time traffic. The better the road, the less the damage and smaller the marginal cost. Traditionally, pavement thickness (including base and sub base) has been the primary determinant of the ability of the pavement to carry numerous axle loads. Now with the emergence of mechanistic design procedure, the research has shown that other components such as asphalt viscosity, air voids, proportion of HMAC aggregate passing #4 sieve, sub base passing # 200 sieve, annual freeze thaw cycle, freeze index, annual precipitation, tire pressure and speed greatly affect the life of the pavement. Designing the pavement for longer life may lead to high initial construction cost, but it saves maintenance and road user costs.

The rapid development of ITS technology provides an array of methods to determine appropriate user charges on a level that was impossible just a few years ago. Weigh-in-motion technology has the capability of measuring the weight on each axle and the spacing between those axles in addition to total weight. Moreover, electronic toll

collection (ETC) technology makes it convenient to impose varying tolls based on per axle weight and time of day they travel (congestion).

1.4 Dissertation Structure

Congestion pricing has been long debated in the US and well implemented in Europe, but pavement damage has been often ignored. This research focuses on road-pricing aspects related to pavement damage, as it has been neglected in economic analyses. Chapter 1 presents a brief introduction on road pricing and pavement damage. It describes the background and motivation for this dissertation, along with literature review, a problem statement, and the dissertation structure. Chapter 2 presents the philosophy of pavement damage, and discusses the key factors involved in pavement damage. Chapter 3 reviews some of widely used empirical and mechanistic pavement deterioration models for flexible pavements such as, AASHTO, SHRP (Strategic Highway Research Program), HDM-IV (World Bank Highway Design Model), KENLAYER, and VESEY, etc. Chapter 4 compares the different models with discussion of pros and cons for each model, and selects the most appropriate model for the analyses in this dissertation. Chapter 5 includes a discussion of input/outputs in pavement deterioration models and various pavement failure criteria. Chapter 6 quantifies the pavement damage for various classes of vehicles. Chapter 7 analyzes the effect of speed and tire pressure on pavement damage. Chapter 8 presents the existing highway tax structure. Chapter 9 will discuss road pricing. Chapter 10 discusses the policy implications of road pricing. Chapter 11 presents the conclusions and recommendations of this dissertation.

CHAPTER 2

PAVEMENT DAMAGE PHILOSOPHY

Light and heavy vehicles account for different shares of the damage they cause to the pavement. The FHWA categorizes all vehicles into 13 classes (see Appendix A). Classes 1 to 4 (cars, vans and buses) causes minimal damage to the pavement and are mostly ignored for design purposes. Classes 5 to 13 (trucks) are primarily responsible for the damage of the pavement structure. This chapter discusses some of the key factors involved in pavement damage.

2.1 Heavy Vehicle Growth

The historical increasing trends in car ownership, traffic growth, and especially the truck weight growth significantly contributed to the continuing damage on the pavements, bridges and roadway capacities. Figure 2-1 shows the percent change in number of trucks by weight from 1992 –1997 ⁽²⁾. For heavy trucks, weighing 50,001 lb to 130,000 lb, an increase of approximately 40% was reported during the 5 years. This reflects an 8% linear growth per year, almost three times the nationwide traffic growth rate, which is about 2-3%. Figure 2-2 (a) and (b) show the percent growth (3-year moving average)* in average daily traffic and average daily load for rural and urban highways. From 1970 to 2001, the rural average daily traffic increased 157%, while the average daily load increased 615%. For urban highways, the average daily traffic increased 15.6% from 1995 to 2001, while the average daily load increased 40.5% ⁽³⁾. The effect of this tremendous increase in heavy truck traffic is evident in the nation's deteriorating highway system. Every pass of a heavy truck causes some damage to the pavement and accelerates its time for repair or rehabilitation.

* Moving averages are one of the most popular and easy to use tools available to the technical analyst. They smooth a data series and make it easier to spot trends, something that is especially helpful with lots of fluctuations.

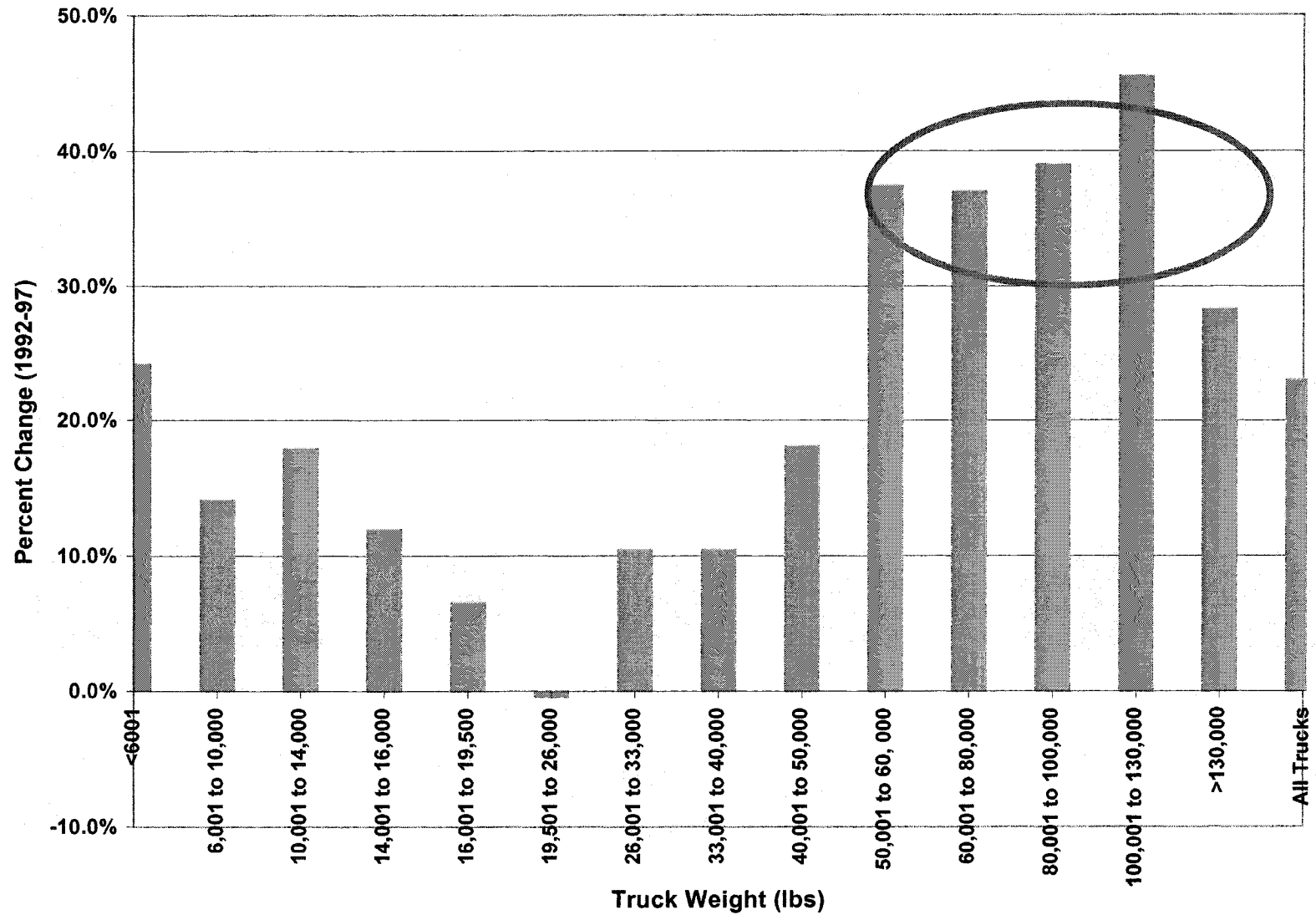


Figure 2-1: Percent Change in Number of Trucks by Weight, 1992-97

[Source: Data obtained from U.S Census Bureau, 1997 Economic census: Vehicle Inventory and Use survey]

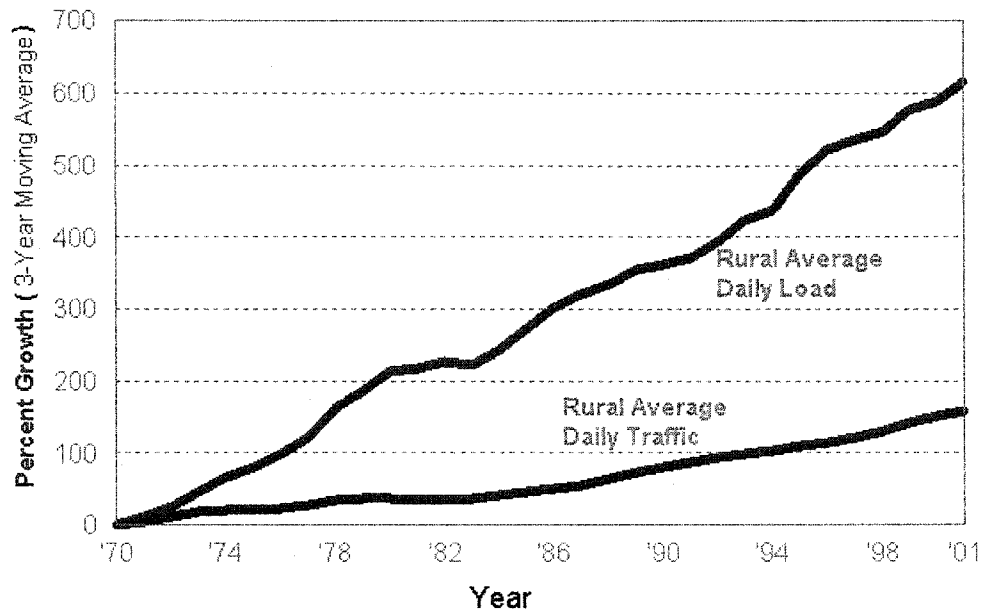


Figure 2-2 (a): Percent Growth of Daily Traffic and Load for Rural Highways, 1970-2001

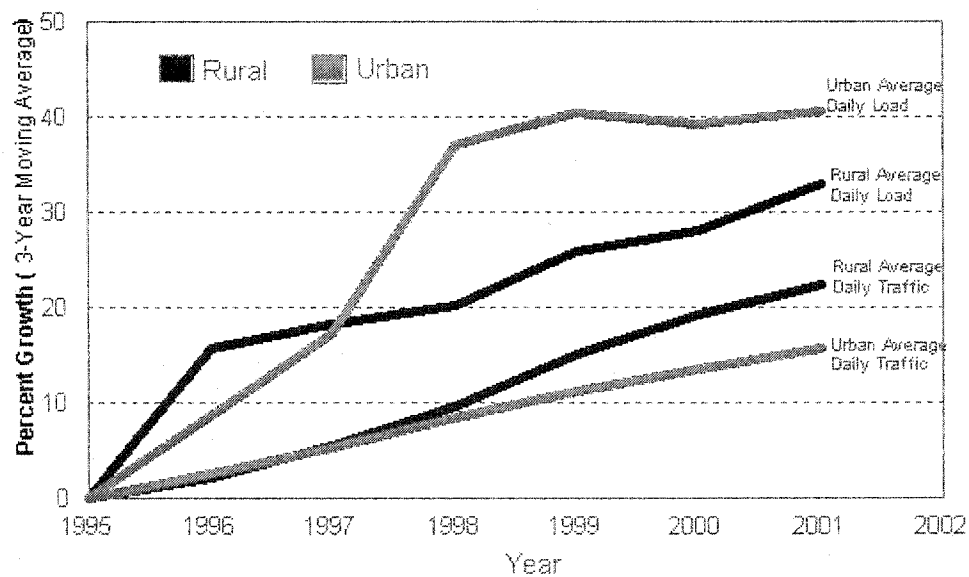


Figure 2-2 (b): Percent Growth of Daily Traffic and Load for Urban and Rural Highways, 1995-2002

[Source: Highway Statistics, 2001]

2.2 Axle Load

In terms of vehicle-specific characteristics, pavement damage increases with axle weight, the number of axle loadings, and the spacing within axle groups, such as for tandem or tridem-axle groups. Pavement impacts are also influenced by vehicle suspensions, tire pressure, and tire type. The gross vehicle weight (GVW) of a vehicle is not the prime determinant of a vehicle's impact on pavements. Rather, pavements are stressed by loads on individual axles directly in contact with the pavement. Of course, the GVW, along with the number and types of axles and the spacing between axles, determines the axle loads. Over time, the accumulated strains (the pavement deformation from all the axle loads) deteriorate the pavement structure, eventually resulting in cracking and permanent deformation, or rutting in flexible pavements. Eventually, if the pavement is not routinely maintained, the axle loads, in combination with environmental effects, such as pavement moisture, accelerate cracking and deformation.

Trucks and buses cause most of the damage, while cars and vans cause a minimal amount of structural damage to the pavement. Figure 2-3 shows the distribution of average daily traffic volume and corresponding damage in terms of equivalent single axle loads (ESAL) on the rural interstate system. Equivalent axle loads provides a means of measuring vehicle wear on pavement by relating them to an 18,000-pound (80 kilo-Newton) single-axle load. All 2-axle, 4-tire trucks include light trucks, pickup trucks, vans and other vehicles (such as campers). In 2000, combination trucks on rural interstate routes with 5 or more axles accounted for 18% of average daily traffic, but 89% of equivalent axle loads. All other vehicles accounted for 82% of average daily traffic, but

only 11% of traffic loads. From 1990 to 2000, traffic on the rural interstate routes increased by 36.4%, and the equivalent axle loads increased by 88.3% ⁽¹⁾.

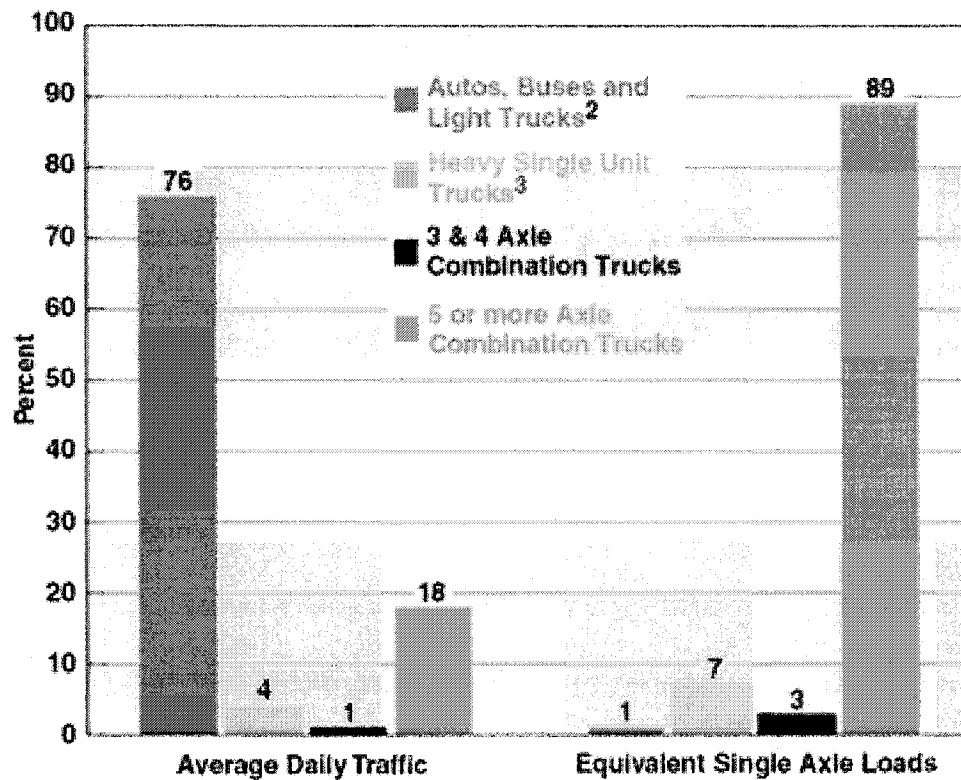


Figure 2-1: Rural Interstate Travel by Vehicle Type [Source: Reference 1]

Road damage increases much more than proportionately with vehicle weight on a road surface. A fourth power relationship between axle load and pavement deterioration has been the rule of thumb since the American Association of State Highway Officials' road test was conducted during the late 1950s. Such a relationship means that if axle loads are doubled from 10,000 pounds to 20,000 pounds, the impact on the pavement will increase by a factor of approximately 16. In other words, if Vehicle A weighs 48,000 pounds and

Vehicle B weighs 4,000 pounds, the damage done to the road by Vehicle A is far more than 12 times greater than the damage done by Vehicle B.

Relative damage is frequently discussed in terms of the Equivalent Standard Axle Loads (ESALs) created by the passage of a vehicle. A standard axle load is defined as 18,000 pounds. Hence, the number of ESALs assigned to a vehicle is a measure of the approximate number of standard axle loads that would have to pass over the road to do as much damage as that vehicle would do on one pass. The fourth-power rule is given by the following equation:

$$\text{ESAL} = \text{Damage} = (\text{Axle Load} / 18,000)^4$$

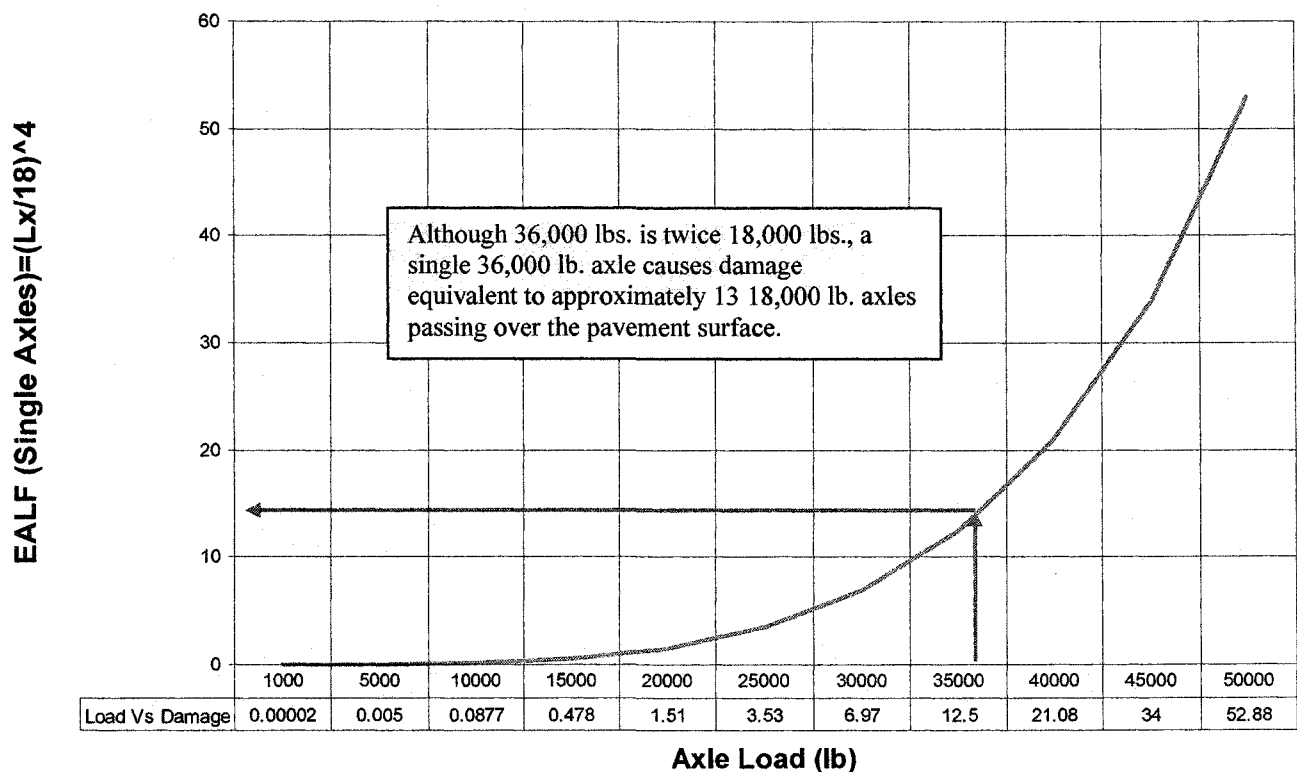


Figure 2-2: Relationship between Axle Load and Equivalence Factors

The fourth power equation states that an increase in the mass of axle loading causes pavements to fail far more rapidly than the increase in mass would suggest; that is, the life of the pavement is not a simple (linear) inverse function of the mass of axle load applied. Figure 2-4 illustrates this by plotting the asphalt institute axle loads versus equivalent axle load factor for a single axle.

The California Department of Transportation conducted a study to compare the pavement structural damage caused by passenger cars and trucks on the basis of pavement deflection analysis, using 35 years of performance data. The study found that one pass of an 18,000 lbs. axle load does about the same amount of structural damage to the pavement as about 1,850 passes of a 3,000 lbs. axle load or about 24,000 passes of a 1,500 lbs. axle load. The following table summarizes the contribution of various vehicle types to the pavement damage in California ⁽⁷⁾.

<u>Vehicle Type</u>	<u>Distribution (%)</u>	<u>Percent Damage</u>
Passenger Cars	77.5	0.3
Panel & Pickups	13.0	0.2
Buses	0.5	10.5
Trucks (over 6000 lbs)	9.0	89.0

The trucks over 6000 lbs. accounted for only 9% of the total traffic, but caused 89% of the pavement damage; while the passenger cars accounted for 77.5% of the traffic, but were responsible for only 0.3% of the pavement damage.

2.3 Speed and Tire Pressure

Speed is another important factor influencing flexible pavement damage arising from the dynamics of a vehicle. In general, slower speeds and stop conditions cause axle loads to

be applied to a given pavement area for a longer period of time, thereby resulting in greater damage. This time period is referred to as the 'load duration.'

Tire pressure directly influences the amount of contact area between truck tires and the pavement surface. The higher the tire pressure, the smaller the contact area and consequently the greater the load distribution per unit area applied to the pavement. This dissertation will address the effects of load duration and contact area on pavement damage in Chapter 7 through a damage analysis using KENLAYER ⁽²¹⁾, a mechanistic pavement analysis tool for flexible pavements.

2.4 Environmental Damage or Weathering

An important factor being argued by the trucking industry has been that trucks should not be held responsible for pavement damage caused by the environment, such as freeze/thaw and rain runoff. The road damage caused by heavy axles is exacerbated by time and weather, especially in severe climates. Wet subsoil is less resistant to the force transmitted through the pavement from a heavy axle. Cracks in the road surface are widened by frost, allowing water to damage the lower part of the highway structure, thereby lessening its ability to withstand future loads. Asphalt loses its flexibility over many years, becoming brittle and more likely to crack under loads.

Trucking industries claim that a substantial fraction of the total maintenance cost of a highway is attributable to age and weather and therefore, the extent of these costs invalidates the argument for user taxes that are steeply graduated by axle weight. All evidence indicates that these effects are mainly interactive. It is weathering of the

pavement in conjunction with heavy loads that causes the problem. Hence, aging and weathering leave a pavement more vulnerable to damage by heavy loads, thereby raising the extra maintenance cost caused by those loads ⁽¹²⁾.

Research conducted by the World Bank has quantified these relationships and concluded that pavement roughness increases with age at a constant rate; in addition to increases caused by traffic. The age-related roughness would be very small in the absence of heavy loads; but any roughness caused by traffic tends to become magnified by age. The rate of roughness increases from 1% (dry warm climates) to 7% (moist-freeze climate). Roughness in an untrafficked lane, in AASHTO road tests, showed an increase of 23% on average per year⁽¹²⁾. This research clearly contradicts claims made by AASHTO researchers themselves, who conclude that “no significant serviceability loss was found in flexible pavements that were not subject to traffic over the 2 year period of the road test”⁽³⁹⁾.

Further investigation of pavement damage due to weathering is beyond the scope of this dissertation. However, previous research has shown that the weathering damage is significant when combined with frequent heavy loading. Regardless of the point of view of various groups, the overall cost of maintaining a highway system includes repair of all damages caused by axle and compounded by weathering. Therefore, an equitable distribution of total damage costs among users according to their share is the fairest method to procure the funds needed to maintain safe roads.

CHAPTER 3

REVIEW OF PAVEMENT DAMAGE PREDICTION MODELS

3.1 Background

Road deterioration is broadly a function of the original design, material types, quality, traffic volume, axle load characteristics, road geometry, environmental conditions, age of pavement, and the maintenance policy pursued. The two general classes of models used for road deterioration analysis are mechanistic and empirical. Mechanistic models use sound fundamental theories of pavement behavior for their development, but they are usually very data intensive and rely on parameters which are difficult to quantify in the field. The empirical models are usually based on statistical analysis of locally observed deterioration trends, and may not be applicable outside the specific conditions upon which they are based. Pavement deterioration manifests itself in various kinds of distresses, each of which should be modeled separately. As each mode of distress develops and progresses at different rates in different environments, it is important that pavement damage relationships should be calibrated to local conditions before using them for road investment analyses. The model coefficients should be used to adjust the rates of deterioration for different types of pavement material. The key variables that are used in the various deterioration models are associated with the climate and environment, traffic, pavement history, road geometry, pavement structural characteristics and material properties.

Traditionally, a pavement is designed to withstand a certain number of passages of “equivalent standard axle loads” (ESALs) before requiring a major rehabilitation or reconstruction. An equivalent axle load factor defines the damage per pass to a pavement

by the axle in question, relative to damage per pass of a standard axle load, usually the 18-kip (80-kN) single axle load. The equivalency factors used to determine the number of ESALs are based on the Present Serviceability Index (PSI) concept, and are dependent on type and thickness of the pavement (e.g., rigid vs. flexible). For evaluating or designing for specific distresses using mechanistic based pavement performance model, actual axle load and vehicle classification data is warranted. In other words, the actual traffic data measured along roadways are used, rather than the conversion of that data into a number that is distress, pavement type and thickness dependent. Weigh-In-Motion (WIM) and Automated Vehicle Classification (AVC) technologies have the potential to obtain the number and configuration of axles, load on each individual axle, tire pressure, AADT, and vehicle speed data. The following section describes the some of available pavement deterioration prediction models.

3.2 AASHTO Empirical Design Equations

The most widely used AASHTO pavement design guidelines ⁽⁸⁾ are based on empirical equations developed as a result of AASHO road tests carried out in 1958-1960 (refer to Figure 3-1). The original equations have been modified numerous times to account for additional design factors such as drainage, load transfer, and mix strength. These guidelines have been critically examined and extended, but AASHTO has been hesitant to deviate from its basic test results. Research has shown that the statistical method used by AASHTO to develop the empirical equation was flawed, and that concrete pavement has considerably shorter life than the AASHTO equation predicts. Kenneth A. Small and Clifford Winston ⁽⁹⁾ concluded that by “using models of pavement deterioration very close to those developed for the AASHO road test, and estimating them from the road test

data, we find evidence that the existing design equation over-estimates the life of the thick pavements. Furthermore, current and past pavement design practice has led to under investment in pavement durability due to reliance upon statistically flawed design equations and failure to incorporate economic optimization”. Another study conducted by Strategic Highway Research Program (SHRP) ⁽¹⁰⁾, Evaluation of the AASHTO Design Equations and Recommended Improvement, shows that although many improvements have been made to the original AASHTO design equations, the equations still do not fully describe data for North American Pavements. In fitting the observed data to the flexible design equation, the coefficient of determination (R squared) never exceeded 0.25, indicating a poor fit. In fitting the observed data to the rigid design equation, the results of a t-test show that the data distribution may be statistically significant at 50 percent reliability, but not at 90 percent ⁽¹¹⁾.

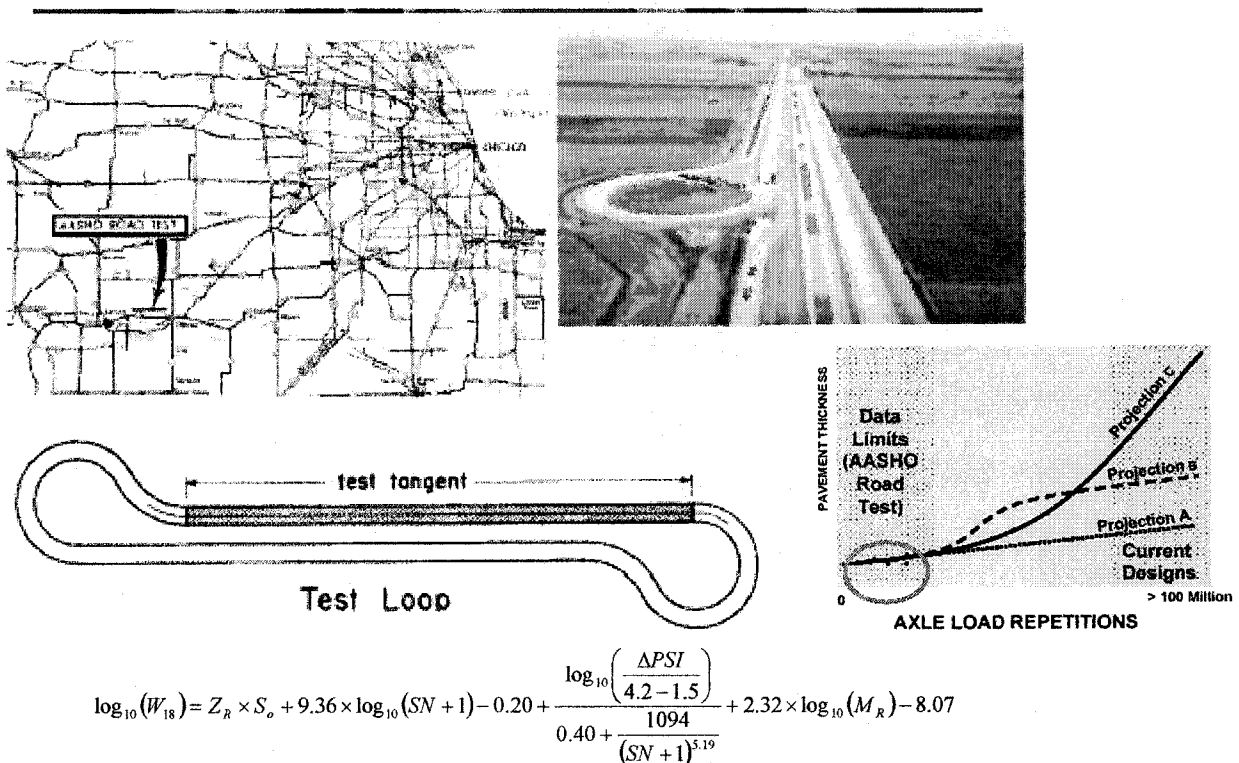


Figure 3-1: AASHTO road test (1958-1960), design equation for flexible pavement and limited load application plot. [Source: Reference 46]

Despite the critique, the AASHTO guide for design of pavements have served well over the past few decades. Nevertheless, many serious limitations exist if their use is to be continued:

- *Traffic loading deficiencies:* Heavy truck traffic volume levels have increased tremendously since the design of pavements used in the 1960's.
- *Rehabilitation deficiencies:* Pavement rehabilitation design procedures were not considered. The AASHTO road test procedures used in the 1993 guide are empirical and limited in their consideration of heavy traffic.
- *Climatic effect deficiencies:* It is impossible to address the effects of different climatic conditions on pavement performance, because the AASHTO road tests were conducted at one specific geographic location.
- *Subgrade deficiencies:* Many types of subgrades exist nationally, resulting in different performance of highway pavements. But, only one type of subgrade was used for all test sections on the road test.
- *Surfacing material deficiencies:* Only one hot mix asphalt (HMA) mixture and one Portland cement concrete (PCC) mixture was used at the road test.
- *Base course deficiencies:* Only two unbound dense granular base/sub base materials were included in the main flexible and rigid pavement section of the AASHTO road test.
- *Truck Characterization deficiencies:* Vehicle suspension, axle configurations, tire type and pressures were the representatives of the types used in the 1950's, many of which are outmoded today.
- *Design life deficiencies:* Because of the short duration of the road test, the long-term effects of climate and aging were not addressed.
- *Performance deficiencies:* The pavement failure modes: rutting, thermal cracking and faulting were not considered when calculating the serviceability of the roadway; instead only pavement thickness was considered.
- The only material property incorporated in the previous AASHTO flexible pavement design procedure was the loosely defined layer coefficient "a". The procedure used cannot determine the required thickness of asphalt-bound material to limit fatigue cracking.

3.3 Mechanistic-Empirical Approach

This critique, between the mechanistic and the empirical approaches, prompted need for more comprehensive tools for pavement design and rehabilitation. A number of mechanistic equations have been developed from LTPP (Long Term Pavement Performance) data in the SHRP study ⁽¹⁰⁾. The AASHTO 2002 (not released yet) guide for design of pavement structure incorporates mechanistic principles. Mechanistic-empirical approaches realistically characterize the behavior of in-service pavements, and have the capability of capturing pavement damage more accurately. The approach incorporates proven technology to account for the changes in climate, traffic loading and material properties during pavement life; and the impact on performance to identify pavement designs that meet the expectations of service life and performance.

The concept of pavement performance includes consideration of functional performance, structural performance and safety. The structural performance of the pavement relates to its physical condition; that is, fatigue cracking, rutting or other conditions that would adversely affect the load-carrying capability of the pavements' structures. The functional performance of the pavement structures concerns how well the pavement serves the highway user and is measured by International Roughness Index (IRI). The typical as-constructed and failure values of IRI are 50 to 100 in/mi and 150 to 200 in/mi, respectively.

In addition to deterioration models developed by SHRP, AASHTO 2002, and World Bank studies, a number of software such as, KENLAYER, VESYS, ELSYM5, MICH-

PAVE and DAMA are available for mechanistic analysis. This following section discusses the different mechanistic or mechanistic-empirical models.

3.4 AASHTO 2002

The long-awaited AASHTO 2002 guide is expected to be released by the end of 2005. Currently, the manual and software both are under review for QA/QC. This guide, when completed, will be a comprehensive procedure that addresses the design of the total pavement structure, not just layer thickness. The ultimate aim of the guide for Mechanistic-Empirical (M-E) design of new and rehabilitated pavement is to provide the highway community with a state-of-the-practice tool that is based on mechanistic-empirical principles.

The Mechanistic-Empirical design procedure included in the design guide provides the tool for evaluating the effect of variations in materials on pavement performance, and provides rational relationship between construction and material specification, and design of pavement structures. The guideline utilizes the analytical solution to the state of stress or strain within a pavement using a multilayered elastic theory, similar to one used by Huang ⁽²¹⁾. The stress solutions are characterized by two material properties for each layer: Poisson's ratio, μ , and elastic modulus, E . Considering triaxial stress of any element, the strains may be determined from the following equation ⁽⁵¹⁾:

- $\epsilon_z = (1/E)[\sigma_z - \mu(\sigma_r + \sigma_t)]$
- $\epsilon_r = (1/E)[\sigma_r - \mu(\sigma_z + \sigma_t)]$
- $\epsilon_t = (1/E)[\sigma_t - \mu(\sigma_z + \sigma_r)]$

The design approach of AASHTO 2002 guide consists of three major stages. Stage 1 consists of development of input values for the analysis. During the first stage, pavement material characterization and traffic data input data are developed. An Enhanced Integrated Climate Model (EICM) is used to model moisture and temperature within the pavement layer and subgrade. Stage 2 of the process is structural/performance analysis. The analysis process is iterative and begins with an initial design. The design requires an estimate of layer thickness, geometric features, initial smoothness, required repairs to existing pavements, pavement material characteristics, and many other inputs. The trial section is analyzed incrementally over time using pavement response and distress models, and the outputs of the process are accumulated damage, the expected amount of distress and smoothness over time. If the trial design does not meet the performance criteria, modifications are made and the analysis is re-run until satisfactory results are obtained. Stage 3 consists of engineering analysis and life cycle cost analysis of the alternatives.

The hierarchical approach is employed with regards to traffic, materials, and environmental inputs. In general, three levels of inputs are provided. **Level 1** inputs provide for the highest level of accuracy and are typically used for designing heavily trafficked pavements, or wherever there are dire safety or economic consequences of early failure. **Level 2** inputs provide an intermediate level of accuracy. This level can be used when resources or equipments are not available for tests required for level 1. **Level 3** inputs provide lowest level of accuracy. This design may be used for design where there are minimal consequences for early failure. However, the use of level 3 inputs by default may kill the purpose of using a mechanistic procedure.

The guide eliminates the equivalent single axle load (ESAL) approach, and uses the full spectra of axle loads applied to a pavement structure by the prevailing or projected traffic stream. However, an ESAL conversion capability is included so that the earlier mathematical models based on ESAL can still be used.

3.4.1 AASHTO Distress Prediction Models:

A variety of structural distresses are considered in flexible pavement design and analysis.

These include:

- Bottom-up fatigue (or alligator) cracking
- Surface down fatigue (or longitudinal) cracking
- Permanent deformation (or rutting)
- Thermal cracking

Fatigue cracking:

The design guide utilizes an approach that models both the top-down and bottom-up cracking. The approach is based on calculating the fatigue damage at the surface for the top-down cracking and at the bottom of each asphalt layer for the bottom-up cracking.

The failure criterion for the fatigue cracking is expressed as ⁽⁵¹⁾:

$$N_f = f_1 (\epsilon_t)^{-f_2} (E1)^{-f_3}$$

Where N_f is the allowable number of load repetitions to failure for fatigue cracking; ϵ_t is the tensile strain at the bottom of asphalt layer; $E1$ is the elastic modulus of asphalt layer; and f_1 , f_2 , f_3 are constants determined from fatigue beam test in the laboratory. The damage ratio, which is a ratio between the actual number of load repetitions and the allowable number of load repetitions, is computed for each load in each season and

accumulated over the years. Estimation of fatigue damage is based upon Miner's Law, which states that damage is given by the following relationship:

$$D = \sum_{i=1}^T (n_i / N_i)$$

where:

D = damage ratio

T = total number of periods

n_i = actual traffic for period i

N_i = traffic allowed under conditions prevailing in i

Permanent Deformation (Rutting):

The rutting is estimated for each sub season at the mid-depth of each sub layer within the pavement system. To estimate the pavement deformation of each individual sub layer, the system verifies the type of layer, applies the model corresponding to the material type of the sub layer, and computes the plastic strain accumulated at the end of each sub season. For asphalt mixtures, it is assumed that the permanent strain is proportional to the resilient strain as represented by the following equation:

$$\epsilon_p / \epsilon_r = 0.0007 \beta_{r1} T^{1.734\beta_{r2}} N^{0.39937\beta_{r3}}$$

in which ϵ_p = permanent strain; ϵ_r = resilient strain; T = AC temperature; N = number of load repetitions; and β 's are calibration factors. The numerical coefficients are obtained from laboratory test and should be adjusted in the field by calibration factors. The overall permanent deformation for a given season is the sum of permanent deformations for each individual layer, and is mathematically expressed as:

$$RD = \sum_{i=1}^{n_{sublayers}} \epsilon_p^i h^i$$

where:

RD = Pavement permanent deformation

$N_{sublayers}$ = Number of sublayers

ξ_p^i = Total plastic strain in sublayer i

h^i = Thickness of sublayer i

Thermal Cracking:

The AASHTO thermal cracking model is basically the same as in the SHRP superpave performance model (Lytton, et al. 1993). The amount of transverse cracking expected in the pavement system is predicted by relating the crack depth to an amount of cracking by the following expression:

$$C_f = \beta_1 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

where:

C_f = Observed amount of thermal cracking

β_1 = Regression coefficient determined through field calibration

$N(z)$ = Standard normal distribution evaluated at (z)

σ = Standard deviation of the log of the depth of cracks

C = Crack depth

h_{ac} = Thickness of asphalt layer

Smoothness (IRI) Prediction

The IRI over the design period depends upon the initial as-constructed profile of the pavement from which the initial IRI is computed, and upon the subsequent development of distresses over time. These distresses include rutting, bottom-up/top-down fatigue cracking, and thermal cracking for flexible pavements. The IRI model uses the distresses predicted using the models included in this guide, initial IRI, and site factors to predict

smoothness over time. The site factors include subgrade and climatic factors to account for the roughness caused by shrinking or swelling soils, and frost heave conditions. IRI is estimated incrementally over the entire design period.

$$IRI = IRI_0 + \Delta IRI$$

3.5 World Bank Highway Development and Management Model (HDM-4)

The Highway Design and Maintenance Standards Model (HDM-III), developed by the World Bank, has been used for over two decades to combine technical and economic appraisals of road projects. The scope of HDM-4 has been broadened considerably beyond traditional project appraisals, to provide a powerful system for the analysis of road management and investment alternatives. The first move towards producing a road project appraisal model was made in 1968 by the World Bank (WB). The first model was produced in response to the terms of reference for a highway design study produced by World Bank in conjunction with the Transportation and Road research laboratory (TRRL), and the Laboratoire des Ponts et Chaussees (LCPC). Following this, TRRL in collaboration with the World Bank, undertook a major field study in Kenya to investigate the deterioration of paved and unpaved roads as well as the factors affecting the vehicle operating costs in developing countries. The work was further undertaken in a number of countries in 1982 to extend the geographic scope of the HDM model including the Caribbean study, India Study and the Brazil Study. While most applications of the various models have been utilized in developing countries, in recent years many industrial countries have begun to make use of the model. This has resulted in the need for additional capabilities to be included, such as models for traffic congestion effects,

cold climate effects, a wide range of pavement types and structures, road safety and environmental effects.

3.5.1 Analytical Framework

The HDM-4 analytical framework is based on the concept of pavement life cycle analysis. This is applied to predict the road deterioration, roadwork effect, road user effect, and socio-economic and environmental effects over the life cycle of a road pavement, which is typically 15 to 40 years. Once constructed, road pavements deteriorate as a consequence of several factors, most notably traffic loading, environmental weathering and effect of inadequate drainage system. Figure 3-2 illustrates the predicted trend in pavement performance represented by the riding quality measured in terms of international roughness index (IRI). The impacts of the road condition, as well as road design standards, on road users are measured in terms of road user costs, and

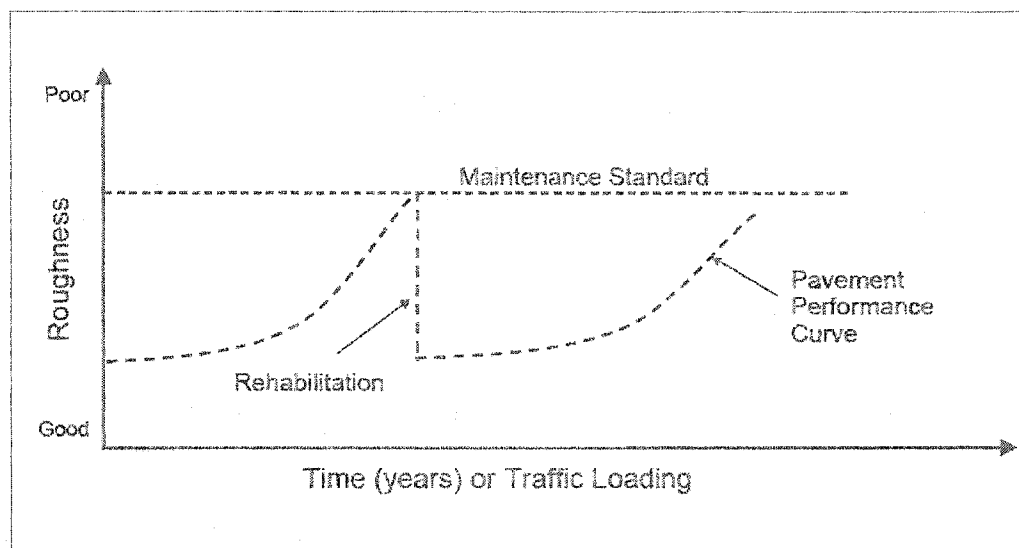


Figure 3-2: Predicted trends in pavement performance [source: HDM –4; volume four]

other social and environmental effects. Road user costs comprise of vehicle operation costs, cost of travel time, cost to the economy of road accidents. The social and environmental effects comprise vehicle emission, energy consumption, traffic, noise and other welfare benefits to the population served by the roads. The overall structure of HDM-4 is illustrated in Figure 3-3. The data manager consists of:

1. *Road Network*: Defines the physical characteristics of road sections in the network to be analyzed.
2. *Vehicle Fleet*: Defines the characteristics of vehicle fleets to be operated on the road network.
3. *Road Work*: Defines the maintenance and improvement standards, together with their unit cost, which will be applied to the different road sections.
4. *HDM Configuration*: Defines the default data to be used in the applications.

Technical analysis within the HDM-4 is undertaken using the following four sets of models ⁽⁴⁹⁾:

1. *Road Deterioration (RD)*: Predicts pavement deterioration for bituminous, concrete and unsealed roads.
2. *Work Effects (WE)*: Simulates the effect of road works on pavement condition and determines the corresponding costs.
3. *Road User Effect (RUE)*: Determines cost of vehicle operation, road accidents and travel times.
4. *Social Environmental Effects (SEE)*: Determines cost of vehicle emissions and energy consumptions.

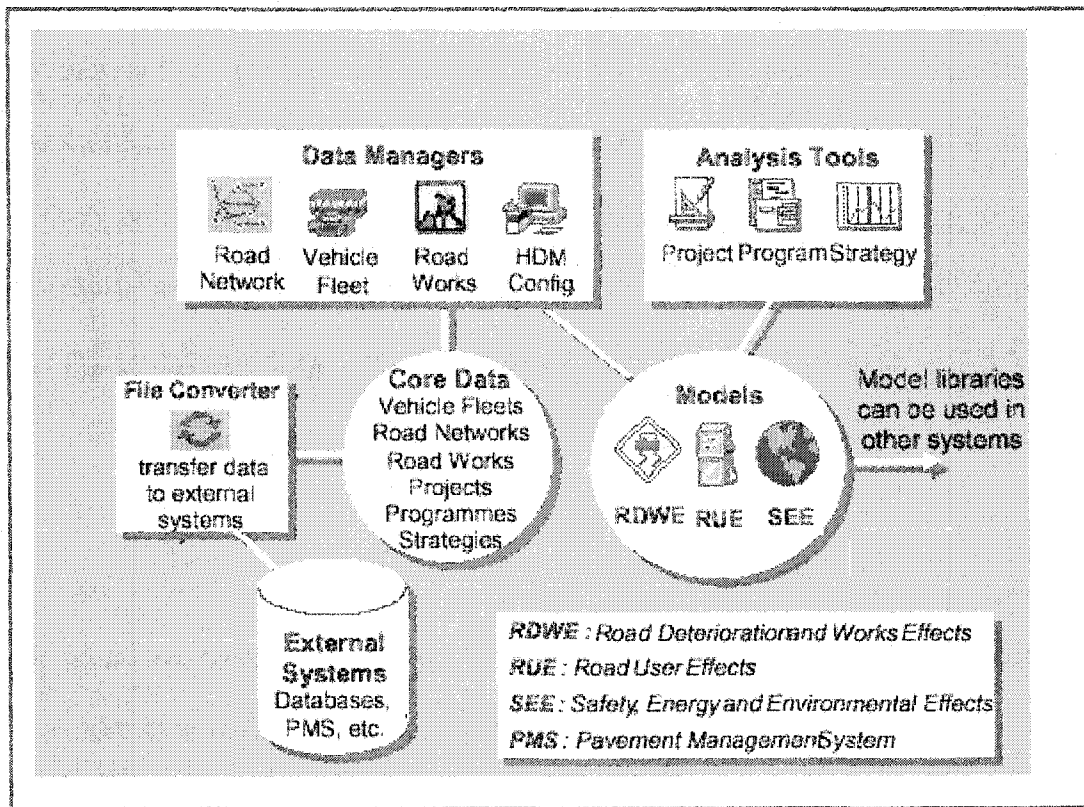


Figure 3-3: HDM-4 System Architecture [source: HDM –4; volume one]

3.5.2 Pavement Deterioration Models

HDM-4 adopted a structured empirical (also known as a mechanistic-empirical) approach for developing road deterioration models. This approach had the advantage that the resulting models combined both the theoretical and experimental bases of mechanistic models with the behavior observed in empirical studies. Road deterioration is predicted through eight separate distress modes, namely: cracking, ravelling, potholing, edge-break, rutting, roughness, texture depth, and skid resistance. Among them, the most critical distresses used as pavement failure criteria are cracking, rutting and roughness.

Crack Modeling:

Cracking is one of the most important distresses in bituminous pavements. Fatigue and aging have been identified as the principle factors which contribute to cracking of bituminous pavement layers. The propagation of the cracking is accelerated through the embitterment resulting from aging and the ingress of water, which can significantly weaken the underlying pavement layers. There are two types of cracking considered in HDM-4:

1. *Structural cracking*

This is effectively load and age/environment associated cracking.

2. *Transverse thermal cracking*

This is generally caused by large temperature changes or in freeze/thaw conditions, and therefore usually occurs only in certain climates.

For each type of cracking, separate relationships are given in HDM for predicting the time to initiation and then the rate of progression. The *structural cracking* is modeled based on the relationship derived by *Paterson (1987)*. The crack initiation is said to occur when 0.5% of the carriageway surface area is cracked. A sample initiation equation is given below⁽⁵⁰⁾:

$$ICA = K_{cia} \left\{ CDS^2 a_0 \exp \left[a_1 SNP + a_2 \left(\frac{YE4}{SNP^2} \right) \right] + CRT \right\}$$

where:	ICA	time to initiation
	K _{cia}	calibration factor for initiation of all structure cracking
	CDS	construction defects indicator for bituminous surfacing
	SNP	average annual adjusted structural number
	YE4	annual number of equivalent standard axles (millions/lane)
	CRT	crack retardation time due to maintenance (years)

ao, a1, a2 coefficient values for initiation of all structural cracking

The transverse thermal cracking is modeled as cracking intensity expressed as the number of cracks per kilometer/mile. A coefficient of thermal cracking (CCT) is used as a variable to predict time to initiation of thermal cracks for the various climate zones. A distinction is made between the time to initiation of transverse thermal cracking in original surfacing, and in overlays or reseals.

Rut depth

Rut depth is defined as the permanent or unrecoverable traffic-associated deformation within pavement layers that, if canalized into wheel paths, accumulates over time and becomes manifested as a rut. Rut depth modeling is performed after the values of all the surface distress at the end of the year have been calculated. The HDM rut depth model is based on the following four components. The total rut depth at any time is the sum of the following four components:

1. *Initial densification:* The initial densification depends upon the degree of relative compaction of the base, sub-base and selected subgrade layers. The key inputs to compute the initial densification in HDM models are: annual number of equivalent standard axle (million/lane), average annual Benkelman beam deflection (mm), average annual adjusted structural number of the pavement, relative compaction (%) and calibration factor for initial densification.
2. *Structural deformation:* The structural deformation model used in HDM-III has been simplified into a linear form for inclusion in HDM-4. Separate terms are proposed for structural deformation without cracking and structural deformation after cracking. The key inputs to compute the structural deformation in HDM

models are: mean monthly precipitation (mm/month), area of indexed cracking at the beginning of the analysis year, annual number of equivalent standard axles (millions/lane), average annual adjusted structural number of the pavement and calibration factor for structural deformation.

3. *Plastic deformation*: The plastic deformation includes a variable, CDS-construction defects indicator, which indicates whether the surfacing is prone to plastic deformation. Other inputs are: annual number of equivalent standard axle (millions/lane), speed of heavy vehicles, total thickness of bituminous surface and the calibration factor for plastic deformation.
4. *Surface Wear*: The surface wear model is applied to environments where vehicles use studded tires during the freezing period. The inputs in the HDM model are the annual number of vehicle passes with studded tires in one direction, average traffic speed, a variable for salted or unsalted road, road width and the calibration factor for surface wear.

Roughness

The roughness model consists of several components including structural deformation, cracking, rutting, potholing, environment and maintenance. The total incremental roughness is the sum of these components. The structural component of roughness relates to the deformation in the pavement material under the shear stress imposed by traffic loading. The incremental changes in roughness due to cracking depend on the incremental changes in area of total cracking during the analysis year. The variation of rut depth also causes the incremental change in roughness due to an incremental change in standard deviation of rut depth during the analysis year. The environmental component

of roughness is due to factors, which include temperature and moisture fluctuations, and foundation movements.

3.6 SHRP Damage Models

SHRP (Strategic Highway Research Program) studies attempted to develop a number of equations from the LTTP (Long Term Pavement Performance) data for predicting distresses and increases in roughness for the various types of pavements under the applicable traffic and environmental conditions. One of the primary objectives of the SHRP study was to improve the ability of highway engineers to design new and overlaid pavement structure. Since 1985, SHRP has been collecting and analyzing data for 770 in-service pavements throughout the United States and Canada.

These initial analyses confirm the belief that “the use of flexible pavement design equation printed in the 1986 AASHTO Design Guide generally represents a serious extrapolation outside the inference space from which the basic equation was derived and that its form does not fit the data from North American flexible pavements ⁽¹⁰⁾”. In addition, the equation appears to predict much higher numbers of ESALs needed to produce a specific Present Serviceability Index (PSI) loss than occurs in reality.

Specific models were developed to predict pavement roughness, rutting, and thermal cracking for flexible pavements and roughness, joint faulting, and transverse cracking for rigid pavements. However, the lack of time-sequence data over reasonable time periods and other data limitations preclude the use of these equations for design at a sufficient confidence level. SHRP recommends the use of the equations for design checks of

pavement structures designed by other procedures; and possibly as a placeholder in pavement management systems until more reliable predictive equations become available. The flexible pavement equations calibrated for New York State are presented below ⁽¹¹⁾:

Roughness Model

$$IRI = N^{0.25} 10^C$$

$$C = 0.0403 + 0.00014AC_{visc} + 0.0704 AC_{void} + 0.314 \log(AC_{thick}) - 0.00162 B_{thick} - 0.00165 DGT + 0.00001628 (FI * AC_{void})$$

Where:	IRI	Roughness (International Roughness Index) (inch/mile)
	N	Cumulative KESAL (1000 ESAL)
	AC _{visc}	Asphalt Viscosity (Poise)
	AC _{void}	Asphalt Air Voids (% Volume)
	AC _{thick}	HMAC Layer Thickness (inch)
	B _{thick}	Base Layer Thickness (inch)
	DGT	Annual Days Greater Than 90 Degrees (days)
	FI	Freeze Index.

Rutting Model

$$RD = N^{0.183} 10^C$$

$$C = 0.0289 - 0.189 \log (AC_{void}) - 0.181 \log (AC_{thick}) - 0.592 \log (AGG) + 0.0000180 AC_{visc} - 0.0436 \log (B_{thick}) + 0.0000323 (PRE * FI)$$

Where :	RD	Predicted Rut Depth (inch).
	AC _{void}	Voids in HMAC Layer (% Volume).
	AC _{thick}	HMAC Layer Thickness (inch).
	AGG	HMAC Aggregate passing Number 4 Sieve (% Weight).
	AC _{visc}	Asphalt Viscosity (Poise).
	B _{thick}	Base Layer Thickness (inch).
	PRE	Annual Precipitation (inch).
	FI	Freeze Index (degree-days).

Thermal Cracking Model

$$CS = N^B 10^C$$

$$B = -0.106 - 0.0074 AC_{thick} - 0.0504 DGT$$

$$C = -0.0201 - 0.0131 AGG + 1.84 PRE - 0.0159 (AC_{thick} * \log(PRE)) + 0.0024 (AC_{thick} * DGT) + 0.00408 (SUB * \log(PRE))$$

Where:	CS	Predicted Crack Spacing (feet).
	AC_{thick}	HMAC Layer Thickness (inch).
	DGT	Annual Days Greater Than 90 Degrees (days).
	AGG	Aggregate Passing Number 4 Sieve (% Weight).
	PRE	Annual Precipitation (inch).
	SUB	Sub-base Passing Number 200 Sieve (% Weight)

3.7 VESYS Model

VESYS is a well-developed probabilistic and mechanistic flexible pavement analysis computer program series. The VESYS series is based on the elastic model of layered homogeneous material in half infinite space with some viscoelastic-plastic theory applications. The pavement models used in VESYS have been calibrated by using full-scale pavement test data, such as AASHO road test data, Federal Highway Administration's Pavement Testing Facility (PTF, or ALF) test data, etc. The pavement performance models used in VESYS include rutting, fatigue cracking, low temperature cracking, roughness and PSI. The following briefly describes the makeup of several of these models.

Rutting Model

There are two rutting models available in VESYS, "Layer Rutting" and "System Rutting" models. The layer-rutting model estimates the permanent deformation in each finite layer

as the product of the elastic compression in that layer and the layer material permanent deformation law associated with that layer. The layer rutting model is expressed by ⁽³⁶⁾

$$R_D = \int_{N_1}^{N_2} U_s^+ \frac{e_t}{e_s} \mu_{sub} N^{-\alpha_{sub}} + \sum_{i=1}^{n-1} \int_{N_1}^{N_2} (U_i^+ - U_i^-) \mu_i N^{-\alpha_i}$$

where U_s^+ = deflection at top the subgrade due to single axle load; U_i^+ and U_i^- = deflection at top and bottom of finite layer i due to the axle group; e_t = strain at top of subgrade due to the axle group; e_s = strain at top of subgrade due to a single axle; μ_{sub} and α_{sub} = permanent deformation parameters of the subgrade; and μ_i and α_i = permanent deformation parameters of layer i ; and N is the number of load repetitions.

The system rutting formulation treats the pavement system as a whole, and first calculates an equivalent set of pavement system permanent deformation parameters, μ_{sys} and α_{sys} , which are determined as functions of load repetitions by least square regression analysis. Pavement surface rut depth is estimated as.

$$R_D = \int_{N_1}^{N_2} U \mu_{sys} N^{-\alpha_{sys}} dN$$

where U is pavement surface deflection.

Fatigue Cracking Model

The fatigue cracking area is determined as follows. First, the number of fatigue cycles (to fatigue cracking) N_q is evaluated by

$$N_q = K_1 \varepsilon^{-K_2}$$

where ε = maximum tensile strain; K_1 and K_2 = model parameters.

The fatigue cracking prediction is based on a probabilistic Miner's hypothesis by assuming that the fatigue ratio is normally distributed; and the cracked area of the pavement is related to the probability of the fatigue ratio. The expected value of the fatigue ratio is (assuming that n_q and N_q are independent)

$$E[C] = \sum_{q=1}^Q E[n_q] E\left[\frac{1}{N_q}\right]$$

Where n_q = current number of load repetitions in the q^{th} incremental analysis period (time interval); N_q = number of load repetitions to fatigue failure in the q^{th} time interval.

Roughness Model

The roughness model is represented by the slope variance, SV, of the longitudinal pavement surface. The slope variance is expressed by

$$SV = \frac{2B}{C^2} \text{Var}(\eta) E[R_D]^2$$

where B and C are pavement system properties defining correlation along the pavement; η is a random variable expressing the variation in material properties along the pavement; and $E[R_D]$ is the mean of rut depth.

Present Serviceability Index (PSI) Model

PSI is defined by AASHTO as

$$PSI = 5.03 - (1.91)\log_{10}(1+SV) - (1.38)R_D^2 - 0.01(C+P)^{0.5}$$

where SV = slope variance, $\text{radian} \cdot 10^{-6}$; R_D = average rut depth, in.; and C+P = surface area of AASHO Class 2 and 3 cracking and patching, $\text{ft}^2/1000 \text{ ft}^2$.

3.8 KENLAYER

The KENLAYER computer program was developed by Huang ⁽²¹⁾. The program is meant to be applied to flexible pavements with a multilayered system under stationary or moving multiple wheel loads, with each layer being either linear elastic, nonlinear elastic or viscoelastic. KENLAYER can perform damage analysis by dividing a year into a number of periods; each having a different set of properties and subjected to varying repetitions of different axle loads. The damage caused by fatigue cracking and permanent deformation in each period over all load groups is summed up to evaluate the design life. The damage analysis is performed for both fatigue cracking and permanent deformation. The reciprocal of the damage ratio is the design life of the pavement.

Damage analysis is based on the horizontal tensile strain at the bottom of the specified asphalt layer, and the vertical compressive strain on the surface of the specified layer, usually the subgrade. To determine the allowable number of repetitions to prevent fatigue cracking, it is necessary to know the elastic modulus of the hot mix asphalt. If the hot mix asphalt is specified as viscoelastic, its elastic modulus is not a constant; but depends on the duration of loading. If the layer is linear elastic, the modulus is constant and no further work needs be done to determine its value. If the layer is nonlinear elastic, the modulus varies with the state of stresses, and a method of successive approximation is applied until it converges.

Fatigue Cracking

The failure criterion for fatigue cracking is expressed as:

$$N_f = f_1(\epsilon)^{-f_2} (E_1)^{-f_3}$$

where N_f is the allowable number of load repetitions to failure for the fatigue cracking; ϵ_t is the tensile strain at the bottom of asphalt layer; E_1 is the elastic modulus of asphalt layer; and f_1 , f_2 , and f_3 are constants determined from laboratory fatigue tests with f_1 modified to correlate with field performance observations.

Permanent Deformation

The failure criterion for permanent deformation is expressed as:

$$N_d = f_4(\epsilon_c)^{-f_5}$$

where N_d is the allowable number of load repetitions to limit permanent deformation, ϵ_c is the compressive strain on the top of subgrade, and f_4 and f_5 are constants determined from road tests or performance.

Further details of KENLAYER model including the procedure for calculating the tensile strain (ϵ_t), compressive strain (ϵ_c), modulus of elasticity (E) and design life is presented in chapter 5.

3.8.1 Axle Load

The KENLAYER program uses load spectra instead of traditional ESALs. Each axle-load group can be considered separately, and each year can be divided into a number of periods with widely different material properties for damage analysis. A series of data elements are used to describe the details of the tire and axle loads for use in the pavement damage model. These include: tire pressure or hot inflation pressure; tire and axle load; axle and tire spacing; and average number of axles by axle type for each truck class. Moreover, KENLAYER has the capability to model speed, which is one of the most important factors influencing pavement damage. Speed is directly related to the duration

of loading. Higher speeds reduce the time duration of wheel load on a given pavement location.

The next chapter compares the different models with discussion of pros and cons for each model, and selects the most appropriate model for the analyses in this dissertation.

CHAPTER 4

SELECTION OF PAVEMENT DAMAGE PREDICTION MODEL

4.1 ESAL vs Load Spectra

Before comparing mechanistic models, it is worthwhile to explore the most significant factor used in pavement design and rehabilitation, that is, Equivalent Single Axle Load (ESAL). The number of ESALs is the traffic feature that has been required for most pavement structural design procedures, including the 1993 AASHTO Design Guide. The agencies take the load information from static weigh station or weigh-in-motion (WIM) stations and then convert that data into relatively simple multipliers, sometimes referred to as truck equivalency factors. These factors represent each truck type in the traffic stream. These multipliers are used to convert mixed streams of traffic into the number of (ESALs). The equivalency factors used to determine the number of ESALs are based on the Present Serviceability Index (PSI) concept, and are dependent on the type and thickness of the pavement (e.g., rigid versus flexible). The difference of using an ESAL versus actual load repetitions was evaluated in the following section using a mechanistic tool (KENPAVE).

An analysis was conducted using data presented in Huang's [21] Table 6.11 (see Table 4-1) to incorporate 12 load groups, which is the maximum capability of the KENPAVE modeling software. These 12 load groups consist of 4 single axle subgroups ranging from 7,000 to 29,999 lbs and 8 tandem axle subgroups ranging from 6,000 to 35,999 lbs. A total of 497 axles including 167 single axles and 330 tandem axles were counted. Each load group was converted into standard equivalent 18,000 lbs. single axle load (ESALs)

using AASHTO Equivalent Axle Load Factor (EALF) assuming a structural number of 5.0 and terminal serviceability of 2.5. When the total 497 tandem and single axles with different load groups were converted into 18,000-ESALs, the total was 255 repetitions.

The load was applied on a three layer flexible pavement system with one 6"-viscoelastic layer and two linear elastic layers with modulus of elasticity of 30,000 (8"-basecourse) and 15,000 psi (subgrade). A Poisson ratio of 0.5 is used for all pavement layers. The tire pressure was assumed to be 80 psi. A speed of 40 mph (load duration of 0.1 sec) was assumed.

KENPAVE was run with one 18 kip load group with 255 repetitions - converted ESALs (*see Table 4-1*). The maximum tensile strain damage ratio at the bottom of layer 1 was found to be 2.096×10^{-5} inches. A second model run was conducted using the 12 load groups; and the actual number of repetitions for a total of 497 repetitions (combined repetitions of the 12 groups with 167 single and 330 tandem axles). KENPAVE indicated that with this number of repetitions the maximum tensile strain damage ratio at the bottom of layer 1 was 1.645×10^{-5} inches. In conclusion, the actual load repetitions results in 27% less damage than that calculated using standard ESALs. This implies that converting the actual load spectra into equivalent single axle load may result in an over design of flexible pavement, and therefore should only be use as an approximation.

4.2 Truck Factor

Most of the agencies use a Truck Factor, a simplified approach, to convert the Annual Average Daily Truck Traffic (AADTT) into ESALs. The Truck Factors are determined

by taking the total ESALs for all load groups, as computed in Table 4-1, and dividing it by the number of trucks weighed at the weigh station. Another analysis was conducted using KENPAVE to compare the ESAL conversion, using a truck factor versus actual load repetitions and axle configuration. For this example, a total of 165 trucks were weighed, therefore using standard ESALs the truck factor is 1.546 ($TF=255.15/165$). The AADT (average annual daily traffic) was assumed to be 12,000 vehicles with 25% trucks, 50% directional distribution and 100% lane distribution. The annual repetitions were computed using a TF of 1.546 = 846,621 repetitions per year (see Table 4-2).

For the first model run, data was entered for one 18 kip load group with 846,621 repetitions per year. The result was a maximum tensile strain damage ratio of 6.953×10^{-2} and a design life of 14.38 years. KENPAVE was run again using actual repetitions for each axle, based upon the truck percentage of traffic, a total of 547,500 repetitions (see Table 3). All other inputs remained identical to the previous run. The result was a maximum tensile strain damage ratio of 1.812×10^{-2} and a design life of 55.18 years.

The conclusion of the second analysis is that the damage ratio obtained when one truck factor is applied uniformly to all axles, with the standard ESALs and 18,000 repetitions, is 3.83 times higher than the damage ratio when each axle is considered individually with actual load and axle configuration. Using actual data, there were a total of 547,500 repetitions per year for axles with varying loads, as compared to 846,621 repetitions using 18,000 repetitions of 18 kips single axle. This deviation and approximation leads to an over design of pavements.

TABLE 4-1: Computation of Truck Factor for Trucks with Five or More Axles					
(Huang Table 6.11-Modified for Maximum Allowable of 12 Groups)					
Axle Load Group		Median (Lx)	Axle Counted	EALF	ESALs
Single Axle					
7,000	7,999	7500	6	0.0320	0.19
8,000	11,999	10000	144	0.087	12.53
12,000	15,999	14000	16	0.360	5.76
16,000	29,999	23000	1	5.389	5.39
				Sub Total=	23.87
Tandem Axle					
6,000	11,999	9000	14	0.010	0.14
12,000	17,999	15000	21	0.044	0.92
18,000	23,999	21000	44	0.148	6.51
24,000	29,999	27000	42	0.426	17.89
30,000	32,000	31000	44	0.753	33.13
32,001	32,500	32251	21	0.885	18.59
32,501	33,999	33250	101	1.002	101.20
34,000	35,999	35000	43	1.230	52.89
			497	Total=	231.28
					Total ESAL = 255.15
Truck Factor = Total ESAL / Total Truck weighted					
LEF= 255.15/165 = 1.546 (NYS TF =1.35 -Flexible)					

TABLE 4-2: ESAL'S CALCULATION							
W18(1yn)= AADT * %veh * LEF * Dd * DI * 365							
AADT	% Truck	LEF	Dd	DI	No. of Days	W18(1yn)	Without LEF
12000	25%	1.546	50%	100%	365	846,621	547,500

TABLE 4-3: KENPAVE INPUT DATA					
ADTT=12000x25%x50%= 1500					
ADDT xTruckx DD					
SA=4 Tires, Tandem=8 Tires					
Proportion	Annual Repetitions	Load per Tire	TP=CP	Contact Area	Contact Radius
1.21%	6610	1875	80	23.44	2.73
28.97%	158632	2500	80	31.25	3.15
3.22%	17626	3500	80	43.75	3.73
0.20%	1102	5750	80	71.87	4.78
2.82%	15423	1125	80	14.06	2.12
4.23%	23134	1875	80	23.44	2.73
8.85%	48471	2625	80	32.81	3.23
8.45%	46268	3375	80	42.19	3.66
8.85%	48471	3875	80	48.44	3.93
4.23%	23134	4031	80	50.39	4.01
20.32%	111263	4156	80	51.95	4.07
8.65%	47369	4375	80	54.69	4.17
100.00%	547,500				

The above two analyses conclude that use of ESAL instead of actual load to allocate pavement damage and cost responsibility for each individual vehicle or class of a vehicle is misleading, and does not capture the fair share of damage each vehicle inflicts on a pavement. Moreover, use of ESAL should be avoided in design procedures as well, and actual load spectra should be used instead. However, if ESAL is used, it should be considered as an approximation only.

4.3 Empirical Models

Several empirical and mechanistic-empirical models were reviewed in this chapter. AASHTO empirical equations do not capture the pavement response because the design procedures were limited in consideration of heavy traffic, surface material, base course material, number of load repetitions, climatic conditions, geographic location, vehicle characterization and the short duration of the road test. In addition, the pavement failure modes: rutting, thermal cracking and faulting were not considered in calculating the serviceability of the roadway; instead only pavement thickness was considered. Therefore, this procedure does not meet the purpose of this dissertation, which is to estimate the pavement damage caused by a particular type of truck carrying a particular weight randomly distributed over the axles, and traveling at a certain speed with a preset tire pressure. A study conducted by Strategic Highway Research Program (SHRP)⁽¹⁰⁾, Evaluation of the AASHTO Design Equations and Recommended Improvement, shows that although many improvements have been made to the original AASHTO design equations, the equations still do not fully define data for North American Pavements. In fitting the observed data to the flexible design equation, the coefficient of determination (R squared) never exceeded 0.25, thus indicating a poor fit. In fitting the observed data to

the rigid design equation, the result of a t-test shows that the data distribution may be statistically similar at 50 percent reliability, but not at 90 percent ⁽¹¹⁾.

4.4 Mechanistic Models

Traffic data is one of the key data elements required for the design/analysis of pavement structures. For evaluating or designing for specific distresses using mechanistic-based pavement performance models, the use of ESAL data is limited and unwarranted because of the approximation and conversion issues discussed above. This dissertation is intended to quantify the pavement damage caused by an individual truck and, therefore, use of ESAL may be misleading. In other words, the actual traffic data measured along roadways should be used, rather than the conversion of that data into a number that is distress, pavement type and thickness dependent.

Both SHRP and HDM models use ESALs that are not a desirable input for mechanistic models. Due to lack of time-sequence data over reasonable time periods and other data limitations, the SHRP study does not recommend the use of the deterioration equations, which were presented in the previous chapter, for design purposes. Rather the study recommends a possible placeholder in pavement management systems until more reliable predictive equations become available ⁽¹⁰⁾. Moreover, no model was developed for fatigue cracking under the SHRP study because the data was considered inadequate. On the other hand, HDM is an excellent tool to explore the economic viability and investment options of highways, but does not capture the pavement damage caused by an individual truck. HDM could be used for strategy analysis, programming analysis and project analysis.

Due to unexpected delays, the AASHTO 2002 mechanistic guide is still not available. Once released, it will replace the existing empirical AASHTO guidelines; but will take several years to be fully implemented. The guide eliminates the ESAL approach and uses the full spectra of axle loads applied to a pavement structure by the prevailing or projected traffic stream. The basic concepts used in distress prediction models are similar to the models incorporated in KENPAVE, developed by Huang. AASHTO 2002 and KENPAVE both consist of two parts. The first part involves the use of mechanistic structural models to determine the stresses, strains, and displacements in the pavement structure. And the second part involves the use of mechanistic-empirical distress models to predict the type and extent of damage at various times. The major difference between the two would be the International Roughness Index model (IRI), which is incorporated in AASHTO, but not in KENPAVE. On other hand, the advantage of KENPAVE over AASHTO is its ability to incorporate tire pressure and load duration or speed for viscoelastic layers.

The results obtained by KENLAYER compare well with those by other layer system programs such as ELSYM 5, VESYS, and DAMA, but not with those by the finite element program such as MICH-PAVE and ILLI-PAVE. The failure of MICH-PAVE and ILLI-PAVE to obtain linear elastic solutions needs to be resolved before they can be put into practical use. The deflection basin obtained by KENLAYER checks reasonably well with that by MICH-PAVE, but deviates considerably from that by ILLI-PAVE ⁽²¹⁾. Therefore, for the purpose of this research, the KENPAVE model is selected because of its availability and ability to capture the damage caused by an individual truck with specific axle configuration, load distribution, tire pressure and speed.

CHAPTER 5

KENPAVE MODEL INPUT/OUTPUT

5.1 Model Description

The KENPAVE model has two components: KENLAYER and KENSLAB. The KENLAYER computer program can be applied to flexible pavements with no joints or rigid layers. The basic component of KENLAYER is the elastic multilayer system under a circular loaded area. For multiple wheels involving two to six circular loaded areas, the superposition principle was applied because the system is linear. For a single wheel loading, the critical location can usually be determined by inspection. For multiple wheels and/or axles, the critical location will be a function of the wheel load configuration and the pavement structure.

KENLAYER can be applied to layer systems with a maximum of 19 layers, each being either linear elastic, nonlinear elastic or linear viscoelastic. If the layer is linear elastic, the modulus is constant and no further work need be done to it in order to determine its value. If the layer is nonlinear elastic, the modulus varies with the state of stresses and a method of successive approximation is applied until it converges at a specified tolerance. If the layer is viscoelastic, elastic solutions under static loads are obtained at a specific number of time durations, usually 11; and then fitted with a Dirichlet series.

5.2 Input/Output Parameters

The KENLAYER model consists of the following methodology:

1. *Pavement Configuration Input*: The number of layers, the thickness of each layer and type of material.
2. *Material Properties Input*: The basic material properties used in the structural model, such as the resilient moduli of HMA, sub-base and subgrade.
3. *Traffic Input*: The number of load groups, each with different load magnitude and configuration including wheel spacing, contact radius, and contact pressure for structural analysis. Also, the number of load repetitions and load duration or vehicle speed for viscoelastic layer used in damage analysis.
4. *Environmental Input*: The environmental factors that influence pavement design includes temperature and precipitation, both affecting the elastic moduli of the various layers. The severity of cold climate is indicated by a freezing index (degree-days), which can be correlated with the depth of frost penetration. The modulus of the HMA depends on pavement temperature, and the modulus of base and subgrade vary with moisture content.
5. *Climate Models*: Climatic models include the heat transfer model for determining the temperature distribution and evaluating frost action in the multi-layered pavement system; the moisture equilibrium model for determining the moisture distribution in the subgrade; and the infiltration and drainage model for predicting the degree of saturation of granular bases. The moisture equilibrium model assumes that rainwater will drain out quickly through the drainage layer, and that the only water in the subgrade is the capillary water.

6. *Structural Response:* The model computes the structural response of the pavement in term of stress, strain and deflection. The methodology involved in computation is discussed later in this chapter.
7. *Damage Analysis:* The structural responses go into the distress models that compute the fatigue cracking, rutting, and low temperature cracking. Then, based on an allowable and predicted number of load repetitions, the damage ratio and design life is computed. A brief description of distress models is also presented in this chapter.

5.3 Failure Criteria

The purpose of the flexible pavement response model is to determine the structural response of the pavement system due to traffic loads and environmental influences. The outputs from the pavement response models are the stress, strain and displacement within the pavement layers. The critical pavement response variables for the damage analysis include:

- Tensile horizontal strain at the bottom/top of the HMA layer that causes HMA fatigue cracking.
- Compressive vertical stresses/strains at the top of sub grade that causes sub grade rutting.

5.3.1 Fatigue or alligator cracking:

The fatigue cracking first shows up as short longitudinal cracks in the wheel path that quickly spread and become interconnected to form chicken wire/alligator cracking patterns. These cracks initiate at the bottom of HMA layer and propagate to the surface under repeated load application. Basically, the pavement of HMA layer deflects under the

wheel loads that result in tensile strains and stresses at the bottom of the layer. With continued bending, the tensile stresses and strains cause cracks to initiate at the bottom of the layer and thereafter, propagate to the surface. This mechanism is illustrated in Figure 5-1 below. Usually either relatively thin or weak HMA layers or higher wheel loads and higher tire pressures cause this type of distress.

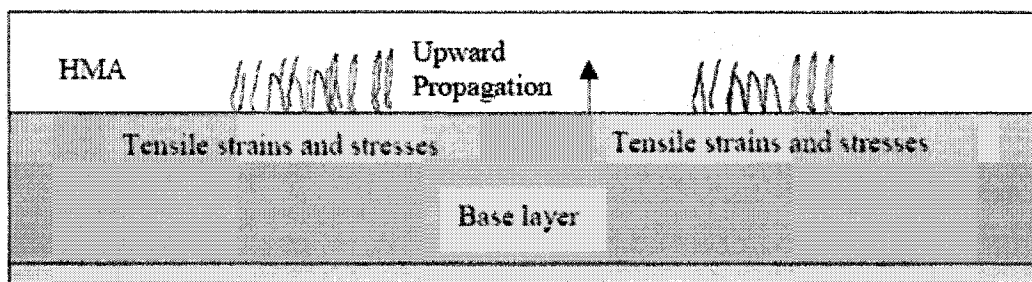


Figure 5-1: Bottom-up fatigue cracking [Source: Reference 51]

The failure criterion relates the allowable number of load repetitions to the tensile strain based on laboratory fatigue tests on small HMA specimens. The most effective way to decrease the tensile strain at the bottom of the asphalt layer is to increase the HMA thickness or the modulus of the base course.

5.3.2 Permanent Deformation or Rutting:

Rutting is a surface deformation in the wheel paths caused by inelastic or plastic deformations in any or all of the pavement layers and subgrade. These plastic deformations are typically the result of: 1) densification or one-dimensional compression and consolidation; and 2) lateral movements or plastic flow of materials from wheel loads.

One-dimensional densification or vertical compression: A rut depth caused by material densification is a depression near the center of wheel path without an accompanying hump on either side of the depression, as shown in the Figure 5-2a. Densification of the materials is caused by excessive air voids or inadequate compaction for any of the bound or unbound pavement layers. This allows the underlying layers to compact when subjected to traffic loads.

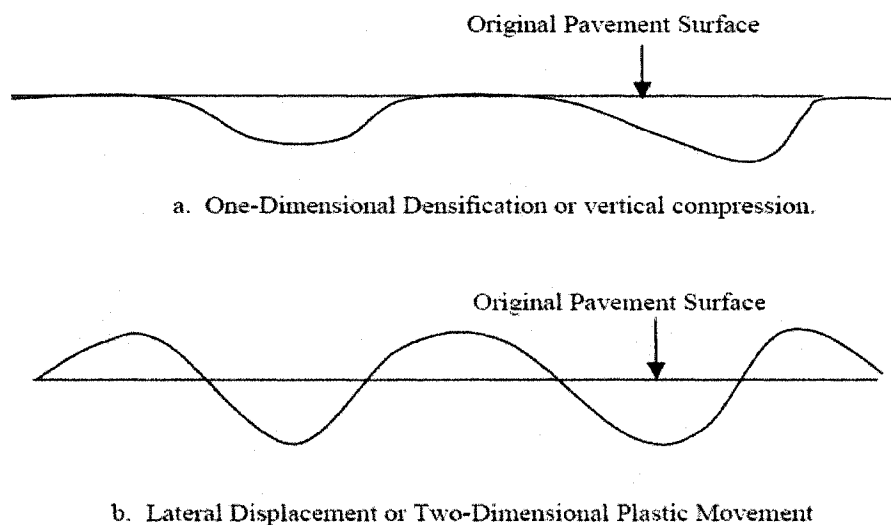


Figure 5-2: Types of rutting in flexible pavements [Source: Reference 51]

Lateral flow or plastic movement: A rut depth caused by the lateral flow of materials is a depression near the center of the wheel path with shear upheaval on either side of the depression, as illustrated in Figure 5-2b. Lateral flow or the plastic movement of the materials will occur in those mixtures with inadequate shear strength and/or large shear stress states due to the traffic loads on the specific pavement cross-section used. Overdensification of the HMA layer by heavy wheel loads can also result in bleeding or flushing in the pavement surface.

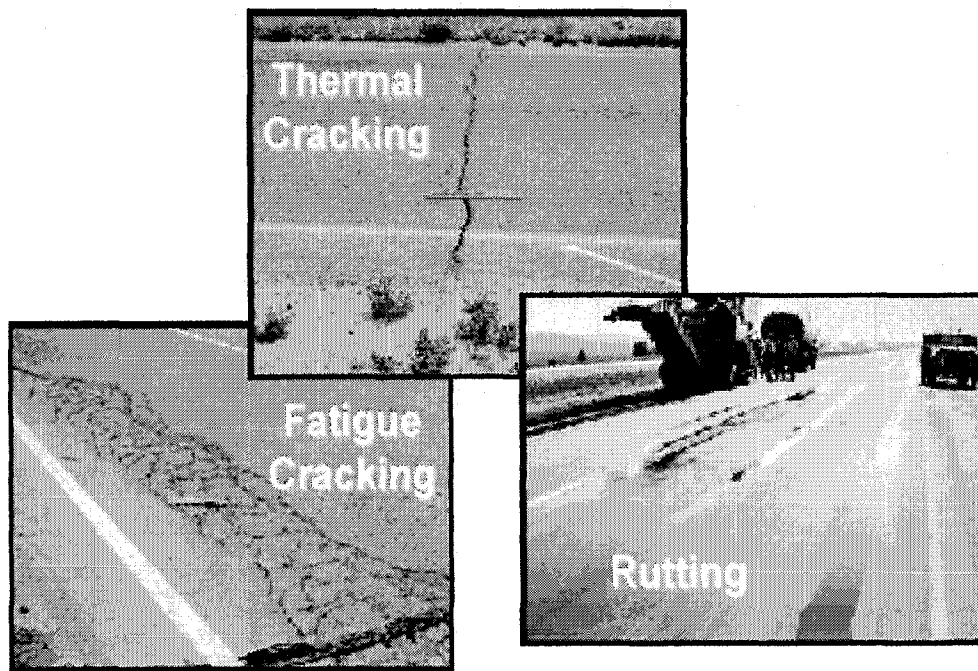


Figure 5-3: Field photos showing thermal cracking, fatigue cracking and rutting

Two design methods have been used to control rutting: one, to limit the vertical compressive strain on the top of subgrade; and the other, to limit rutting to a tolerable amount, for example, 0.38 in (for New York State). The first method, which requires a failure criterion based on correlations with road tests or field performance, is much easier to apply and has been used by Shell Petroleum and the Asphalt Institute as well as KENLAYER. This method is based on the contention that, if the quality of the surface and base courses is well controlled, rutting can be reduced to a tolerable amount by limiting the vertical compressive strain on the subgrade. The second method, which computes directly the rut depth, can be based on empirical correlations with road tests and has been used in SHRP models. If rutting is primarily due to the decrease in thickness for the component layers above the subgrade, as was found in the AASHTO

Road Test, the use of this method should be more appropriate. The most effective way to decrease the compressive strain on top of the subgrade is to increase the thickness of the granular base and subbase, or the modulus of the subgrade. Figure 5-3 exhibits field photos showing thermal cracking, fatigue cracking and rutting.

5.4 Damage Analysis

Damage analysis is performed for both fatigue cracking and permanent deformation (rutting). Damage analysis is based on the horizontal tensile strain at the bottom of the specified asphalt layer usually the HMA, or layer 1, and the vertical compressive strain on the surface of specified layer, usually the subgrade. The failure criterion for fatigue cracking is expressed as:

$$N_f = f_1(\epsilon_t)^{-f_2} (E_1)^{-f_3}$$

Where N_f is the allowable number of load repetitions to failure for the fatigue cracking; ϵ_t is the tensile strain at the bottom of asphalt layer; E_1 is the elastic modulus of asphalt layer; and f_1 , f_2 , and f_3 are constants determined from laboratory fatigue tests with f_1 modified to correlate with field performance observations. The Asphalt Institute used 0.0796, 3.291, and 0.854 for f_1 , f_2 , and f_3 , respectively, in their analytically based design procedure; the corresponding values used by Shell are 0.0685, 5.671 and 2.363. The failure criterion for the permanent deformation is expressed as:

$$N_d = f_4(\epsilon_c)^{-f_5}$$

Where N_d is the allowable number of load repetitions to limit permanent deformation, ϵ_c is the compressive strain on the top of subgrade, and f_4 and f_5 , are constants determined from road tests or field performance. Values of f_4 and f_5 , are suggested as 1.365×10^{-9} and

4.477 by the Asphalt Institute, 6.15×10^{-7} and 0.4 by Shell, and 1.13×10^{-6} and 3.571 by the University of Nottingham.

The vertical compressive strain on the surface of subgrade and the horizontal principle strain in tension at the bottom of asphalt layers are used for the damage analysis. The horizontal tensile strain ϵ_t is computed by:

$$\epsilon_t = (\epsilon_x + \epsilon_y) / 2 - [((\epsilon_x - \epsilon_y)/2)^2 + \gamma^2]^{1/4}$$

where ϵ_x and ϵ_y are strains in x and y directions and γ is the shear strain; and determined from the following equations:

$$\epsilon_x = (1/E) [\sigma_x - \nu (\sigma_z + \sigma_y)]$$

$$\epsilon_y = (1/E) [\sigma_y - \nu (\sigma_z + \sigma_x)]$$

$$\gamma = 2(1 + \nu) (\tau_{xy}) / E$$

5.4.1 Elastic Modulus

To determine the allowable number of repetitions to failure for fatigue cracking, it is necessary to know the elastic modulus of the hot mix asphalt. If the hot mix asphalt is specified as viscoelastic, its elastic modulus is not a constant but depends on the duration of loading. The elastic modulus of a viscoelastic layer to be used to compute fatigue cracking and permanent deformation is computed from the three principal stresses and the minor principal strain by.

$$E = [\sigma_3 - \nu (\sigma_1 + \sigma_2)] / \epsilon_3$$

The same E is obtained if the major principal strain is used:

$$E = [\sigma_1 - \nu (\sigma_2 + \sigma_3)] / \epsilon_1$$

Where σ_1, σ_2 and σ_3 are three principle stresses; ν is poison ratio; ϵ_1 is major principle strain and ϵ_3 is minor principle strain.

5.4.2 Viscoelastic Solutions

A viscoelastic material possesses both the elastic property of a solid and the viscous behavior of a liquid. Due to the viscous component, the behavior of viscoelastic materials is time-dependent: the longer the time subjected to load, the more the flow. Since HMA is a viscoelastic material whose behavior depends on the time of loading, KENLAYER applies the theory of viscoelasticity. There are two general methods to characterize viscoelastic materials: one by a mechanical model and the other by a creep compliance curve. The latter is used in KENLAYER due to its simplicity. Because Poisson ratio, ν , has relatively small effect on pavement behavior, it is assumed to be elastic and independent of time. Therefore, only modulus E is considered to be viscoelastic and time dependent.

The reciprocal of the elastic modulus is called the creep compliance and their values at a number of times must be specified. To obtain the viscoelastic solution for moving loads, the creep compliances must be expressed in a Dirichlet series by the collocation method so that the Boltzmann's superposition principle can be applied. The use of Dirichlet series for creep compliances also makes possible the prediction of creep compliances at any temperature from those at a given temperature. The important information to be provided by the users in KENLAYER is the creep compliances of each layer at 11 different time durations at a reference temperature.

5.4.3 Creep Compliance

Creep compliance, at various times, is used to characterize materials. $D(t)$, is defined as:

$$D(t) = \frac{\epsilon(t)}{\sigma}$$

where $\epsilon(t)$ is the time-dependent strain under a constant stress. And under a constant stress, the creep compliance is the reciprocal of Young's modulus. For the generalized model, the creep compliance can be expressed as:

$$D(t) = 1/E_0 (1+t/T_0) + \sum_{i=1}^n 1/E_i [1-\exp(-t/T_i)] \dots\dots\dots (1)$$

Given the various viscoelastic constants, E_0 , T_0 , E_i , and T_i , for a generalized model, the creep compliances, at various times, can be computed from the above equation. If a creep compliance curve is given, the viscoelastic constants of a generalized model can be determined by the method of collocation. The collocation method is an approximate method to collocate the computed and actual responses at a predetermined number of time durations. Several values of T_i are arbitrarily assumed, and corresponding E_i values are determined by solving a system of simultaneous equation. Since pavement design is based on a moving load with a short duration, the creep compliance caused by viscous strain is negligible, so equation (1) can be written as:

$$D(t) = 1/E_0 + \sum_{i=1}^n 1/E_i [1-\exp(-t/T_i)] \dots\dots\dots(2)$$

It is, therefore, convenient to express creep compliance as a Dirichlet series:

$$D(t) = \sum_{i=1}^n G_i \exp(-t/T_i) \dots\dots\dots(3)$$

$$G_i = 1/E_o$$

$$G_n = 1/E_o + \sum 1/E_i$$

In KENLAYER, the collocation method is applied two times. First, the creep compliances at a reference temperature are specified at a number of time durations and fitted with Dirichlet series, so that the compliance at any other temperature can be obtained by the time-temperature superposition principle. Second, the elastic solutions obtained at these durations are fitted with a Dirichlet series, to be used for analyzing a moving load.

The creep compliances of viscoelastic materials are determined from creep tests. A 1000-sec creep test with compliances measured at 11 different time durations (0.001, 0.003, 0.01, 0.03, 0.1, 1, 3, 10, 30 and 100 seconds), as recommended by FHWA to cover all possible ranges of interest. This range from 0.001 to 100 sec should be able to take care of moving loads with both short and long duration as well as the change in creep compliances with temperature. The responses under a static load can be expressed as a seven-term Dirichlet series, using the following T_i values; 0.01, 0.01, 0.1, 1, 10, 30, and ∞ seconds.

5.4.4 Analysis of Moving Loads

A simplified method has been used in KENLAYER for moving load analysis. In this method, it is assumed that the intensity of load varies with time, according to the Haversine function shown in Figure 5-4. With $t=0$ at the peak, the load function is expressed as:

$$L(t) = q \sin^2(\pi/2 + \pi t/d) \dots\dots\dots(4)$$

Where d is the duration of the load. When the load is at a considerable distance from a given point, or $t = \pm d/2$, the load above the point is zero, or $L(t) = 0$. When the load is directly above the given point, or $t=0$, the load intensity is q . The duration of load depends on the vehicle speed s and the tire contact radius a . A reasonable assumption is that the load has practically no effect when it is at a distance of $6a$ from the point, or

$$d = (12a/s)$$

For example, if $a = 6\text{in.}$ and $s = 40\text{ mph.}$ ($64\text{km/h} = 58.7\text{ft./s}$ (17.9 m/s)) $d = 0.1\text{s.}$

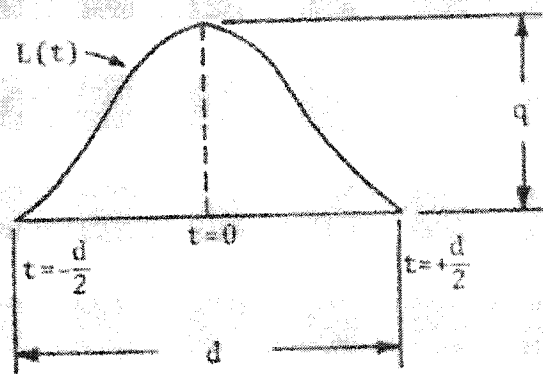


Figure 5-4: Moving load as a function of time [source 21]

The response under static load can be expressed as a Dirichlet series:

$$R(t) = \sum_{i=1}^7 c_i \exp(-t/T_i) \dots\dots\dots(5)$$

The response under moving load can be obtained by Boltzmann's superposition principle:

$$R = \int_{-d/2}^0 R(t) (dL/dt) dt \dots\dots\dots(6)$$

substituting equations (4) and (5) into (6) and integrating yields:

$$R = q\pi^2/2 \sum_{i=1}^n c_i [1 + \exp(-d/2T_i) / \pi^2 + (d/2T_i)^2]$$

5.5 Damage Ratio

The damage ratio, which is the ratio between predicted and allowable number of repetitions, is computed for each load group in each period, and summed over the year by

$$D_r = \sum_{i=1}^p \sum_{j=1}^m (n_{ij} / N_{ij})$$

Where D_r is the damage ratio at the end of the year, n_{ij} is the predicted number of load repetitions for load j in period i , N_{ij} is the allowable number of load repetition based on fatigue cracking and permanent deformation equations, p is the number of periods in each year and m is the number of load groups. The design life, which is equal to $1 / D_r$, is evaluated for both fatigue cracking and permanent deformation; and the one with a shorter life controls the design.

CHAPTER 6

DAMAGE ANALYSIS

6.1 Methodology

Traditionally, the total weight of trucks was considered in assessing the toll rather than the per axle load. In order to quantify pavement damage more accurately, however, load per axle is more important than the total vehicle load. When a vehicle travels on a road it causes some damage to the surface and advances the date at which the pavement needs to be repaired. The damage vehicles do to the pavement depends on the characteristic of the vehicle, type of the pavement, axle load, tire pressure/contact area, speed and duration of load/congestion.

The KENPAVE modeling software was used for the purpose of the damage analysis discussed in Chapter 5. The pavement thickness and layer characteristics were extracted from Huang's example #4 with a one 6-inch viscoelastic layer (for which the default creep compliance is at 65.2°F, for one period) and two linear elastic layers with $E=30,000$ (where $E=Modulus\ of\ Elasticity$) and 15,000 psi, respectively. A poisson ratio of 0.5 for all pavement layers was used. The layer thickness for the base course was 6 inches (layer 2), and was infinite for the subgrade (layer 3). The tire pressure was assumed to be 80 psi.

6.2 Loading

Truck weights for 4-axle (FHWA Class 8) and 5-axle (FHWA Class 9) trucks, and their axle weight share, were obtained from research conducted by Florida State DOT⁽¹⁶⁾ using Weigh in Motion (WIM) technology {Appendix B}. A sample of fourteen 4- and 5-axle

trucks was extracted from the WIM data. Axle weight share and spacing varied for each truck. The average weight share for loaded trucks on each axle, and average spacing between axles, for class 9 and 8 trucks are shown in Figure 6-1 and Figure 6-2, respectively.

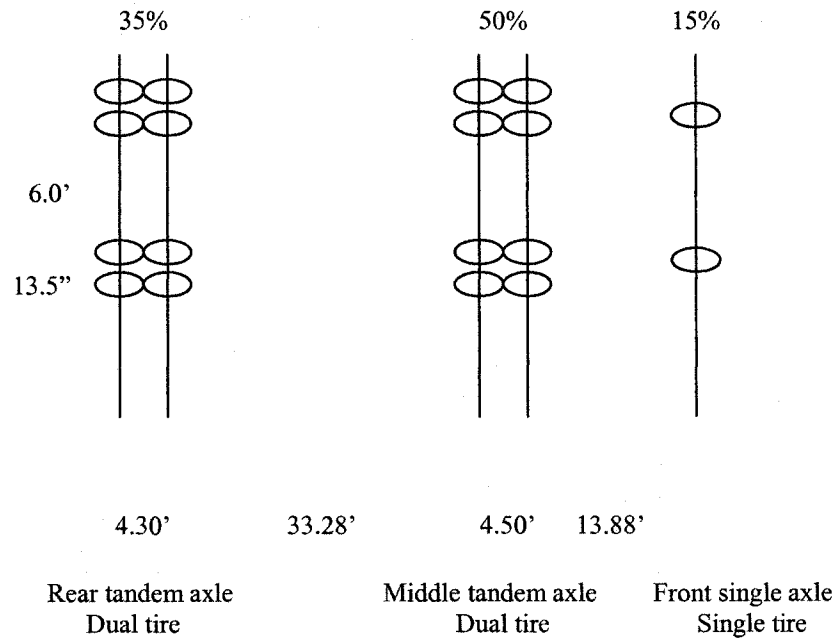


Figure 6- 1: 5-Axle (Class 9) Truck

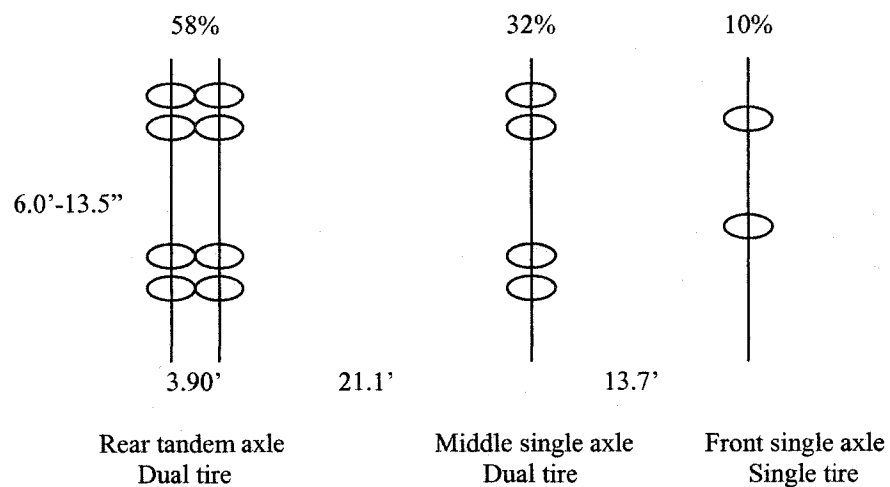


Figure 6- 2: 4-Axle (Class 8) Truck

The gross weight range was as follows:

Truck Type	Min (lbs)	Max (lbs)
<u>5-Axle</u>		
Unloaded	10,000	<30,000
Loaded	>30,000	120,000
<u>4-Axle</u>		
Unloaded	8,000	<25,000
Loaded	>25,000	100,000

Unloaded trucks have a higher weight share on the front axle. Among the Class 9 vehicles, 30% of the weight rested on the front axle for unloaded trucks versus 15% for the loaded trucks.

6.3 4-Axle vs. 5-Axle Truck Damage Analysis

An analysis was conducted to compare the damage caused by 4-axle and 5-axle trucks using averages obtained from the WIM data. The weight share per axle (single axle or tandem axle) was assumed to be 20% on the front axle, 40% on the middle axle/s, and 40% on the rear axles, based upon the average WIM statistics for weight distribution. Tire pressure was considered to be 80 psi. The corresponding contact area and contact radius for each tire was calculated to input in the KENPAVE model, as shown in Table 6-1. Model runs were conducted for each truck type at different gross weights, from 10,000 lbs. to 120,000 lbs., in 10,000 lbs. intervals. Class 8 trucks inputs were limited to 100,000 lbs., based on the maximum weight limit listed above.

The results (Figures 6-3 through 6-5) illustrate that the 4-axle truck causes more pavement damage, at any given load, as compared to the 5-axle trucks. Both tensile strain at the bottom of layer 1 (Figure 6-3) and compressive strain at the top of layer 3 (Figure

6-4) was substantially greater for identical loads from the 4-axle truck than the 5-axle truck. For example, at 50,000 lbs. the Class 8 truck produced more than twice the tensile strain (239%) produced from a Class 9 truck carrying the same weight. And at 100,000 lbs., the Class 8 truck created 277% of the tensile strain created by a Class 9 truck.

The damage ratio for the compressive strain comprises a greater percentage of the difference in pavement damage between the two truck types than the tensile strain. With loads of 10,000 lbs. and 100,000 lbs., respectively, the Class 8 truck produced 527% and 557% greater compressive strain than that produced by the Class 9 truck.

Therefore, axle weight distribution has a greater impact on the subgrade than the interface between the asphalt and base course. Trucking outfits that utilize the 4-axle trucks pay less in tolling costs, but they not only inflict a greater amount of damage, but damage at the most costly location to repair. The tolling is an incentive for companies to collectively use more 4-axle trucks than 5-axle trucks, which increases the rate at which full-depth pavement repairs must be conducted vs. resurfacing alone.

Table 6-1: 4-Axle vs. 5-Axle Truck Damage Analysis Input Data

Class 8 -Four Axle

Gross Weight (lbs)	A-Axle : Single Axle with Single Tire						B-Axle : Single Axle with Dual Tire						C+D Axle : Tandem Axle						
	Share (20%)		Load/Wheel		TP=CP	CA	Share (40%)		Load/Wheel		TP=CP	CA	Share (40%)		Load/Wheel		TP=CP	CA	CR
	(lbs)		SA-single		(psi)	(sq-in)	(lbs)		SA-dual		(psi)	(sq-in)	(lbs)		(lbs)		(psi)	(sq-in)	(inch)
10,000	2,000		1,000	80	80	12.50	4,000		1,000	80	80	12.50	1,000		4,000		80	6.25	1.41
20,000	4,000		2,000	80	80	25.00	8,000		2,000	80	80	25.00	2,000		8,000		80	12.50	1.99
30,000	6,000		3,000	80	80	37.50	12,000		3,000	80	80	37.50	3,000		12,000		80	18.75	2.44
40,000	8,000		4,000	80	80	50.00	16,000		4,000	80	80	50.00	4,000		16,000		80	25.00	2.82
50,000	10,000		5,000	80	80	62.50	20,000		5,000	80	80	62.50	5,000		20,000		80	31.25	3.15
60,000	12,000		6,000	80	80	75.00	24,000		6,000	80	80	75.00	6,000		24,000		80	37.50	3.45
70,000	14,000		7,000	80	80	87.50	28,000		7,000	80	80	87.50	7,000		28,000		80	43.75	3.73
80,000	16,000		8,000	80	80	100.00	32,000		8,000	80	80	100.00	8,000		32,000		80	50.00	3.99
90,000	18,000		9,000	80	80	112.50	36,000		9,000	80	80	112.50	9,000		36,000		80	56.25	4.23
100,000	20,000		10,000	80	80	125.00	40,000		10,000	80	80	125.00	10,000		40,000		80	62.50	4.46

Class 9 -Five Axle

Gross Weight (lbs)	A-Axle : Single Axle with Single Tire						B+C Axle : Tandem Axle						D+E Axle : Tandem Axle								
	Share (20%)		Load/Wheel		TP=CP	CA	CR	Share (40%)		Load/Wheel		TP=CP	CA	CR	Share (40%)		Load/Wheel		TP=CP	CA	CR
	(lbs)	(sq-in)	(psi)	(sq-in)	(inch)	(lbs)	(sq-in)	(psi)	(sq-in)	(inch)	(lbs)	(sq-in)	(psi)	(sq-in)	(inch)	(lbs)	(sq-in)	(psi)	(sq-in)	(inch)	
10,000	2,000	12.50	80	12.50	1.99	4,000	500	80	6.25	1.41	4,000	500	80	6.25	1.41	4,000	500	80	6.25	1.41	
20,000	4,000	25.00	80	25.00	2.82	8,000	1,000	80	12.50	1.99	8,000	1,000	80	12.50	1.99	8,000	1,000	80	12.50	1.99	
30,000	6,000	37.50	80	37.50	3.45	12,000	1,500	80	18.75	2.44	12,000	1,500	80	18.75	2.44	12,000	1,500	80	18.75	2.44	
40,000	8,000	50.00	80	50.00	3.99	16,000	2,000	80	25.00	2.82	16,000	2,000	80	25.00	2.82	16,000	2,000	80	25.00	2.82	
50,000	10,000	62.50	80	62.50	4.46	20,000	2,500	80	31.25	3.15	20,000	2,500	80	31.25	3.15	20,000	2,500	80	31.25	3.15	
60,000	12,000	75.00	80	75.00	4.89	24,000	3,000	80	37.50	3.45	24,000	3,000	80	37.50	3.45	24,000	3,000	80	37.50	3.45	
70,000	14,000	87.50	80	87.50	5.28	28,000	3,500	80	43.75	3.73	28,000	3,500	80	43.75	3.73	28,000	3,500	80	43.75	3.73	
80,000	16,000	100.00	80	100.00	5.64	32,000	4,000	80	50.00	3.99	32,000	4,000	80	50.00	3.99	32,000	4,000	80	50.00	3.99	
90,000	18,000	112.50	80	112.50	5.98	36,000	4,500	80	56.25	4.23	36,000	4,500	80	56.25	4.23	36,000	4,500	80	56.25	4.23	
100,000	20,000	125.00	80	125.00	6.31	40,000	5,000	80	62.50	4.46	40,000	5,000	80	62.50	4.46	40,000	5,000	80	62.50	4.46	
110,000	22,000	137.50	80	137.50	6.62	44,000	5,500	80	68.75	4.68	44,000	5,500	80	68.75	4.68	44,000	5,500	80	68.75	4.68	
120,000	24,000	150.00	80	150.00	6.91	48,000	6,000	80	75.00	4.89	48,000	6,000	80	75.00	4.89	48,000	6,000	80	75.00	4.89	

Note : Load distribution is assumed to be equal in both cases (20, 40, 40%); Actual may be different.

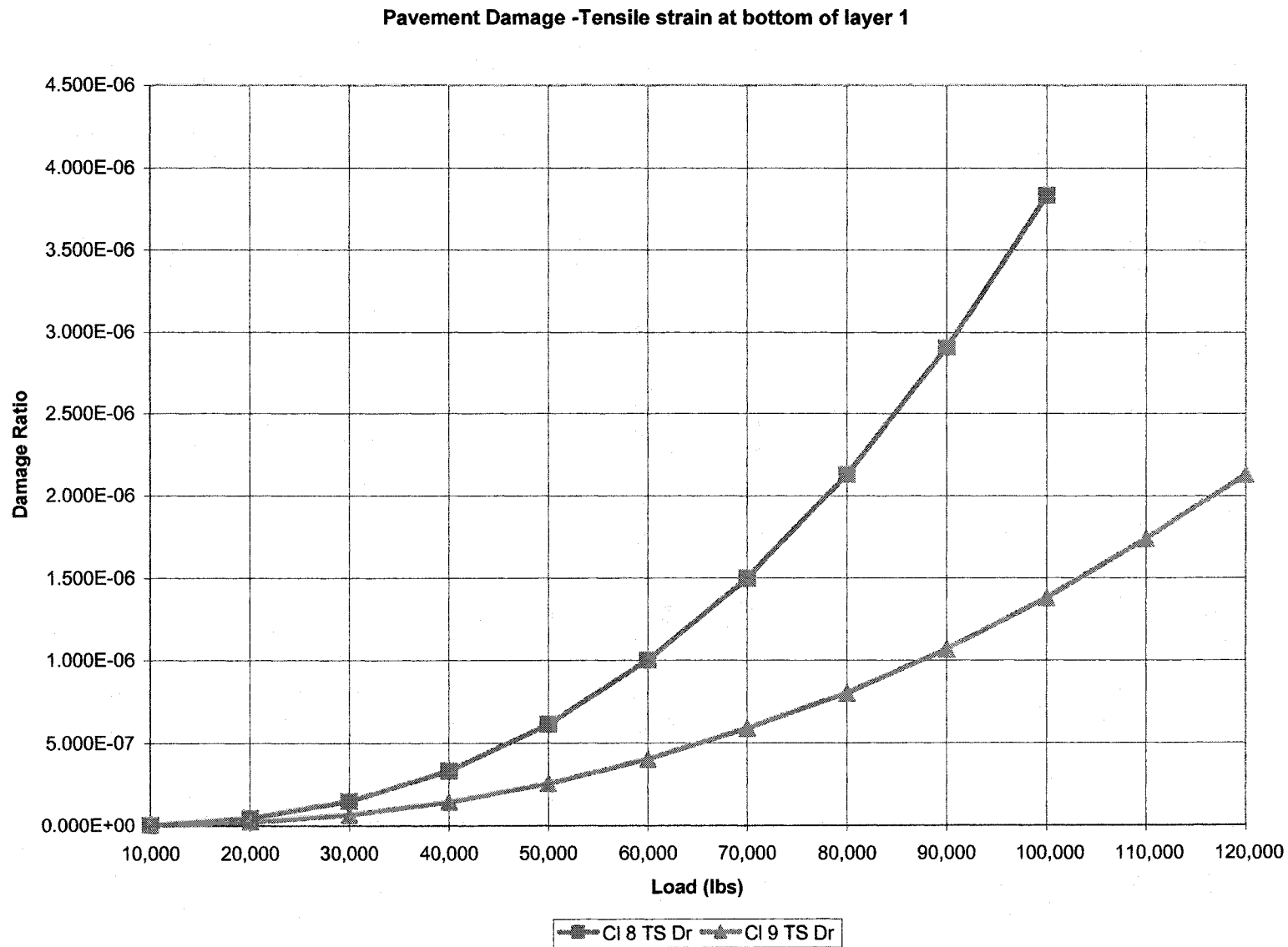


Figure 6- 3: 4-Axle vs. 5-Axle Truck Damage Analysis – Tensile Strain at the bottom of Layer 1

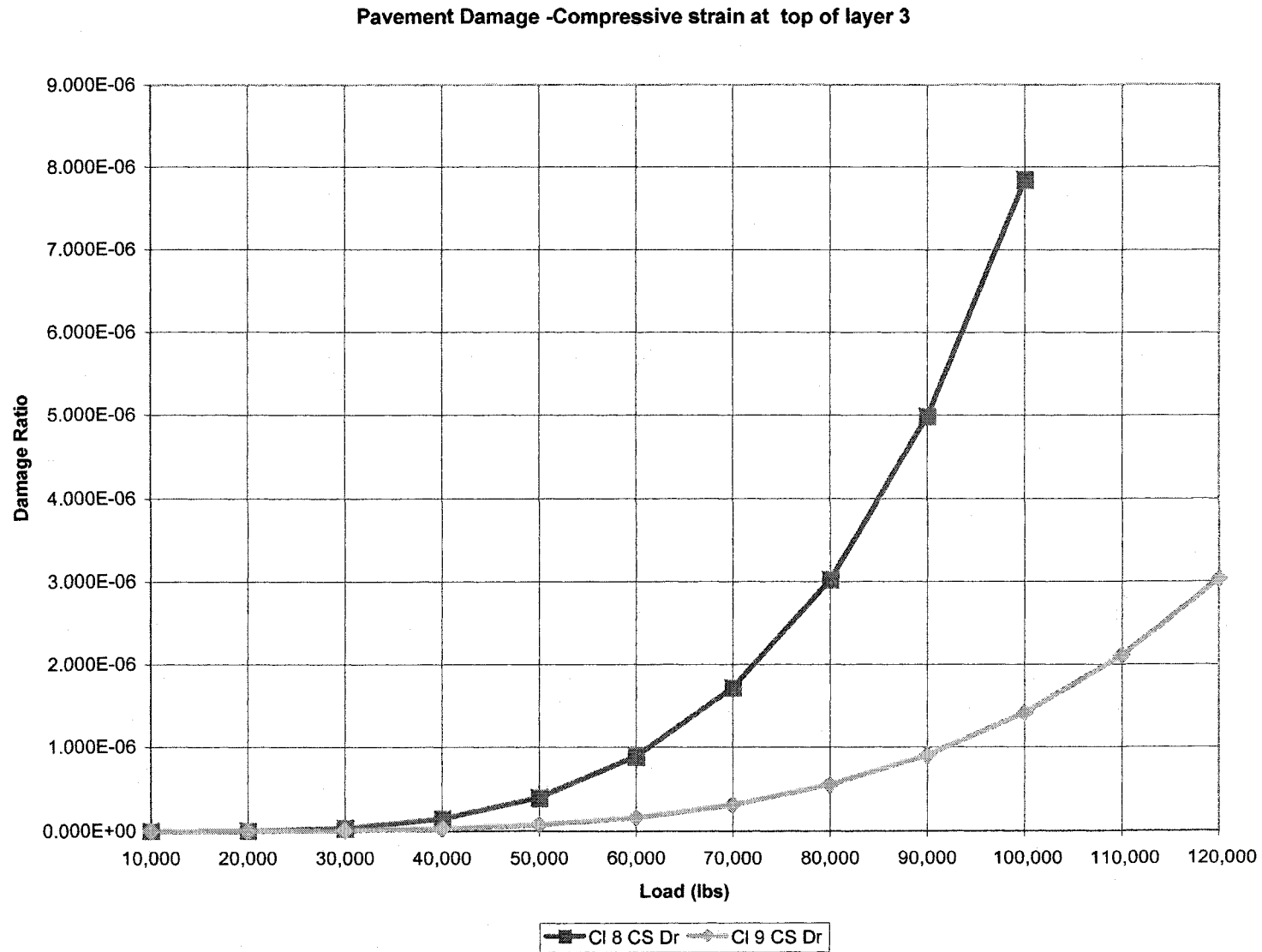


Figure 6- 4: 4-Axle vs. 5-Axle Truck Damage Analysis – Compressive Strain at the top of Layer 3

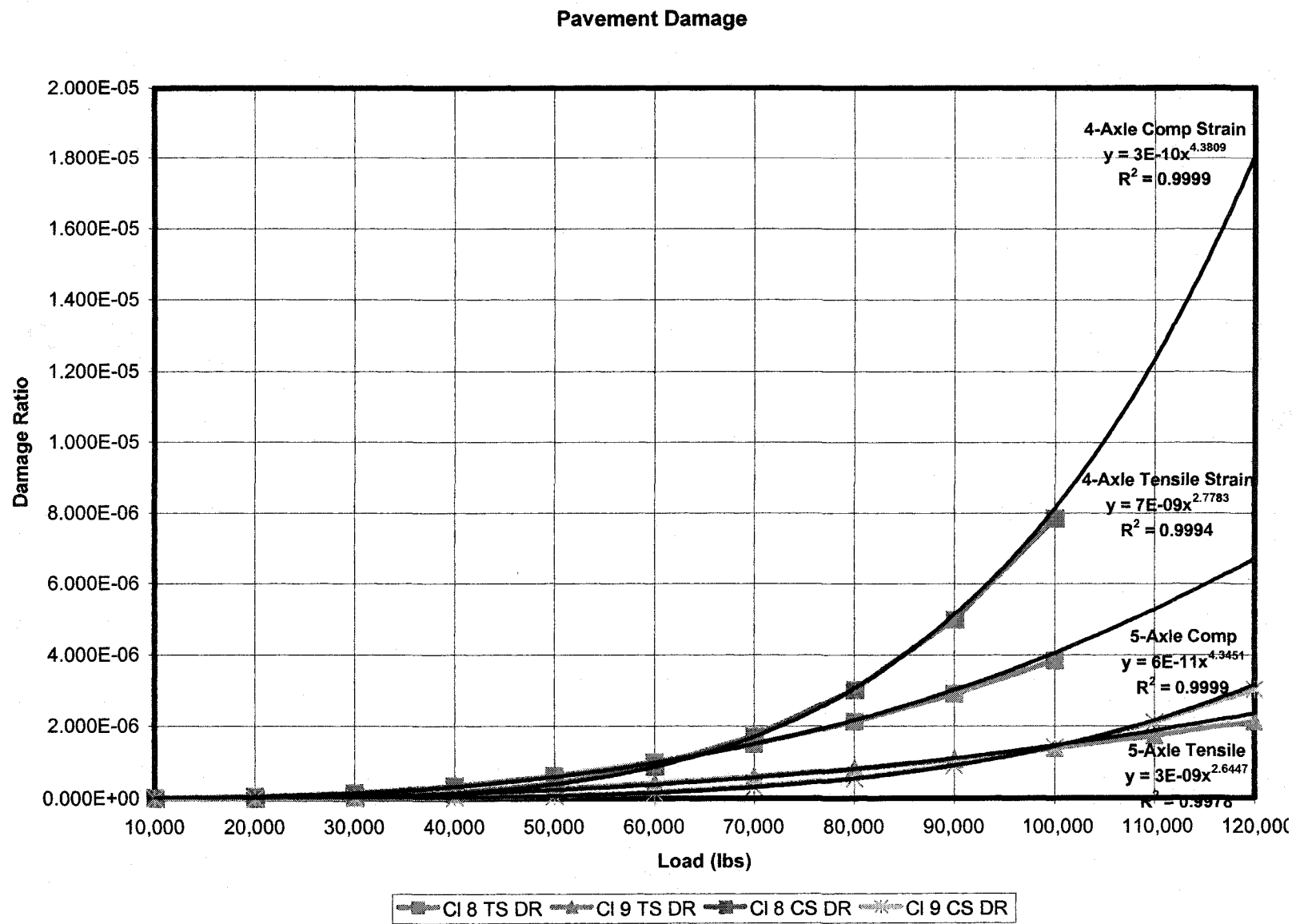


Figure 6- 5: 4-Axle vs. 5-Axle Truck Damage Analysis – Best Fit Equations

When fitting a curve to the data set for both tensile strain and compressive strain, the compressive strain curve follows the AASHTO 4th power curve more closely than the tensile strain (refer to Figure 6-5). The AASHTO test (1960) provided good evidence that the damaging power of a vehicle axle on a paved road was approximately proportionate to the 4th power of its loading. AASHTO measures the damaging power of vehicles by the number of Equivalent Standard Axle Loads (ESALs - as discussed in Chapter 3), where 1 ESAL is taken as a load of 18,000 lbs. These results have been critically examined by a number of researchers. Among various other critiques, Kenneth A. Small and Clifford Winston ⁽⁹⁾ criticized this 4th power rule as well. They estimated a somewhat less steep relationship between pavement life and axle load – closer to a third power law than to the fourth-power law conventionally used to approximate the AASHTO findings. Our analysis validates both AASHTO's and Kenneth Small's research. Using a mechanistic approach, damage is quantified in terms of tensile strain at the bottom of top layer and compressive strain at the top of the subgrade. The tensile strain closely follows a third-power law and the compressive strain a forth-power law, as shown in Figure 6-5. This is true for both 4-axle and 5-axle trucks. However, 4-axle trucks demonstrated a steeper curve, that is, more damage that a 5-axle truck.

Additionally, as can be seen in Figure 6-5, tensile strain governs the damage inflicted on the pavement until the load reaches 65,000 lbs. and 100,000 lbs. for Class 8 and Class 9 trucks, respectively. At this point the compressive strain begins to overtake the tensile strain as the greater percentage of total damage inflicted. Therefore, at loads greater than 65,000 lbs. (for a 4-axle truck) and 100,000 lbs. (for a 5-axle truck), the damage inflicted

becomes increasingly more costly to repair as the pavement starts to fail at the top of the subgrade, in addition to the bottom of the surface course.

6.4 5-Axle Truck Damage Simulation using Real Time Field Data

A damage simulation for a sample of 13 individual trucks was conducted using actual truck weight, weight distribution per axle, and axle spacing taken from Florida DOT's WIM data. The load distribution per axle and axle spacing varied among 13 Class 9 trucks. In other words, a damage simulation was performed for the same truck but with different load combinations and distributions. The tensile and compressive strain damage ratios were calculated for each truck, with load ranges from 25,300 lbs. to 88,500 lbs. (Table 6-2).

The results, as expected, show more damage at greater loads, but the curves reinforce the notion that the compressive strain follows the expected 4th power curve, while the tensile strain follows a 3rd power curve (see Figures 6-6 and 6-7), as discussed above. It was also notable that trucks with more evenly distributed weight among the two tandem axles caused less damage than their less evenly distributed counterparts; even with a higher load. For example, as can be seen in Figure 6-6, a 53,300 lbs. truck with 16% of the weight distributed on the front axle, 53% on the middle tandem axle, and 31% on the rear tandem axle (16-53-31%) caused slightly less tensile strain at the bottom of layer 1 (2.969×10^{-7} inches) than a 51,000 lb. truck with 20-51-21% distribution (3.049×10^{-7} inches). The 53,300 lbs. truck has 4.5% more load than the 51,000 lbs. truck, but produces 3% less damage. Similarly, a 63,400 lb. truck with a 15-52-33% weight distribution produced 2.147×10^{-7} inches of compressive strain at the top of layer 3 vs.

2.106×10^{-7} inches of compressive strain for a 66,700 lb. truck with a 15-40-45% weight distribution. The 66,700 lb. truck has 5% more load, but produces 2% less damage than the 63,400 lbs. Truck (Figure 6-7). This analysis clearly demonstrates two facts concerning differential damage: one, the extent of loading on the same truck, whether empty, partially loaded or fully loaded; and two, the distribution of the load over the axles. The same truck carrying 88,500 lbs. causes as high as 11 times more damage than a truck with 25,300 lbs. (refer to Figure 6-6).

Table 6-2: Model Input for Class 9 Truck with Varying Load and Axle Spacing

Gross Weight (lbs)	A-Axle : Single Axle with Single Tire						B+C Axle : Tandem Axle					
	Share	Load	Load/Wheel	TP=CP	CA	CR	Share	Load	Load/Wheel	TP=CP	CA	CR
	%	(lbs)	SA-single	(psi)	(sq-in)	(inch)	%	(lbs)	SA-dual	(psi)	(sq-in)	(inch)
25300	30.8%	7,800	3,900	80	48.75	3.94	41.5%	10,500	1,313	80	16.41	2.29
26500	31.3%	8,300	4,150	80	51.88	4.06	49.4%	13,100	1,638	80	20.47	2.55
34200	13.2%	4,500	2,250	80	28.13	2.99	65.8%	22,500	2,813	80	35.16	3.35
34400	22.7%	7,800	3,900	80	48.75	3.94	45.1%	15,500	1,938	80	24.22	2.78
41300	19.4%	8,000	4,000	80	50.00	3.99	61.0%	25,200	3,150	80	39.38	3.54
51000	19.8%	10,100	5,050	80	63.13	4.48	51.2%	26,100	3,263	80	40.78	3.60
53300	15.8%	8,400	4,200	80	52.50	4.09	53.1%	28,300	3,538	80	44.22	3.75
57000	11.2%	6,400	3,200	80	40.00	3.57	57.4%	32,700	4,088	80	51.09	4.03
63400	15.3%	9,700	4,850	80	60.63	4.39	51.7%	32,800	4,100	80	51.25	4.04
66700	15.4%	10,300	5,150	80	64.38	4.53	39.9%	26,600	3,325	80	41.56	3.64
71200	12.4%	8,800	4,400	80	55.00	4.18	43.7%	31,100	3,888	80	48.59	3.93
81400	9.6%	7,800	3,900	80	48.75	3.94	45.0%	36,600	4,575	80	57.19	4.27
88500	10.2%	9,000	4,500	80	56.25	4.23	46.4%	41,100	5,138	80	64.22	4.52

D+E Axle : Tandem Axle						Spacing	Spacing
Share	Load	Load/Wheel	TP=CP	CA	CR	B+C	D+E
%	(lbs)	(lbs)	(psi)	(sq-in)	(inch)	inches	inches
27.7%	7,000	875	80	10.94	1.87	56.4	49.2
19.2%	5,100	638	80	7.97	1.59	57.6	50.4
21.1%	7,200	900	80	11.25	1.89	54.0	51.6
32.3%	11,100	1,388	80	17.34	2.35	60.0	56.4
19.6%	8,100	1,013	80	12.66	2.01	51.6	48.0
29.0%	14,800	1,850	80	23.13	2.71	54.0	50.4
31.1%	16,600	2,075	80	25.94	2.87	54.0	48.0
31.4%	17,900	2,238	80	27.97	2.98	51.6	49.2
33.0%	20,900	2,613	80	32.66	3.22	54.0	51.6
44.7%	29,800	3,725	80	46.56	3.85	56.4	49.2
44.0%	31,300	3,913	80	48.91	3.95	55.2	51.6
45.5%	37,000	4,625	80	57.81	4.29	54.0	54.0
43.4%	38,400	4,800	80	60.00	4.37	57.6	55.2

Class 9: 5 Axle Actual Truck Load and Axle Spacing-Damage Ratio
Tensile Strain at Bottom of Layer 1

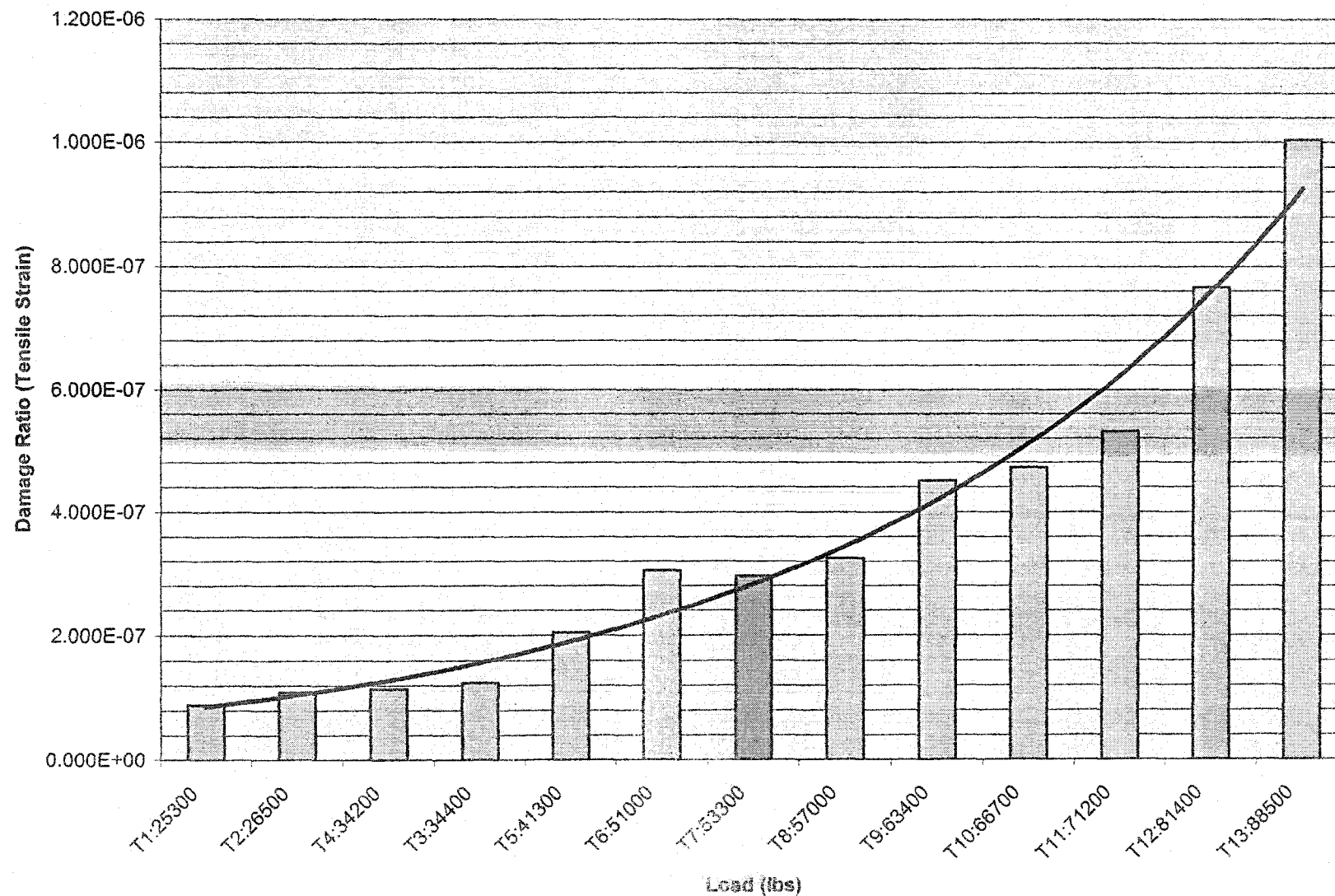


Figure 6-6: Damage simulation for class 9 truck using actual data –Tensile strain at the bottom of layer 1

**Class 9: 5 Axle Actual Truck Load and Axle Spacing- Damage Ratio
Compressive Strain on Top of Layer 3**

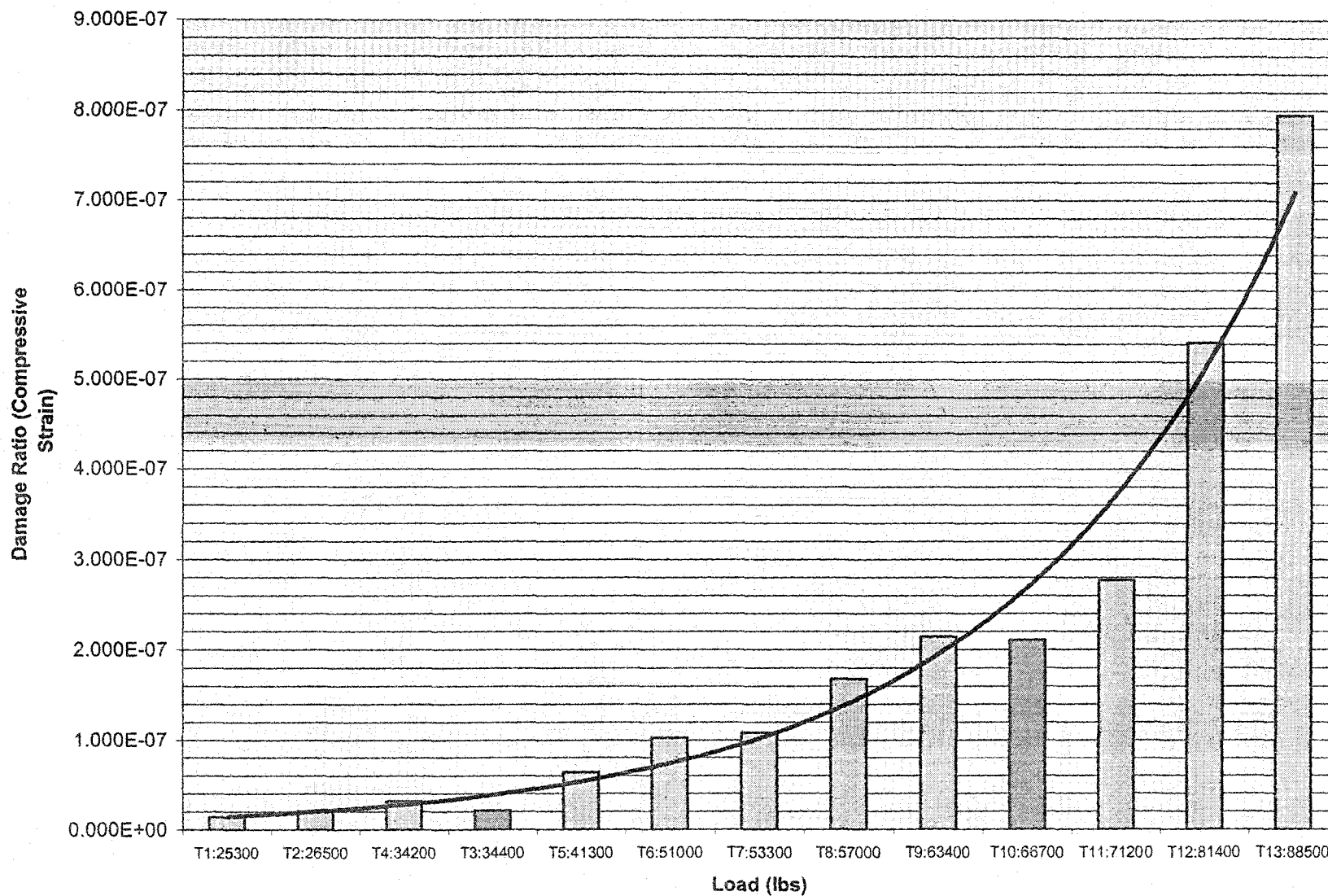


Figure 6-7: Damage simulation for class 9 truck using actual data –Compressive strain at the top of layer 3

6.5 Weight Distribution Sensitivity Analysis for Class 9 Trucks

Eight 80,000 lbs. 5-axle trucks were analyzed using KENPAVE for weight distribution sensitivity. In all cases, the weight share on the front axle was kept constant at 10%, or 8,000 lbs. The weight share on the middle axle vs. the rear axle was varied from 10% to 80% of the total truck weight (see Table 6-3). Other parameters kept constant included a tire pressure of 80 psi and the same pavement structure used in the previous examples.

The model output indicates that load distributions can be optimized to minimize pavement damage. The minimum strain occurred for trucks with weight distributions of 10-40-50% and 10-50-40%. Based upon the symmetry of these results as well as the curve fitting the data points in Figure 5-8, it appeared that a load distribution of 10-45-45% would be optimum. Therefore, this load distribution was also run through the model, confirming that it is the optimum weight distribution among the trailer axles, which evenly distributes the trailer load among its 16 tires.

Additionally, this analysis shows that uneven loads produce significantly more strain, though the compressive strain is the most affected by weight share. At a load distribution of 10-10-80% (and 10-80-10%), the compressive strain was 435% higher than at 10-40-50%, and the tensile strain was 108%. This result also implies that uneven loads are more destructive to the most expensive pavement layer (subgrade) to repair, but when loads are distributed evenly, the compressive strain at the top of layer 3 is actually less than the tensile strain at the bottom of layer 1. It is important to note that with even distribution, the tensile strain failure criteria governs. But with uneven distribution of the same load (80,000 lbs. in this example), compressive strain failure criteria on top of the subgrade governs.

Table 6-3: Model Input for Class 9 Truck Axle Weight Distribution Sensitivity

Gross Weight (lbs)	Overall Weight Distribution (%)	A-Axle : Single Axle with Single Tire						B+C Axle : Tandem Axle					
		Share %	Load (lbs)	Load/Wheel SA-single	TP=CP (psi)	CA (sq-in)	CR (inch)	Share %	Load (lbs)	Load/Wheel SA-dual	TP=CP (psi)	CA (sq-in)	CR (inch)
80,000.00	10-10-80	10.0%	8,000	4,000	80	50.00	3.99	10.0%	8,000	1,000	80	12.50	1.99
80,000.00	10-20-70	10.0%	8,000	4,000	80	50.00	3.99	20.0%	16,000	2,000	80	25.00	2.82
80,000.00	10-30-60	10.0%	8,000	4,000	80	50.00	3.99	30.0%	24,000	3,000	80	37.50	3.45
80,000.00	10-40-50	10.0%	8,000	4,000	80	50.00	3.99	40.0%	32,000	4,000	80	50.00	3.99
80,000.00	10-50-40	10.0%	8,000	4,000	80	50.00	3.99	50.0%	40,000	5,000	80	62.50	4.46
80,000.00	10-60-30	10.0%	8,000	4,000	80	50.00	3.99	60.0%	48,000	6,000	80	75.00	4.89
80,000.00	10-70-20	10.0%	8,000	4,000	80	50.00	3.99	70.0%	56,000	7,000	80	87.50	5.28
80,000.00	10-80-10	10.0%	8,000	4,000	80	50.00	3.99	80.0%	64,000	8,000	80	100.00	5.64

D+E Axle : Tandem Axle					
Share %	Load (lbs)	Load/Wheel (lbs)	TP=CP (psi)	CA (sq-in)	CR (inch)
80.0%	64,000	8,000	80	100.00	5.64
70.0%	56,000	7,000	80	87.50	5.28
60.0%	48,000	6,000	80	75.00	4.89
50.0%	40,000	5,000	80	62.50	4.46
40.0%	32,000	4,000	80	50.00	3.99
30.0%	24,000	3,000	80	37.50	3.45
20.0%	16,000	2,000	80	25.00	2.82
10.0%	8,000	1,000	80	12.50	1.99

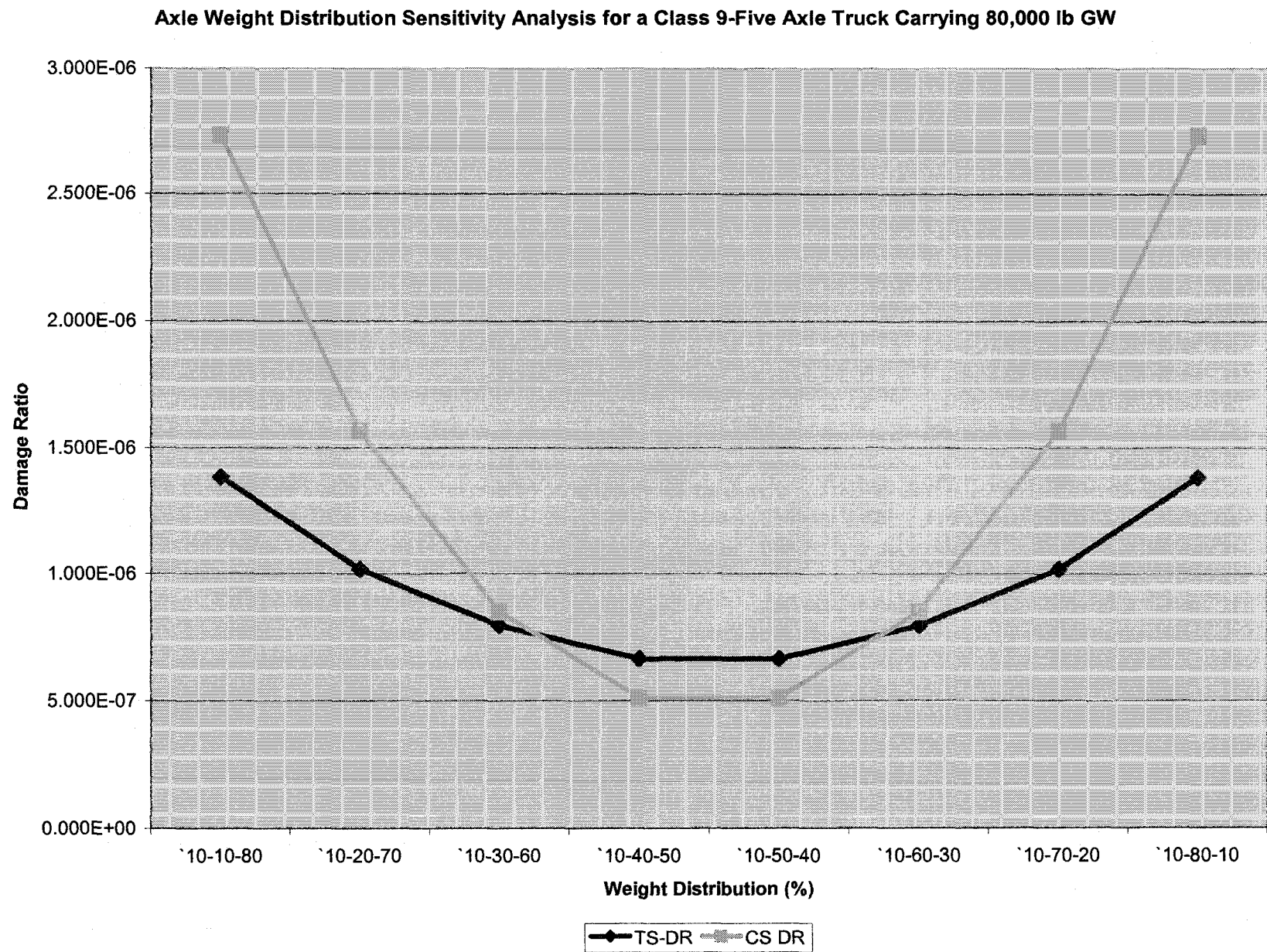


Figure 6-8: Axle weight distribution sensitivity analysis for a 5-axle truck carrying 80,000 lb GVW

6.6 Comparison of Surface Deflection

For this analysis the data from a Class 8 and Class 9 truck of similar weights were extracted from the Florida DOT WIM report. Using the actual weight, weight distribution per axle and spacing (see Table 6-4), the truck data were input to the KENPAVE model. Other parameters kept constant included tire pressure of 80 psi and the same pavement structure used in the previous examples.

As can be seen in Figure 6-9, the surface deflections under each individual axle for the Class 9 truck was less than the Class 8 truck, with the exception of the front axle. This is because the Class 9 truck carries more weight than the Class 8 truck on this identical axle type (single axle, single wheel). The middle axle for the Class 9 truck (tandem axle, dual tire) carries 36% more weight than the Class 8 truck (single axle, dual tire), but the Class 8 truck produced 16% more surface deflection due to more weight per tire. The Class 8 truck carries 31% more load on the rear axle group, and produces 34% more surface deflection than the Class 9 truck. Combined, the 5-axle truck produced 16% overall less surface deflection than the 4-axle truck.

Table 6-4: Model input for comparison of surface deflection for Class 8 and class 9 trucks carrying similar weight

Class 8 -Four Axle

Gross Weight (lbs.)	A-Axle : Single Axle with Single Tire						B Axle : Single Axle Dual Tire					
	Share	Load	Load/Wheel	TP=CP	CA	CR	Share	Load	Load/Wheel	TP=CP	CA	CR
	%	(lbs)	SA-single	(psi)	(sq-in)	(inch)	%	(lbs)	SA-dual	(psi)	(sq-in)	(inch)
70,700	9.8%	6,900	3,450	80	43.13	3.70	32.2%	22,800	5,700	80	71.25	4.76

D+E Axle : Tandem Axle						Spacing	Spacing
Share	Load	Load/Wheel	TP=CP	CA	CR	B+C	D+E
%	(lbs)	(lbs)	(psi)	(sq-in)	(inch)	inches	inches
58.0%	41,000	5,125	80	64.06	4.52	0.0	46.8

Class 9 -Five Axle

Gross Weight (lbs.)	A-Axle : Single Axle with Single Tire						B+C Axle : Tandem Axle					
	Share	Load	Load/Wheel	TP=CP	CA	CR	Share	Load	Load/Wheel	TP=CP	CA	CR
	%	(lbs)	SA-single	(psi)	(sq-in)	(inch)	%	(lbs)	SA-dual	(psi)	(sq-in)	(inch)
71,200	12.4%	8,800	4,400	80	55.00	4.18	43.7%	31,100	3,888	80	48.59	3.93

D+E Axle : Tandem Axle						Spacing	Spacing
Share	Load	Load/Wheel	TP=CP	CA	CR	B+C	D+E
%	(lbs)	(lbs)	(psi)	(sq-in)	(inch)	inches	inches
44.0%	31,300	3,913	80	48.91	3.95	55.2	51.6

FIGURE 5-9: Surface Deflection for Class 8 vs. Class 9 Vehicles with Similar Loads

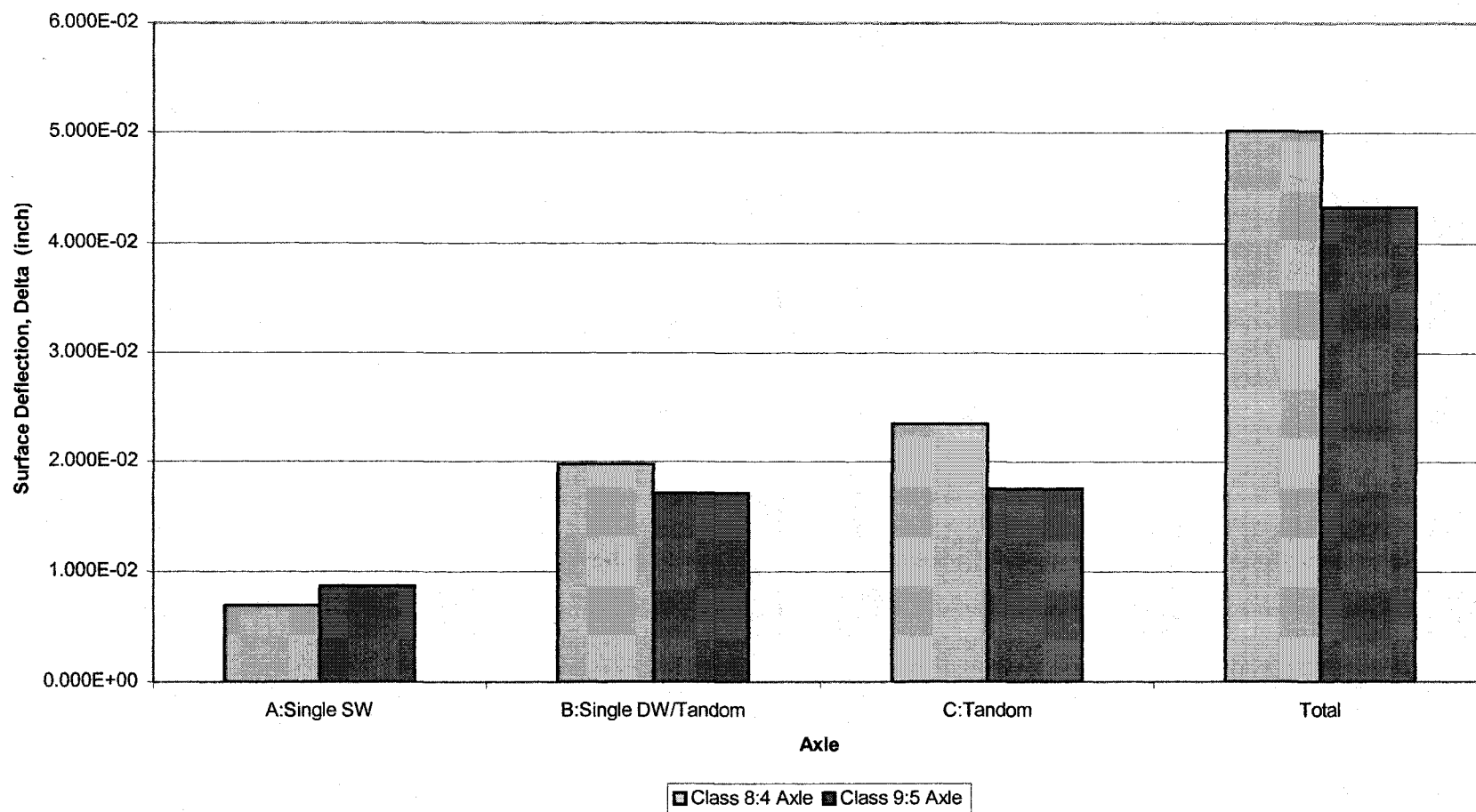


Figure 6-9: Surface deflection class 8 vs class 9 trucks

CHAPTER 7

EFFECT OF TIRE PRESSURE AND SPEED/CONGESTION ON DAMAGE

7.1 Vehicle Speed and Load Duration

Operational speed is an important input for flexible pavement design because it directly influences the stiffness response of the asphalt concrete layers within the pavement structure. As the traffic moves along the highway, a large number of rapidly applied stress pulses are applied to each element of material within the pavement system. These stress pulses last for only a short period of time, and the magnitude and duration depends on the vehicle speed, type and geometry of the pavement structure. Slower speeds and stop conditions cause vehicle loads to be applied to a given pavement area for a longer period of time, which results in greater damage. If the pavement has been poorly designed, the impact of higher load duration can be evident where heavy vehicles frequently come to a stop, such as bus stops, loading zones, and approaches to controlled intersections frequented by heavy trucks or buses.

A field investigation conducted in PACCAR Technical Center in Mount Vernon, Washington ⁽³³⁾ concluded that the effect of truck speed on asphalt concrete pavement response is significant. Increasing the truck speed from a slow crawl (1.7 mph) to 40 mph reduced the peak longitudinal strain in the asphalt concrete by approximately 30 to 40% . The effect of speed on transverse strain was lower. Sebaaly and Tabatabaee ⁽³⁴⁾ also analyzed the effect of vehicle speed on the pavement response. They observed that one particular range of speeds was most significant in influencing pavement damage – an increase in vehicle speed from 20 mph to 35 mph reduced the tensile strain at the bottom of the asphalt layer by 50%.

Under NCHRP Project 1-25 ⁽³⁵⁾, the mechanics of truck-pavement interaction were studied to identify relationships between truck characteristics and pavement damage in the form of fatigue and rutting in wheel paths. The study found that for rigid pavements, vehicle speed influences fatigue by increasing peak dynamic wheel loads; and for flexible pavements, the duration of loading was the critical factor influencing rutting. Generally, higher speeds are slightly more damaging to rigid pavements and less damaging to flexible pavements. For flexible pavements, the potential damage from increased dynamic wheel loads is offset by the shorter duration of applied axle loads at the increased speed. Thus, flexible pavement fatigue remains fairly constant with speed in most cases; while rutting diminishes with increased speeds by decreasing the loading time.

7.2 Speed Sensitivity

The interaction between vehicle speed and pavement damage is illustrated in Figure 7-1. A damage analysis was conducted using KENLAYER ⁽²¹⁾, to assess the pavement's sensitivity to speed / load duration. For demonstration purposes, an illustrative example from Huang ⁽²¹⁾ was selected. A viscoelastic pavement system with three layers was subjected to a moving circular load with a contact radius of 6 in., a contact pressure of 80 psi, and a load duration of 0.1 sec. Layer 1 is linear viscoelastic and Layers 2 and 3 are elastic. The load repetitions was 500 per day, or 182,520 per year.

The speed was increased from 5 to 70 mph at intervals of 5 mph, with all other parameters constant. Speed is directly related to the duration of loading. The duration of

load depends on the vehicle speed and tire contact radius. Higher speeds reduce the duration that a wheel load bears on a given pavement location. A moving load is considered to have a negligible effect on the pavement when that load is away from a given point on the roadway by a distance of 6 times the tire contact radius ⁽²¹⁾. For a vehicle with a 6" tire contact radius, traveling at 5 mph will impose the wheel load for 0.8163 seconds on a given pavement location, while a load duration of 0.0583 seconds corresponds to 70 mph. The model indicated that the vehicle speed significantly affects the horizontal strain at the bottom of the asphalt layer, which ultimately affects the design life of the pavement. The analysis shows that increased exposure time (lower speed) reduces the design life of the viscoelastic material in flexible pavements. The decrease in speed from 70 mph to 5 mph resulted in a reduction of design life from 15 years to 5 years, assuming that all other loading and pavement parameters were kept constant.

7.3 Effect of Congestion on Pavement Damage

The reality of the damaging effects of decreased speeds on pavement life suggests that traffic congestion subjects pavement to additional strain, and is therefore critical to pavement design. Traffic congestion is pervasive in the United States, with most major highways in urban and suburban settings experiencing congestion during peak periods, often with "stop and go" traffic and crawling speeds ranging from 5 to 30 mph. Nevertheless, the effect of vehicle speed in pavement design and rehabilitation has been ignored. Therefore, a damage analysis was conducted using KENLAYER ⁽²¹⁾, to assess the effects of congestion on pavement design life due to the resulting lower travel speeds.

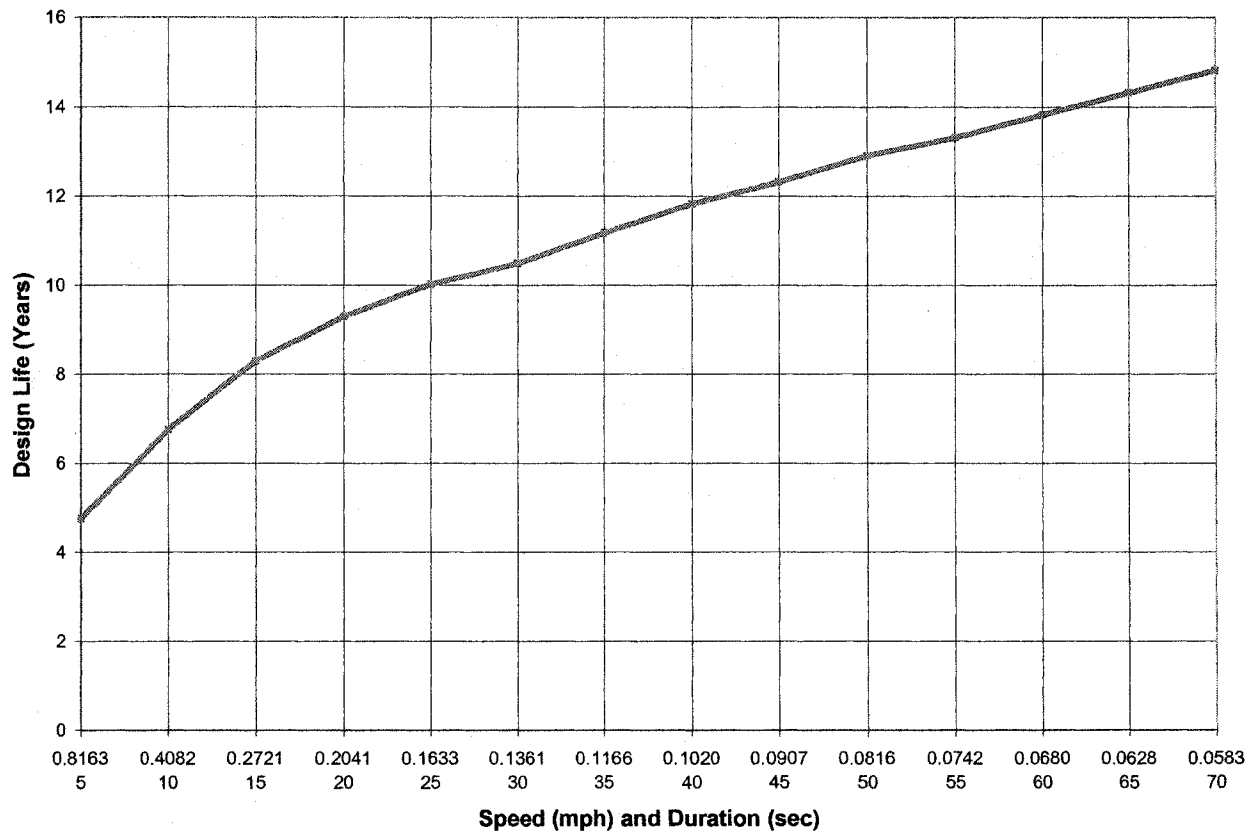


Figure 7-1: Vehicle Speed and Pavement Damage

Data for input to the model was taken from Florida DOT's WIM data, shown below in Table 7-1. The WIM data collected on a section of I-95 south of the Jacksonville, FL, on a typical day is presented in Appendix B. The FHWA Class 5 through Class 13 vehicles include all trucks on this section of I-95, with the 5-axle Class 9 trucks representing the largest proportion (50%) of trucks surveyed. This section of highway carries an average daily truck traffic (ADTT) of 12,172 trucks per day, of which 25% travel during peak periods (7-10AM and 4-7PM). Although the WIM data does not show a typical congestion pattern on this section of I-95, for the analysis purposes of this dissertation, the peak period average speed was chosen to be 25mph. The average speed extracted

from WIM data during off-peak hours was 58 mph. The directional split was 56/44% with 59% of trucks using the center or right lane. AASHTO's recommended lane usage factor for a highway with 3 lanes in each direction is 60 to 80%. Therefore, to be conservative, 70% was used in the analysis.

TABLE 7-1: Florida DOT Weigh-In-Motion Data - Interstate 95 at Jacksonville, FL (2004)							
Truck Traffic Data				Lane Distribution Data			
Class	ADTT	Proportion	AM/PM Peak (25%)	Lane	Percentage Use	Directional Distribution	Lane Distribution
5	3,347	27%	837	1	21	56	59%
6	855	7%	214	2	33		
7	48	0%	12	3	2		
8A	197	2%	49	4	1	44	59%
8B	1,153	9%	288	5	17		
9	6,090	50%	1,523	6	26		
10	86	1%	22		100	AASHTO LD = 60 - 80%	
11	290	2%	73				
12	81	1%	20				
13	25	0%	6				
	12,172	100%	3,043				
Notes: (1) 12.5% of trucks in AM Peak 7-10AM at 25 mph (2) 12.5% of trucks in PM Peak 4-7PM at 25 mph (3) 75% of trucks in Off Peak at 58 mph (4) 70% of lane usage in center or right lanes							

The truck traffic loading was converted in Table 7-2 into an 18 kip equivalent single axle load (ESAL), using a load equivalency factor of 1.35 (NYSDOT) and a 2.5% annual straight-line growth rate, to obtain the inputs for the KENLAYER Model.

TABLE 7-2: 18 kip Equivalent Single Axle Load (ESAL)								
Period	ADTT	LEF	Dd	DI	No. of Days	W18 (1 year)	Growth Factor	W18 (1 year)
Peak	3,043	1.35	56%	70%	365	587,780	2.50%	602,474
Off Peak	9,129	1.35	56%	70%	365	1,763,339	2.50%	1,807,423
Total	12,172	1.35	56%	70%	365	2,351,119	2.50%	2,409,897
Contact Radius Calculation				Load Duration Calculation				
Load per Tire	TP=CP	Contact Area	Contact Radius	Speed (mph)	Duration (sec)	XW	YW	
4500	80	56.25	4.23	25	0.12	0	13.5	
				58	0.05	0	13.5	
Truck Factor (NYSDOT) = 1.35 Growth Factor = 2.5%								

A three-layer viscoelastic pavement system was used for the analysis. The top layer consists of 8" asphalt concrete, with a 10" layer of base course consisting of granular material. The third layer was the subgrade with infinite thickness. Table 7-3 shows the results of the KENLAYER model. At a constant speed of 58 mph, the design life of the pavement system was 29.2 years. At the reduced speed of 25 mph during congestion periods, the design life was reduced from 29.2 to 24.3 years – a reduction of 5 years. The KENLAYER model indicated that reducing the average speed from the off-peak 58 mph to the peak 25 mph results in the tensile strain increasing by 20%, and the compressive strain increasing by 37%. However, since the compressive strain values are less than 10% of the tensile strain, the tensile strain damage ratio is more significant to the effect of speed on pavement damage.

TABLE 7-3: Effect of Congestion/Lower Speed on Flexible Pavement			
Scenario	Layer 1 Tensile Strain Damage Ratio	Layer 3 Compressive Strain Damage Ratio	Design Life (years)
Ignoring Congestion Constant speed - 58 mph	0.03425	0.001888	29.2
Congestion Consideration Peak speed - 25 mph Off peak speed - 58 mph Total peak/off peak	0.01538 0.02569 0.04107	0.001172 0.001416 0.002588	24.3
Reduction in Design Life =			4.9 years

The difference between static and dynamic loads is another factor when considering pavement design. The majority of pavement design and analysis procedures, including AASHTO, consider only static loads. The above analysis clearly indicates that ignoring vehicle speed in pavement design may cause significant economic consequences by triggering earlier maintenance needs and a shorter pavement life. In viscoelastic theory, such as used in the KENLAYER model, speed is directly related to the duration of loading. If the elastic theory is used, the resilient modulus of each paving material should be properly selected to be commensurate with the vehicle speed. This is an approximate method of incorporating speed in static models. Generally, the greater the speed, the larger the modulus, and the less the pavement damage.

It can be seen from PACCAR ⁽³³⁾, Sebaaly and Tabatabaee ⁽³⁴⁾, NCHRP Project 1-25 ⁽³⁵⁾, and the KENLAYER model analysis that decreases in speed cause increased pavement damage and a significant decrease in pavement design life. Extending the effects of speed into periods with known traffic congestion quantifies the additional reduction in pavement life due to the congestion, at 5 fewer years with an average peak period speed

of 25 mph and an off-peak speed of 58 mph. Three practical implications can be extracted from these conclusions:

1. Unless the pavement is rough or has some geometric or safety requirements, vehicle speeds should not be restricted unnecessarily. The slower speeds will cause more damage to the pavement.
2. It is evident that more rational pavement models should be investigated. The ideal pavement analysis model should consider the dynamic nature of traffic loads and viscoelastic properties of the asphalt-concrete (AC) material.
3. Trucks should be encouraged through policy making to travel during the off-peak periods when the speeds are higher, to minimize the pavement damage.

7.4 Tire Pressure and Contact Area

In the mechanistic method of design, the axle load is assumed to be uniformly distributed over the contact area between the tires and pavement. The size of the contact area depends on contact pressure, and the contact pressure is assumed to be equal to the tire pressure. The approximate shape of the contact area of the each tire is composed of a rectangle and two semi circles as shown in Figure 7-2. However, for flexible pavement design using layered theory, it is assumed that each tire has a circular contact area.

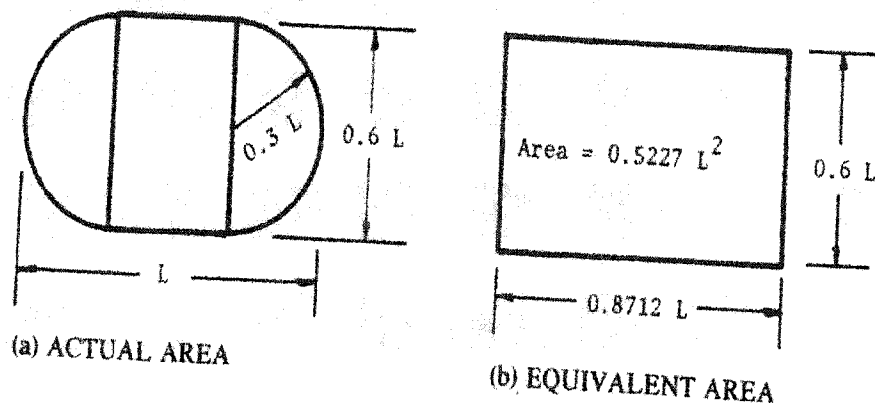


Figure 7-2: Shape of contact area [source 21]

Truck tire inflation pressure is a parameter readily set and varied by truck operators. Variations in tire inflation pressure affect pavement damage by changing contact patch size and tire vertical stiffness. The decrease in contact area at high inflation pressures has a moderate impact on rigid pavement fatigue. On the other hand, flexible pavement fatigue is strongly affected by these changes. A field investigation conducted in PACCAR Technical Center in Mount Vernon, Washington ⁽³³⁾ concluded that the effect of decreasing tire pressure to below normal levels on the response of AC pavement is significant. Decreasing the tire pressure from 90 to 30 psi reduced the longitudinal strain at the bottom of the AC layer by 20 to 40%. The effect of tire pressure was significantly lower at the surface of the AC layer.

Under NCHRP Project 1-25 ⁽³⁵⁾, the mechanics of truck-pavement interaction were studied to identify relationships between truck characteristics and pavement damage (fatigue and rutting in wheel paths). The study found that over inflation of conventional tires (e.g., 11R22.5) by 25 psi nearly doubles the flexible pavement fatigue. Similarly, over inflation of wide-base single tires is especially critical, increasing fatigue by a factor of 4. This 4-fold increase occurs because the contact length changes significantly with inflation pressure of the same load. Tire pressure was found to have only a moderate influence on rigid pavement fatigue.

7.5 Tire Pressure Sensitivity

A preliminary damage analysis was conducted using KENLAYER ⁽²¹⁾ to assess the sensitivity of pavement to tire pressure and contact area. For demonstration purposes, data from Huang ⁽²¹⁾ (used in the preceding sections on speed) was input to the model

with inflation pressures from 60 to 100 psi at intervals of 5 psi, keeping all other parameters constant. As the pressure was increased from 60 to 100 psi, the contact radius also varied from 6.91 to 5.35 inches, respectively, resulting in a corresponding decrease in pavement life from 17 years at 60 psi to 9 years at 100 psi. Therefore it is concluded that higher tire pressure results in more damage due to the increase in load per unit area. The results are plotted in Figure 7-3, below.

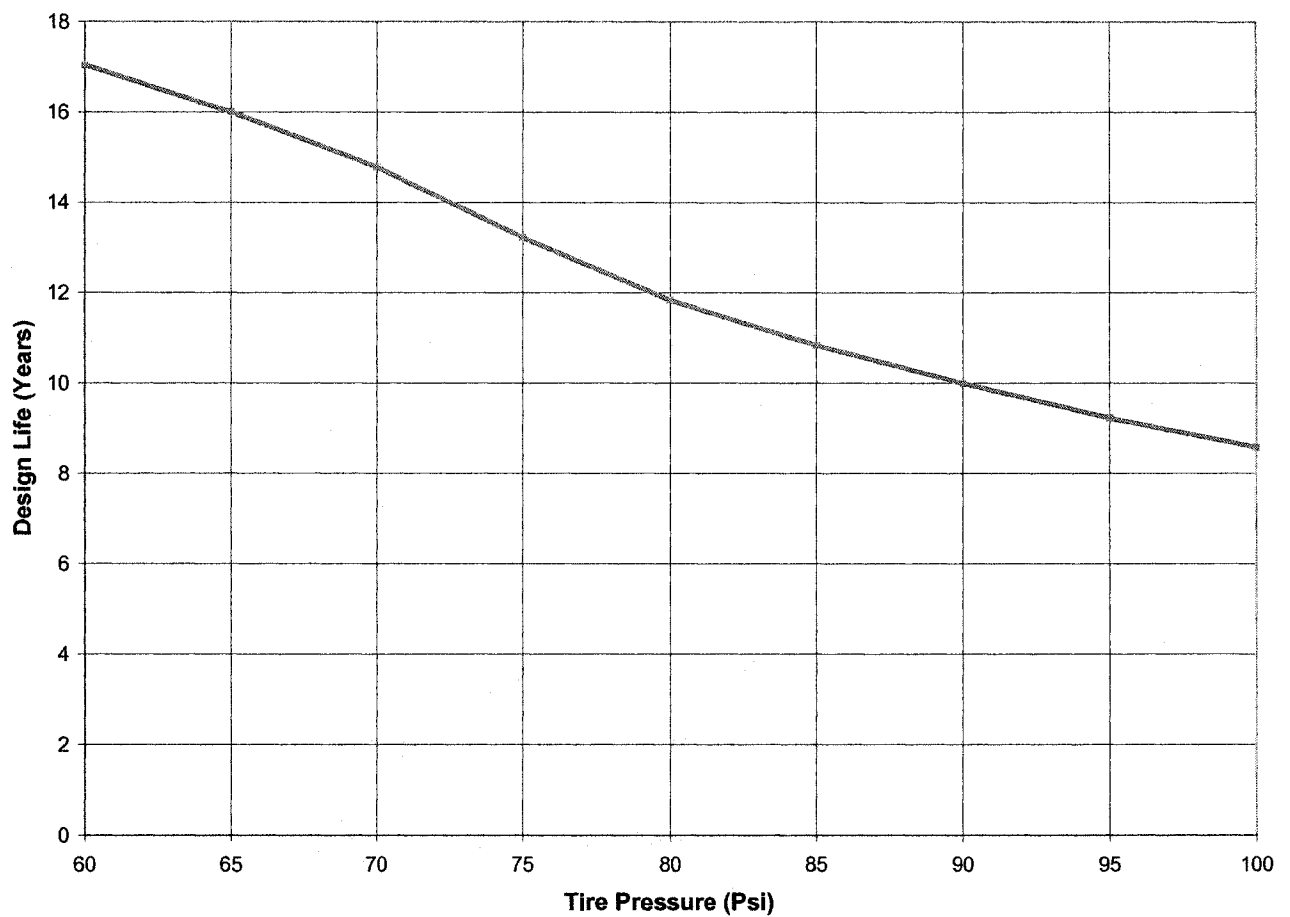


FIGURE 7-3: Tire Pressure and Pavement Damage

7.6 Effect of Varying Tire Pressure using FDOT Data

FDOT WIM data used in the congestion section above was used here to assess the effect of tire pressures on pavement damage. First, the KENLAYER model was run assuming that all 12,172 trucks (Class 5 to 13) have a tire pressure of 80 psi, and ignoring any variation in tire pressure. This resulted in a pavement design life of 29.2 years. The model was then run again assuming 1/3 of trucks have tire pressures at each of 80, 100 and 120 psi, keeping all other parameters constant. The model output (Table 7-4) indicates that the average tensile strain and compressive strain increased slightly at the higher tire pressures, resulting in a 1.4-year decrease in design life.

TABLE 7-4: Effect of Tire Pressure on Flexible Pavement			
Scenario	Layer 1 Tensile Strain Damage Ratio	Layer 2 Compressive Strain Damage Ratio	Design Life (years)
100% at 80 psi	0.03425	0.001888	29.2
33% at 80 psi 33% at 100 psi 33% at 120 psi	0.03603	0.001903	27.8
Reduction in Design Life =			1.4

It can be seen from PACCAR ⁽³³⁾, NCHRP Project 1-25 ⁽³⁵⁾, and the KENLAYER model analyses that an increase in tire pressure can cause increased pavement damage and a decrease in pavement design life. Most of the truckers tend to over inflate tire pressure, which allows them to carry heavier load and travel at higher speed. A comprehensive policy to regulate the optimum tire pressure is required. ITS technology can be used to implement such regulations and to monitor compliance.

CHAPTER 8

EXISTING TAX STRUCTURE

8.1 Highway User Revenue (HUR)

Traditionally, highway user revenues are classified by type or structure. The “First Structure” is made up of fixed fees, or taxes, that are independent of the amount of highway use. Prime examples include vehicle registration, titling, privilege tax, and driver licensing fees. Since payment of First Structure taxes are required in order to obtain legal permission for a vehicle to be driven on a public road, such fees may be considered entry fees for the highway system. The “Second Structure” consists of fuel taxes. And although there is a direct relationship between such taxes and miles traveled, they do not incorporate any relationship between load and pavement damage, and do not differentiate between usage of limited access highways and local road use. Taxes on gasoline, diesel fuel, and special fuels are the greatest source of highway revenue, both nationally and at the state level. “Third Structure” taxes are user-related fees directly linked to vehicle weight and highway miles traveled. Tolls, weight-distance taxes, and tire taxes are examples of these types of taxes. Following World War II, eleven states adopted Third Structure taxes, which attempted to assess heavy vehicles according to their total weight and distances traveled. Table 8-1, below shows the total 1994 Highway User Revenues (HURs) for all levels of government by type of fee, breaking down revenues at each level of government into sources by these three broad tax structure categories that have traditionally been used to classify HURs ⁽⁴⁾.

Table 8-1: 1994 HURs by Type for All Levels of Government (\$ Billions)				
Revenue Categories	Federal	State	Local	All Levels
First Structure (Fixed Fees)				
Registration	---	9.1	---	9.1
Title Fees	---	3.4	---	3.4
Ad Valorem	---	6.2	---	6.2
Drivers' License	---	0.8	---	0.8
Heavy Vehicle Use	0.6	---	---	0.6
Other or Miscellaneous	1.4	---	0.8	2.2
Subtotal	2.1	19.5	0.8	22.4
Second Structure (Fuel Taxes)				
Gasoline	13.9	19.6	0.5	34.0
Diesel	3.5	4.4	0.2	8.1
Gasohol	0.7	1.7	--	2.4
Other	0.4	0.2	--	0.6
Subtotal	18.4	25.9	0.7	45.0
Third Structure (Use Related Fees)				
Weight-Distance	--	0.6	--	0.6
Tire	0.3	--	--	0.3
Tolls and Other	--	3.8	1.1	4.9
Subtotal	0.3	4.4	1.1	5.8
Total	20.8	49.9	2.5	73.2

[Source: <http://www.fhwa.dot.gov/policy/hcas/summary/sum4.html#highway>]

The federal government has the lowest proportion of its tax structure in both First and Third Structure user taxes (10% and 1%, respectively) of the three levels of government, and the highest proportion (89%) in Second Structure taxes. Thus, the federal user fee structure reflects costs directly related to VMT well, but does not account for the variations in costs related to weight and other vehicle characteristics, which are considered in the typical state/local tax structure. However, the federal fuel tax structure includes a higher diesel fuel tax rate (a "diesel differential" of 6 cents per gallon), a feature that significantly improves the federal tax structure in relation to cost responsibility. The states vary greatly in their relative mixes of the three types of taxes.

As a whole, states rely more on First Structure taxes (39%) than either of the other two levels of government. However, several states have shares of First Structure taxes about as low as at the Federal level, and obtain a substantial share of their revenue from Third Structure taxes. None of the states has a higher proportion of its tax structure in Second Structure taxes than the Federal Government, although a few come close in the 70 to 80% range. Also, only a few states have substantially higher diesel fuel tax rates similar to the federal diesel differential of 6 cents per gallon. Although local governments as a whole recover only about 10% of their costs from highway users, they do collect the highest share from Third Structure taxes (about 45%), almost all in the form of tolls.

8.1.1 New Jersey Turnpike

Tolls have the potential for reflecting cost responsibility quite well depending on the toll structure and the extensiveness of toll facilities. However, many toll road fee schedules currently do a poor job of reflecting differences in cost responsibility among different vehicle classes. For example, Figure 8-1 shows the existing toll structure for different classes of vehicles traveling the entire length of the *New Jersey Turnpike* from Exit 1 to Exit 18W. This tolling structure is consistent only with VMT and does not reflect each individual vehicle's contribution to pavement damage. All trucks of the same class pay the same toll whether loaded or unloaded. A Class Six truck with 6 axles pays a higher toll than a 4-axle or 5-axle truck for the same load even though the 6-axle truck causes less damage to the pavement by distributing the load among more axles; and therefore, a greater area of pavement surface contact. Moreover, all vehicles with more than 6 axles (FHWA Class 11-13, multi-trailer, refer to Appendix A) pay the same toll as Class 6 trucks, regardless of per-axle load or pavement damage.

FIGURE 8-1: Classification of Revenue Vehicles – NJ Turnpike
(Toll Rates from Exit 1 to Exit 18W)

Class 1 - 2-Axle Passenger Cars (\$6.45)

- passenger car
- light truck
- taxis & hearses
- motorcycles



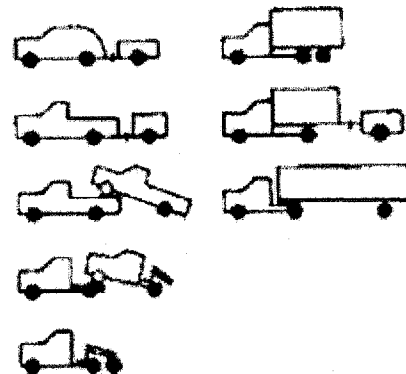
Class 2 - 2 Axle Trucks (\$13.30)

- two-axle, dual-tire vehicle
- two-axle tractor, wide tire



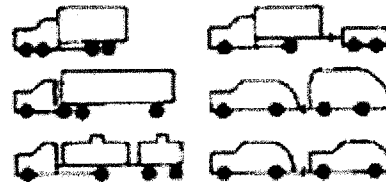
Class 3 - 3 Axle Trucks (\$16.60)

- passenger car with trailer
- two-axle, single tire truck with trailer
- two light trucks piggyback
- dual-axle tractor without trailer
- three-axle, single unit truck
- three-axle, semi-trailer combination
- two-axle, dual tire truck with single axle trailer



Class 4 - 4-Axle Trucks (\$19.95)

- any dual-tire truck & trailer with four-axes & single unit trucks with four-axes
- passenger car with two-axle trailer
- two cars tandem



Class 5 - 5-Axle Trucks (\$23.20)

- any truck & trailer with five-axes



Class 6 - 6 Axle Trucks (\$26.55)

- tractor trailer with six or more axes
- three-axle tractors-tandem
- vehicle with more than six axes must be axle varied for the proper number of axes



8.1.2 Oregon Weight-Mile Tax Incentive

Another example is Oregon's weight-mile tax, which is levied on all trucks weighing more than 26,000 pounds. An amendment to this tax in 1990 added incentives for trucks weighing more than 80,000 pounds to add axles. The additional axles within a weight class reduce the amount of road damage by distributing the load over more tires and, ultimately, over larger pavement contact area. Trucks subject to the weight-mile tax are exempted from Oregon's diesel fuel tax. Fuel taxes are levied for vehicles weighing less than 26,000 pounds. Trucks subject to the weight-mile tax must declare a maximum operating weight. The declared weight alone determines the tax rate for trucks between 26,001 pounds and 80,000 pounds. For trucks declaring maximum operating weights between 80,001 pounds and 105,500 pounds, the weight and the number of axles determine the tax rate. Within each weight class, the tax rate declines with more axles. The rate of decline is based on the expected reduction in road damage. The highest single rate is for trucks declaring operating weights up to 98,000 pounds, with only five axles. Such trucks are subject to a tax rate of 19.2 cents per mile traveled in the State of Oregon. However, adding a sixth axle with the same declared weight lowers the tax by 17.45% to 15.85 cents per mile. Adding a seventh axle for the same declared weight would lower the tax by an additional 12.93% to 13.8 cents per mile. Taxes are reduced for up to nine axles. Table 8-2, below ⁽⁵⁾ shows Oregon weight-mile rates for vehicles over 80,000 lbs., along with the percentage difference in tax rates by number of axles for each weight class. As the number of axles increases from 5 to 9, the tax rate falls between 23% and 36%, depending on the weight class. The rationale for calculating the tax rates is based on ESAL.

TABLE 8-2: Oregon Weight-Mile Tax Rates

Oregon Weight-Mile Tax Rates: Percent difference in rate by number of axles (Rate is specified in mills per mile)										
	5		6		Number of Axles 7		8		9	Total %
Declared Weight		%		%		%		%		
80,001 to 82,000	141.0	8.51%	129.0	6.59%	120.5	4.98%	114.5	5.68%	108.0	23.40%
82,001 to 84,000	145.5	9.97%	131.0	6.49%	122.5	5.31%	116.0	5.60%	109.5	24.74%
4,001 to 86,000	150.0	10.67%	134.0	7.09%	124.5	5.62%	117.5	5.53%	111.0	26.00%
86,001 to 88,000	155.0	11.61%	137.0	7.66%	126.5	5.53%	119.5	5.86%	112.5	27.42%
88,001 to 90,000	161.0	12.73%	140.5	8.54%	128.5	5.45%	121.5	5.76%	114.5	28.88%
90,001 to 92,000	168.0	13.99%	144.5	9.69%	130.5	5.36%	123.5	5.67%	116.5	30.65%
92,001 to 94,000	175.5	15.38%	148.5	10.77%	132.5	5.28%	125.5	5.98%	118.0	32.76%
94,001 to 96,000	183.5	16.62%	153.0	11.44%	135.5	5.90%	127.5	5.88%	120.0	34.60%
96,001 to 98,000	192.0	17.45%	158.5	12.93%	138.0	6.16%	129.5	5.79%	122.0	36.46%
98,001 to 100,000			164.5	14.29%	141.0	6.38%	132.0	6.06%	124.0	24.62%
100,001 to 102,000					144.0	6.25%	135.0	6.67%	126.0	12.50%
102,001 to 104,000					147	6.12%	138	6.88%	128.5	12.59%
104,001 to 105,500					151	6.62%	141	7.09%	131	13.25%

Oregon's weight-distance tax structure was designed to provide incentives to the trucking industry to use more axles. This method is an effective way of combining weight and number of axles for assigning a toll. Although it provides incentive for use of more axles, which translates into less pavement damage, it does not, however, capture the real cost associated with pavement damage caused by a particular type of axle carrying a particular load at a particular location on a particular type of pavement. Moreover, the Oregon tax structure was adjusted downward to account for the trips made below the registered weight or trips made with no additional weight (empty). The procedure is simplified so that all miles for trips at extended weights were reported at the truck's registered weight. Several classes of trucks have the option of being taxed on a flat-fee basis. Trucks

operating under flat-fees pay a monthly tax based on the average mileage for trucks of that type operating under the flat fee.

8.2 Cost Responsibility

The operating agencies are under intense pressure to enlarge and improve the road system while keeping down the taxes. The American Automobile Association (AAA) and railroad industry want trucks to pay a higher share to offset the damage they cause. A 1998 US Department of Transportation Cost Allocation Study found that under the current truck-tax structure, heavy trucks underpay their pavement-damage cost responsibility by as much as 50%, while smaller trucks overpay by as much as 150% ⁽⁶⁾.

Fuel taxes used as a proxy for charging directly for road space and damage represent an inequitable distribution of taxes, because vehicles with higher fuel-efficiency effectively pay less fuel tax for the same road space and/or road deterioration as its less fuel-efficient counterparts. This is especially true during peak periods, when road space is scarce. The more fuel-efficient vehicles pay substantially less than their less fuel-efficient counterparts, while contributing equally to pavement damage by increasing congestion; and thereby increasing the load duration, especially for trucks. The fuel tax inequities have a pronounced effect on businesses in typical rural areas, because they are more likely to use older small trucks than their more affluent urban counterparts.

Additionally, the rougher the road, the higher the cost on the vehicle operator due to increased vehicle depreciation and maintenance costs. These increased maintenance costs are due to an increased rate of degradation of critical auto parts, such as suspension and

braking systems. Vehicle operating cost depends on the quality of the road as measured by its roughness and also on road geometry which, however, remains constant. Consequently, when a vehicle damages the road surface and increases its roughness, it thereby increases the vehicle operating costs of subsequent vehicles, and creates road damage externalities.

These imbalances lead to the conclusion that Third Structure taxes are a more efficient and equitable source of income for road network maintenance and development in urban areas than the federal Second Structure fuel-tax. In 1999, Senator John Chafee proposed a nation-wide weight-distance tax for large trucks. He suggested substituting the weight-distance tax for three current taxes and reducing the fourth. The law suggested reducing the current federal diesel-fuel tax by 6%, eliminating the 12% sales tax on new trucks, the tire tax, and the heavy vehicle registration fee. He argued that weight-based registration fees don't account for the additional pavement damage caused by heavy-mileage trucks; while fuel taxes don't proportionally capture additional pavement damaged inflicted by heavier loads ⁽⁶⁾.

8.3 Highway Cost Allocation Study (HCAS)

The question of how to create an equitable distribution of highway taxes among users has encouraged a variety of studies conducted by federal and state highway agencies. The objective of the studies were to determine the proportionate share of each class of vehicles to the cost occasioned in design, construction, rehabilitation, and maintenance of highways. The following section presents the methodologies used for the federal and state cost allocation studies. While these methods do not fully capture the individual

vehicle's cost of damage inflicted, they offer insight into the problem of inequity and useful assessments towards creating an overall strategy in redesigning highway user taxes.

8.3.1 Cost-Occasioned Approach

The cost-occasioned approach has been the standard for user tolls (Third Structure taxes) over the latter half of the 20th Century. This approach starts from the premise that the best way to determine the fair share to be paid by each class of road users is to quantify the costs associated with each class's use of the road system. The equity of any tax system is then judged by how well payments by road users match the costs resulting from their use of the road system.

The principal alternative to the cost-occasioned approach is the benefits approach in which an attempt is made to identify and measure the benefits received by both direct users of the system and nonusers. The benefits approach starts from the recognition of significant benefits from highways to society in general, and therefore to others besides the direct users of highways. The argument for using nonuser fees to pay for highways is based on the benefits society receives from the highway system in terms of increased mobility, safety, and economic development. The principal weakness of the benefits approach is that there are a number of conceptual and practical problems in attempting to assign responsibility for highway costs to nonusers. Benefits, particularly nonuser benefits, are inherently difficult to quantify. Because of these problems, the federal government and most states conducting cost allocation studies now rely on a cost-occasioned approach to determine responsibility for highways.

The underlying philosophy of the cost-occasioned approach is that each user should pay the highway costs that it creates or “occasions”. The costs or expenditures allocated in a HCAS can be those for a past period or those anticipated for a future period. Most of the studies have allocated both historical and planned expenditures. The disadvantage associated with allocating only projected future expenditures is that it relies on forecasts that may be subject to greater error than the historical data. As discussed above, both the federal and state studies exclude the social costs associated with highway use. Another issue is what costs to consider. Previous federal and state cost allocation studies have focused on highway agency costs paid from highway user charges.

Within the cost-occasioned approach, there are different methods that may be used to allocate costs or expenditures to the various vehicle classes.

8.3.2 Incremental Method

The basic principle of the incremental method is that of avoidable cost. If a cost can be avoided because a particular vehicle class is excluded, then this cost is properly attributable to that class. The method involved the design and cost estimation of pavements required to serve increments of axle loads. The heaviest loads are then reduced successively in each increment. The pavement was then re-designed to serve the lighter load. The cost differences for each increment were allocated among vehicles whose axle loads were reduced, thereby resulting in reduced pavement thickness.

8.3.3 Federal Method

This method is the updated version of the incremental method. This method divides selected aspects of highway costs into increments, allocating the costs of successive increments to only those vehicles needing the higher cost increment. A minimum pavement is defined that is adequate to support light vehicle traffic only, and withstand environmental influences such as freeze-thaw cycles. Costs associated with the basic road are considered common costs allocated to all vehicle classes based on vehicle miles traveled (VMT) or passenger car equivalent (PCE) weighted VMT. Hypothetically, the basic road is upgraded in a series of increments that reflects the needs of successively heavier classes.

For example, the basic road might be designed to have pavement 9 inches in depth, that designed to support medium trucks being 10 inches in depth and that designed for heavy trucks being 12 inches in depth. Since all vehicle classes share the cost of the basic road, medium trucks share that cost as well as a portion of additional 1-inch increment. Heavy trucks then assume a portion of the cost of the basic road, a portion of the first additional increment, and the full cost of the final increment. The big difference between the incremental and federal method is the allocation of pavement reconstruction and rehabilitation costs. The incremental method lumps all costs together as though all pavements were being newly constructed. The federal method uses an approach that has been termed the “consumption approach”.

The consumption approach allocates the pavement costs to vehicles based on a deterioration model. The deterioration based method uses the AASHTO fourth-power

relationship between increasing axle loads and pavement deterioration. A doubling of the weight on a single axle, in other words, results in an approximately 16-fold (i.e., $2 \times 2 \times 2 \times 2$) increase in the amount of stress applied to a pavement. In 1979, the Congressional Budget office recommended a deterioration model method for all pavement costs (source: FHWA HCAS Tool). As a compromise, the 1982 HCAS adopted the thickness-based (incremental) method for new pavement costs and deterioration-based method for pavement rehabilitation costs. This combination became known as *the federal method*. The FHWA is currently in a transition phase of replacing the existing deterioration model with mechanistic-empirical models conforming to the AASHTO 2002 guidelines for the future highway cost allocation studies.

8.3.4 Marginal Cost Approach

Some critics of the traditional cost-occasioned approach argue that economic efficiency is more important than equity, and that highway user charges should reflect the true cost of each vehicle's use of the highway, not the share of highway agency expenditures allocated to different vehicle classes. Those who advocate focusing cost allocation on efficiency rather than equity generally favor a marginal cost approach to cost allocation whereby vehicles would be charged in proportion to their marginal cost of highway use. In essence, both the cost-occasioned and the marginal cost approaches assign cost responsibility based on principles of cost-occasioning. The traditional cost-occasioning approach limits the scope of "costs" considered to highway agency obligations or expenditures. The marginal cost approach, on the other hand, does not consider highway agency expenditures, but rather estimates the economic cost of additional increments of

highway use by each vehicle class. This estimate includes both the infrastructure costs that ultimately result in highway agency expenditures, as well as environmental and other social costs occasioned by the operations of each vehicle class that is not reflected in highway agency budgets. The disadvantage of this method is the difficulty in determining each vehicle's equitable share of pavement costs and social costs. Nevertheless, this method has never been completely applied in a major study. All major federal and state studies use the cost-occasioned approach discussed above.

8.4 Federal Highway Cost Allocation Study –1997 (HCAS)

The objective of the HCAS study conducted in 1997 was to evaluate the equity and efficiency of current federal highway user charges. This was achieved by comparing the costs occasioned by each vehicle class to the revenue paid by each class in order to establish the equity ratio. Table 8-3, below, shows the results of the study as it pertains to trucks and passenger vehicles. The equity ratio (ER) is defined as the ratio of revenues to costs, that is, to determine if each class of vehicle is paying its "fair share". The values that are greater than 1 indicate an overpayment and those that are less than 1 indicate an underpayment. The study indicates the following for the ISTEA base period:

- Single unit trucks carrying more than 25,000 lbs. pay for 50 to 80% of the damage they create (ERs of 0.5 and 0.8). But the same trucks weighing less than 25,000 lbs. pay for 160% of the damage they create (ER of 1.6);
- Combination trucks carrying more than 80,000 lbs. pay for slightly more than ½ the damage they create (ERs of 0.6 and 0.5); whereas the same trucks weighing

less than 75,000 lbs. pay for more than their share of the damage created (ERs of 1.7, 1.2 and 1.1);

- Most trucks carrying heavy loads are underpaying their share of the damages they create (ERs varying from 0.5 to 0.9); whereas the lightest trucks (ER = 1.6 and 1.7), pickup trucks and vans (ER = 1.4) are paying more than their share; and
- Automobiles are paying their fair share for the damage they inflict (ER = 1).

The equity ratios forecasted for the year 2000 are all within 0.1 of the base period values. This study indicates that the greater the weight of a vehicle within a vehicle class, the lower its equity ratio as compared to lighter vehicles within the same class. Conversely, lighter vehicles have higher equity ratios, and pay more than their fair share, as compared to heavier vehicles within their vehicle class.

8.4.1 Federal HCAS Recommendations

Suggestions made as a result of the Federal Highway Cost Allocation Study (HCAS) include the following potential user fee changes to improve the equitable distribution of such charges ⁽⁴⁾:

1. **Scenario 1:** Adding 1 cent per gallon to the diesel differential would reduce the underpayment of heavy trucks. But this is not sufficient to be reflected in improved equity ratios for those vehicles.
2. **Scenario 2:** Adding 6 cents per gallon to the diesel differential would reduce underpayment and improve the equity ratios for trucks. But it would not eliminate the underpayment by heavier trucks.

3. **Scenario 3:** Eliminating the cap on the heavy-vehicle use tax for all vehicles registered above 75,000 lb (34,020 kg) would somewhat reduce the underpayment by the heaviest vehicles. But it would do nothing to improve equity ratios for trucks registered at weights less than 75,000 lbs.
4. **Scenario 4:** Creating a two-tier HVUT (Heavy Vehicle User Tax) structure for single units and combinations with more progressive rates for the heaviest trucks could reduce underpayment by trucks as a group. But it increases inequities between low-mileage and high-mileage vehicles.
5. **Scenario 5:** Introducing a WDT can better reflect the influence of both weight and VMT on highway costs than the previous tax scenarios and the current federal user-fee structure. A weight- and distance-oriented highway tax structure provides more flexibility to the current tax structure. The equity ratios for trucks, including heavier and high-mileage trucks, improve as compared to the current user-fee structure.
6. **Scenario 6:** Imposing an axle-WDT provides more flexibility to address vehicle weight and mileage factors, and it provides the additional advantage of recognizing the relationship between the number of axles on a vehicle and that vehicle's cost responsibility.

Scenarios 5 and 6 suggest Weight-Distance Taxes, however Scenario 6 provides the better subdivisions by number of axles, loads and distance traveled. Scenario 6 promotes the most equitable distribution of fees based upon actual damage. This recommendation together with the analysis presented in previous chapter establish a need for a

comprehensive pricing policy that account for weight per axle, duration of loading, or the contact area between tires and pavement. Such a pricing policy would result in an equitable distribution of costs among users within each class. The next chapter discusses the implications of just such a potential pricing policy.

TABLE 8-3: 1997 Data from the Federal Highway Cost Allocation Study (HCAS)

Table VI-1. Base Period and Forecast Period Equity Ratios for Broad Vehicle Classes						
Vehicle Class/Registered Weight	ISTEA Base Period			2000 Forecast Period		
	User Fee Shares	Cost Shares	Equity Ratio	User Fee Shares	Cost Shares	Equity Ratio
Auto	41.2	44.2	0.9	42.6	43.8	1.0
Pickups/Van	21.6	15.6	1.4	21.4	15.4	1.4
All Personal Use Vehicles	62.8	59.8	1.1	64.0	59.2	1.1
Buses	0.1	0.7	0.1	0.1	0.7	0.1
Single Unit Truck						
<25,000 pounds	5.6	3.6	1.6	5.5	3.6	1.5
25,001 - 50,000 pounds	2.3	3.0	0.8	2.2	3.1	0.7
>50,000 pounds	2.1	4.5	0.5	1.8	4.0	0.5
All Single Units	10.0	11.0	0.9	9.6	10.7	0.9
Combination Trucks						
<50,000 pounds	1.1	0.7	1.7	1.1	0.7	1.6
50,001 - 70,000 pounds	1.9	1.6	1.2	1.9	1.7	1.1
70,001 - 75,000 pounds	1.4	1.3	1.1	1.4	1.4	1.0
75,001 - 80,000 pounds	20.9	21.8	1.0	20.3	22.5	0.9
80,001-100,000 pounds	1.0	1.7	0.6	1.0	1.8	0.6
>100,001 pounds	0.7	1.3	0.5	0.7	1.4	0.5
All Combinations	27.1	28.4	1.0	26.4	29.4	0.9
All Trucks	37.1	39.5	0.9	35.9	40.1	0.9
All Vehicles	100.0	100.0	1.0	100.0	100.0	1.0

CHAPTER 9

ROAD PRICING

The quantitative analysis of actual pavement damage caused by the different loading characteristics of heavy vehicles, combined with the current criteria for taxation clearly shows that the current tax structures do a poor job of capturing pavement damage. Charging vehicles by their number of axles, instead of by axle load, encourages hauling heavy loads on too few axles. On the other hand, charging per axle instead of by total load would not only reduce the heaviest axle weights, by encouraging trucking companies to distribute the load more evenly, but also holds vehicles accountable for their true share of pavement damage. This creates the need for a comprehensive methodology that could capture the pavement damage caused by an individual truck based on real time axle-weight, axle spacing, load distribution over axles, travel on a particular pavement at a particular speed, and tire pressure.

9.1 Pricing

There are two components to the costs that must be captured in order to provide a system of equitable cost distribution: a pavement damage component (PDC) and a congestion component (CC). The PDC is the cost a user imposes on the agency responsible for maintaining the highway system; and the cost a user imposes on society through his contribution to pavement damage. The CC is the cost imposed on the agency by slower speeds, in the form of increased pavement damage due to increased load duration and braking frequency. The CC also includes the cost imposed on other users from increases in travel time, vehicle depreciation, vehicle maintenance and repair, and collisions.

Congestion differs from pavement damage in one important respect – congestion occurs only at certain times and places. These components combined are the marginal cost defined as *the change in the total social cost of travel on existing roads, including cost of maintenance and cost incurred by all its users, brought about by adding one vehicle of a particular type and weight, at a particular place and time* ⁽⁹⁾. In simpler terms, the marginal cost is the additional cost incurred by one vehicle on the road due to all the other vehicles on the road.

The best way to economize on maintaining and using an existing road is to apply a user charge equal to the actual cost each user imposes on the infrastructure and on other users. The principle behind road damage charges is to charge vehicles for the damage they inflict on pavements based on the damaging power of their axle loads, time of the day they travel (congestion and speed), and tire pressure.

Accepting the assumption that determination of user charges should depend upon the design of the pavement structure, pavement maintenance and rehabilitation costs, and real time congestion, it is essential to use mechanistic tools and intelligent technologies to correctly predict the pavement degeneration based upon real time traffic. Having an accurate picture of the anticipated deterioration of a structure is critical to attaining the most effective proactive maintenance efforts to facilitate preservation of optimum pavement conditions. Sustaining optimal pavement conditions provides the greatest support for heavy loads and consequently, minimizes pavement damage resulting in the smallest marginal costs.

Traditionally, pavement thickness, including base and sub-base layers, has been the primary determinant of its ability to carry numerous axle loads. Now that technological improvements have allowed the pavement industry to use mechanistic design procedures, research has shown that other components such as asphalt viscosity, air voids, proportion of HMAC aggregate passing the #4 sieve, proportion of the sub-base soil passing the #200 sieve, the annual freeze/thaw cycle, the freeze index, annual precipitation, axle load, axle spacing, tire pressure, and speed greatly affect the life of the pavement. Knowledge of how to fine-tune these parameters improves the quality of pavement design and lengthens design life. Although this may lead to higher initial construction costs, over the long term it provides substantial savings on maintenance costs; and therefore, decreased road user costs.

The analysis presented in Chapters 6 and 7 determined, through mechanistic modeling, that pavement damage caused by trucks can be minimized with the loads distributed to achieve an even division of load per unit contact area between tires and pavement. The analysis also shows that this load, per unit contact area, could be reduced by adding axles. Furthermore, additional reductions in pavement damage can be achieved by minimizing the duration of loading through congestion mitigation efforts, in order to allow travel at higher speeds. Accordingly, the following sections outline the proposed methods to determine real-time pavement damage and appropriate user charges.

9.2 Example for Calculating the Cost Responsibility

An analysis was conducted, using KENLAYER ⁽²¹⁾ to compute the share of pavement damage caused by an individual vehicle, in order to assign a cost responsibility. The following steps were involved in calculation.

Step1: Computation of Total Pavement Damage

The first step in the analysis was to compute the total pavement damage inflicted, throughout its design life, by all classes of vehicles. This involved computation of tensile strain damage ratio at the bottom of the asphalt concrete layer and compressive strain damage ratio on the top of the subgrade, as described in Chapter 5. The damage ratio that governs the design (which is the higher of the two numbers) was used to perform damage analysis, and to compute the design life.

The Weigh-in-Motion (WIM) data that was used for this analysis was collected on a section of I-95 just south of the Jacksonville, FL. Three classes of vehicles were chosen for the analysis: Class 8A (3-axle truck), Class 8B (4-axle truck) and class 9 (5-axle truck). Table 9-1 shows the average gross weight, the weight on each axle, and axle spacing for the each class of vehicle. For demonstration purposes, all other vehicle classes were ignored.

For the initial design, an average speed of 58 mph was obtained from WIM data. Tire pressure was kept constant at 80 psi for all trucks. Table 9-2 presents the computation of contact area and the contact radius used for KENLAYER input. Table 9-3 shows the number of annual repetitions for each vehicle class. An annual straight-line growth rate of

2.5% was used. A three-layer asphalt concrete pavement system was used for this analysis. Table 9-4 presents the properties of this pavement system.

Table 9-1: Summary of WIM data

Description	# of Axles	Proportion TT %	Avg. Gross Wt (lbs)	Axle 1 (lbs)	Axle 2 (lbs)	Axle 3 (lbs)	Axle 4 (lbs)	Axle 5 (lbs)	# of Axle Spaces	ASP1 (ft)	ASP2 (ft)	ASP3 (ft)	ASP4 (ft)
Class 8 A	3	2	41,235	12,868	15,880	12,486	-	-	2	14.3	25.8	0.0	0.0
Class 8 B	4	9	74,262	27,749	23,708	11,099	10,719	-	3	15.8	26.7	4.5	0.0
Class 9	5	50	68,865	15,450	13,964	13,582	12,886	12,984	4	12.9	3.3	25.1	3.8

Table 9-2: Actual Loading: 3-Axle, 4-Axle and 5 Axle Trucks

Description	Type	Axle Share	Avg. Weight (lbs)	Load per Tire (lbs)	TP=CP (psi)	Contact Area (sq-in)	Contact Radius (in)	XW (in)	YW (in)
Class 8A									
Axle 1	SASW	31%	12868	6434	80	80.43	5.06	0	0
Axle 2	SADW	39%	15880	3970	80	49.63	3.97	0	13.5
Axle 3	SADW	30%	12486	3122	80	39.02	3.52	0	13.5
Class 8B			41234						
Axle 1	SASW	38%	27749	13875	80	173.43	7.43	0	0
Axle 2	SADW	32%	23708	5927	80	74.09	4.86	0	13.5
Axle 3&4	TA	30%	21818	2727	80	34.09	3.29	4.5	13.5
Class 9			73275						
Axle 1	SASW	22%	15450	7725	80	96.56	5.54	0	0
Axle 2&3	TA	40%	27546	3443	80	43.04	3.70	3.3	13.5
Axle 4&5	TA	38%	25868	3234	80	40.42	3.59	3.8	13.5
			68864						

SASW= single axle single wheel; SADW= single axle dual wheel; TA=tandem axle

Table 9-3: Number of Annual Repetitions

Class	ADTT	Dd	DI	NO of Days	W18(1year)	GF	W18(1year)
Class 8 A	197	56%	70%	365	28,187	2.50%	28,891
Class 8 B	1153	56%	70%	365	164,971	2.50%	169,096
Class 9	6090	56%	70%	365	871,357	2.50%	893,141
Total Repetitions =							1,091,128

Table 9-4 Other data:			Poisson ratio	0.5
Speed	58 mph		E (AC)	To be calculated
Load duration	0.05 sec		E (BC)	30,000 psi
Tire pressure	80 psi		E (Subgrade)	15,000 psi
AC layer	8 in		Reference temp	70 deg F
Base course	10 in		Pavement temp	65.2 deg F

Table 9-5 presents the results of this analysis. The damage accumulation by each class of vehicle is shown. The allowable number of repetitions for fatigue cracking and permanent deformation was calculated using the following equations:

$$N_f = f_1(\epsilon)^{-f_2} (E_1)^{-f_3}$$

$$N_d = f_4(\epsilon_c)^{-f_5}$$

Where N_f is the allowable number of load repetitions to failure for the fatigue cracking; ϵ_1 is the tensile strain at the bottom of asphalt layer; E_1 is the elastic modulus of asphalt layer; N_d is the allowable number of load repetitions to limit permanent deformation, ϵ_c is the compressive strain on the top of subgrade, and f_1, f_2, f_3, f_4 and f_5 are constants determined from laboratory tests. The Asphalt Institute values presented at the bottom of Table 9-5 were used for this analysis.

The damage ratio, which is the ratio between predicted and allowable number of repetitions, is computed for each load group in each period and summed over the year by:

$$D_r = \sum_{i=1}^p \sum_{j=1}^m (n_{ij} / N_{ij})$$

Where D_r is the damage ratio at the end of the year, n_{ij} is the predicted number of load repetitions for load j in period i , N_{ij} is the allowable number of load repetitions based on fatigue cracking and permanent deformation equations, p is the number of periods in each year and m is the number of load groups. The design life, which is equal to $1 / D_r$, is evaluated for both fatigue cracking and permanent deformation; and the one with a shorter life controls the design. The procedure for computing the tensile strain at the bottom of AC layer, compressive strain on top of subgrade and modulus of elasticity is presented in Chapter 5.

Table 9-5: Damage Accumulation by Various Class of Trucks (As Designed)

Vehicle Type	Annual Load Repetitions	Axle Type	Tensile Strain	Modulus of Elasticity (psi)	Allowable Load Repetitions for Fatigue Failure	Tensile Strain Damage Ratio	Comp Strain	Allowable Load Repetitions for Permanent Deformation	Compressive Strain Damage Ratio
			ϵ_t	E	N_f	D_r	ϵ_c	N_d	D_r
Class 8A									
Axle1	28891	SASW	3.949E-05	1.834E+06	1.106E+08	2.611E-04	7.737E-05	3.483E+09	8.294E-06
Axle2	28891	SADW	4.033E-05	1.836E+06	1.031E+08	2.801E-04	8.546E-05	2.232E+09	1.295E-05
Axle3	28891	SADW	3.227E-05	1.836E+06	2.148E+08	1.345E-04	6.740E-05	6.460E+09	4.472E-06
Sub-Total			1.121E-04			6.757E-04	2.302E-04		2.571E-05
					Life (yrs)	1480			
Class 8B									
Axle1	169096	SASW	7.018E-05	1.836E+06	1.666E+07	1.015E-02	1.601E-04	1.343E+08	1.259E-03
Axle2	169096	SADW	5.835E-05	1.836E+06	3.059E+07	5.529E-03	1.271E-04	3.775E+08	4.480E-04
Axle3	169096	TADW	4.925E-05	1.838E+06	5.339E+07	3.167E-03	1.150E-04	5.907E+08	2.862E-04
	169096	Differential	1.424E-06	1.838E+06	6.194E+12	2.730E-08	1.402E-06	2.188E+17	7.727E-13
Sub-Total			1.792E-04			1.885E-02	4.036E-04		1.993E-03
					Life (Yrs)	53			
Class 9									
Axle1	893141	SASW	4.552E-05	1.835E+06	6.928E+07	1.289E-02	9.205E-05	1.600E+09	5.581E-04
Axle2	893141	TADW	6.511E-05	1.837E+06	2.131E+07	4.191E-02	1.468E-04	1.980E+08	4.510E-03
	893141	Differential	2.568E-06	1.838E+06	8.896E+11	1.004E-06	9.909E-07	1.035E+18	8.630E-13
Axle3	893141	TADW	6.000E-05	1.837E+06	2.789E+07	3.202E-02	1.377E-04	2.637E+08	3.387E-03
	893141	Differential	2.982E-06	1.838E+06	5.439E+11	1.642E-06	1.220E-06	4.078E+17	2.190E-12
Sub-Total			1.762E-04			8.682E-02	3.788E-04		8.455E-03
					Life (Yrs)	11.52			
Grand Total			4.675E-04		Governing Dr Design Life (Yrs)	1.063E-01	1.013E-03		1.047E-02
						9.40			

f1=0.0796

f2=3.291

f3=0.854

f4=1.37E-09

f5=4.477

SASW= single axle single wheel; SADW= single axle dual wheel; TA=tandem axle

The results of the analysis showed that Class 9 vehicles caused 81.6% of the total damage, while class 8B caused 17.7% and class 8A 0.6%, respectively. This is proportionate with number of repetitions for each class of vehicles. The tensile strain damage ratio, with its higher value, controlled the design. The total damage ratio computed for all load groups was 1.063E-01 yielding a design life of 9.40 years.

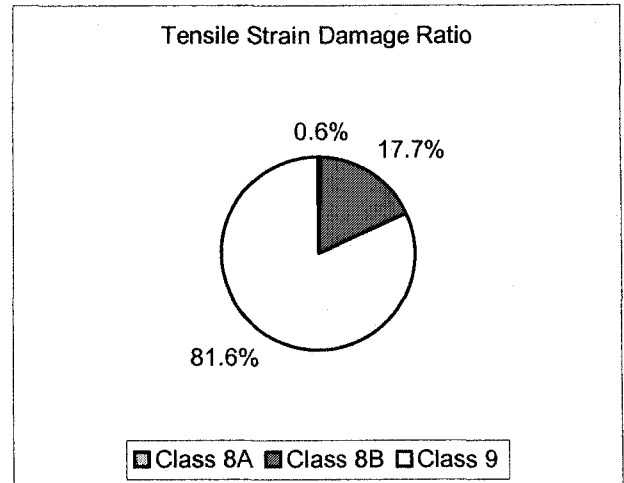


Figure 9-1: Damage share of each class of vehicles

Step 2: Computation of Individual Pavement Damage

Once the total pavement damage was computed for the design life of the pavement, the second step was the computation of damage share for an individual truck based on its real time axle weight, weight distribution over the axles, speed, and tire pressure.

A 5-axle truck carrying a gross weight of 68,684 lbs with a 22-40-38% distribution was selected for the analysis. The analysis was performed for 20, 40, 60 and 80 mph speed with a varying tire pressure of 80, 100 and 120 psi. Table 9-6 shows the input data. The load was imposed on the same pavement configuration as the analysis in the previous step. And the damage caused by an individual truck was also calculated using the same procedure discussed above. The results are presented in Table 9-7. The damage share and cost responsibility of one individual truck was computed as follows:

For example for 80 mph speed with tire pressure of 80 psi;

Damage Share = Damage caused by one truck / total damage

Damage share = $8.039\text{E-}08 / 1.063\text{E-}01 = 7.560\text{E-}07$

Cost Responsibility = (Damage caused by one truck / total damage) x LCC (per mile)

$= 7.560\text{E-}07 \times 71,450^1 = \$0.05 \text{ per mile}$

Table 9- 6: Class 9 Trucks with varying tire pressure and speed

Vehicle Type	Axle Type	Axle Share	Gross Weight (lbs)	Load per Tire (lbs)	TP=CP (psi)	Contact Area (sq-in)	Contact Radius (in)	XW (in)	YW (in)	Speed (mph)	Load Duration (sec)
Class 9										5	0.582
Axle 1	SASW	22%	15450	7725	80	96.56	5.54	0	0	10	0.291
Axle 2&3	TA	40%	27546	3443	80	43.04	3.70	3.3	13.5	15	0.194
Axle 4&5	TA	38%	25868	3234	80	40.42	3.59	3.8	13.5	20	0.145
			68864							25	0.116
Class 9										30	0.097
Axle 1	SASW	22%	15450	7725	100	77.25	4.96	0	0	35	0.083
Axle 2&3	TA	40%	27546	3443	100	34.43	3.31	3.3	13.5	40	0.073
Axle 4&5	TA	38%	25868	3234	100	32.34	3.21	3.8	13.5	45	0.065
			68864							50	0.058
Class 9										55	0.053
Axle 1	SASW	22%	15450	7725	120	64.38	4.53	0	0	60	0.048
Axle 2&3	TA	40%	27546	3443	120	28.69	3.02	3.3	13.5	65	0.045
Axle 4&5	TA	38%	25868	3234	120	26.95	2.93	3.8	13.5	70	0.042
			68864							80	0.036

¹ The life-cycle maintenance cost for an 8-inch thick AC pavement with a 12- inch base was obtained from reference 11, for a typical New York State design. The actual cost may differ depending on the pavement design and maintenance strategy, as well as on the policy that which costs should be charged to the user. However, this will not affect the damage share or cost allocation calculated for an individual truck.

Table 9-7: Damage share of an individual 5-Axle truck at varying speed and tire pressure

Speed (mph)	Tire Pressure (psi)	Individual Truck Damage	Damage Share	Cost Share (\$)
80	80	8.039E-08	7.560E-07	0.05
60	80	9.721E-08	9.141E-07	0.07
40	80	1.237E-07	1.163E-06	0.08
20	80	1.978E-07	1.860E-06	0.13
80	100	8.408E-08	7.907E-07	0.06
60	100	1.024E-07	9.629E-07	0.07
40	100	1.306E-07	1.228E-06	0.09
20	100	2.087E-07	1.963E-06	0.14
80	120	8.716E-08	8.196E-07	0.06
60	120	1.063E-07	9.996E-07	0.07
40	120	1.359E-07	1.278E-06	0.09
20	120	2.180E-07	2.050E-06	0.15

[GVW=68865; 22-40-38% axle distribution]

As Designed Damage Ratio to Failure=

0.10634

[Table 9-5]

Per mile life-cycle maintenance cost=

71,450.00

[Ref:11]

9.2.1 Speed and Tire Pressure Sensitivity

Figure 9-2 shows a plot of cost responsibility at 20, 40, 60 and 80 mph with a tire pressure of 80, 100 and 120 psi. The effect of slower speed is very pronounced while the effect of tire pressure is very small. The pavement damage increases at a higher rate when the vehicle is moving at slower speeds. For example, reducing the speed from 40 to 20 mph, at 80 psi tire pressure, increases the cost responsibility by 63%; from 8 cent to 13 cent per mile. A 20 psi increase in tire pressure caused only a 1 cent upward shift in the curve. Changing the tire pressure from 80 to 120 psi, at a vehicle speed of 20 mph, resulted in an increase of 15%, that is, from 13 cents to 15 cents.

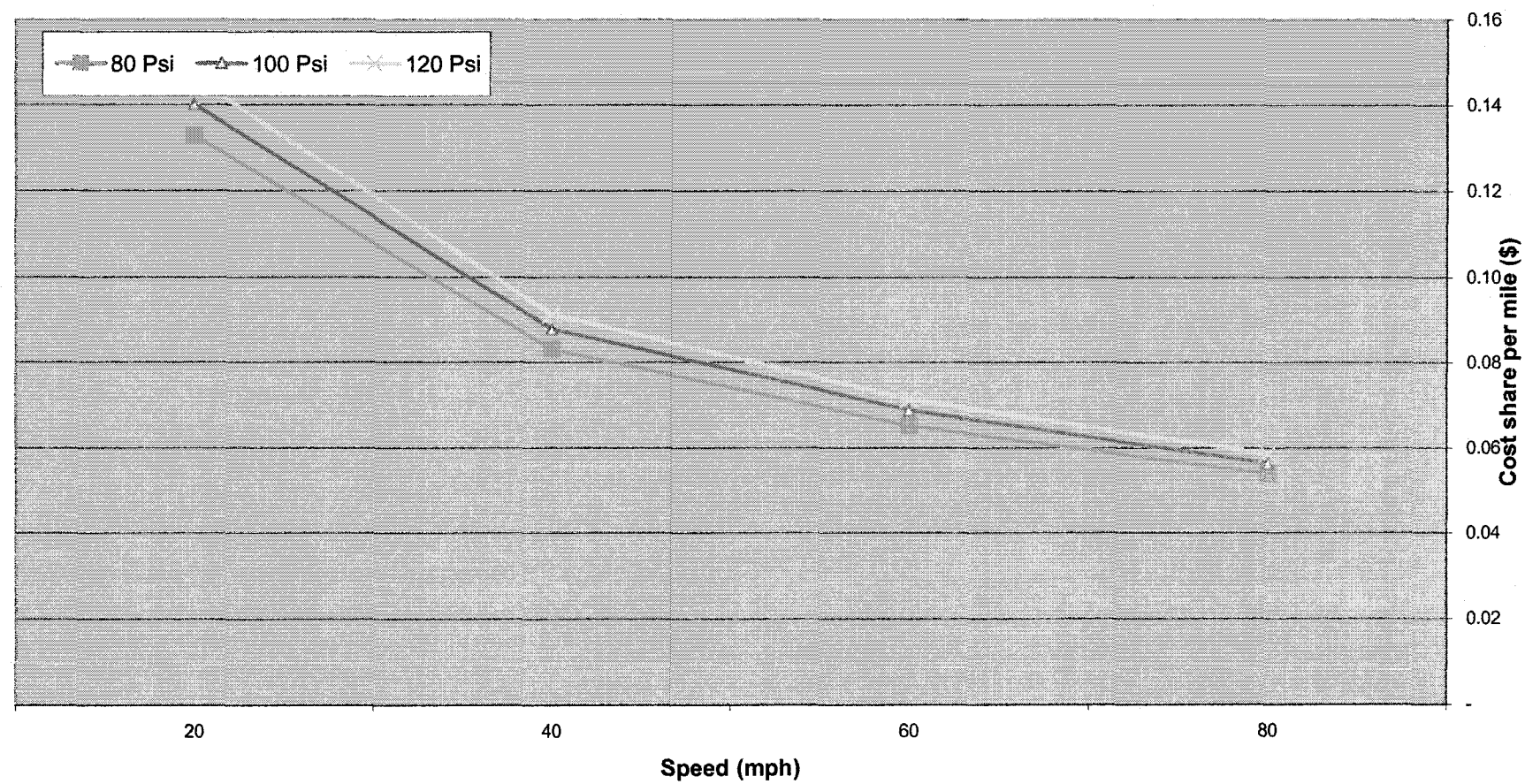


Figure 9-2: Cost responsibility for a class 9 truck carrying GVW of 68,865 lbs with 22-40-38% distributions, at varying speed and tire pressure

9.2.2 Load and Speed Sensitivity

Table 9-8 shows the results of pavement damage and cost responsibility for a Class 9 vehicle (5-axle truck) at various loads, ranging from 20,000 to 120,000 lbs at 20, 40 and 60 mph speed. The results are plotted in Figure 9-3. The plot clearly demonstrates that the same truck carrying different load should be charged differently, depending upon its contribution to pavement damage. For example, the cost responsibility for a Class 9 truck when traveling empty is approximately 2 cent per mile. However, when carrying 100,000 lbs at 60 mph, the same vehicle shows a precipitous increase in cost, to 21 cent per mile. The impact of the same truck at slower speeds is much more pronounced. Traveling at 20 mph, the vehicle is assigned a cost responsibility of 42 cent per mile with same 100,000 lbs. load. It is interesting to note that the curve shift at slower speed is wider, meaning that more damage occurs at slower speeds.

Table 9-8: Damage share of an individual 5-Axle truck at varying load
[Axle distribution= 20-40-40%; Tire pressure =80 psi]

Gross Vehicle Weight (lbs)	Speed (mph)	Individual truck Damage	Damage share	Cost Share (\$)
20000	20	4.313E-09	4.056E-08	0.00
40000	20	3.837E-08	3.608E-07	0.03
60000	20	1.332E-07	1.253E-06	0.09
80000	20	3.224E-07	3.032E-06	0.22
100000	20	6.327E-07	5.950E-06	0.43
120000	20	1.102E-06	1.036E-05	0.74
20000	40	2.661E-09	2.502E-08	0.00
40000	40	2.393E-08	2.250E-07	0.02
60000	40	8.368E-08	7.869E-07	0.06
80000	40	2.036E-07	1.915E-06	0.14
100000	40	4.018E-07	3.778E-06	0.27
120000	40	7.019E-07	6.600E-06	0.47
20000	60	2.071E-09	1.947E-08	0.00
40000	60	1.874E-08	1.762E-07	0.01
60000	60	6.573E-08	6.181E-07	0.04
80000	60	1.603E-07	1.507E-06	0.11
100000	60	3.172E-07	2.983E-06	0.21
120000	60	5.548E-07	5.217E-06	0.37

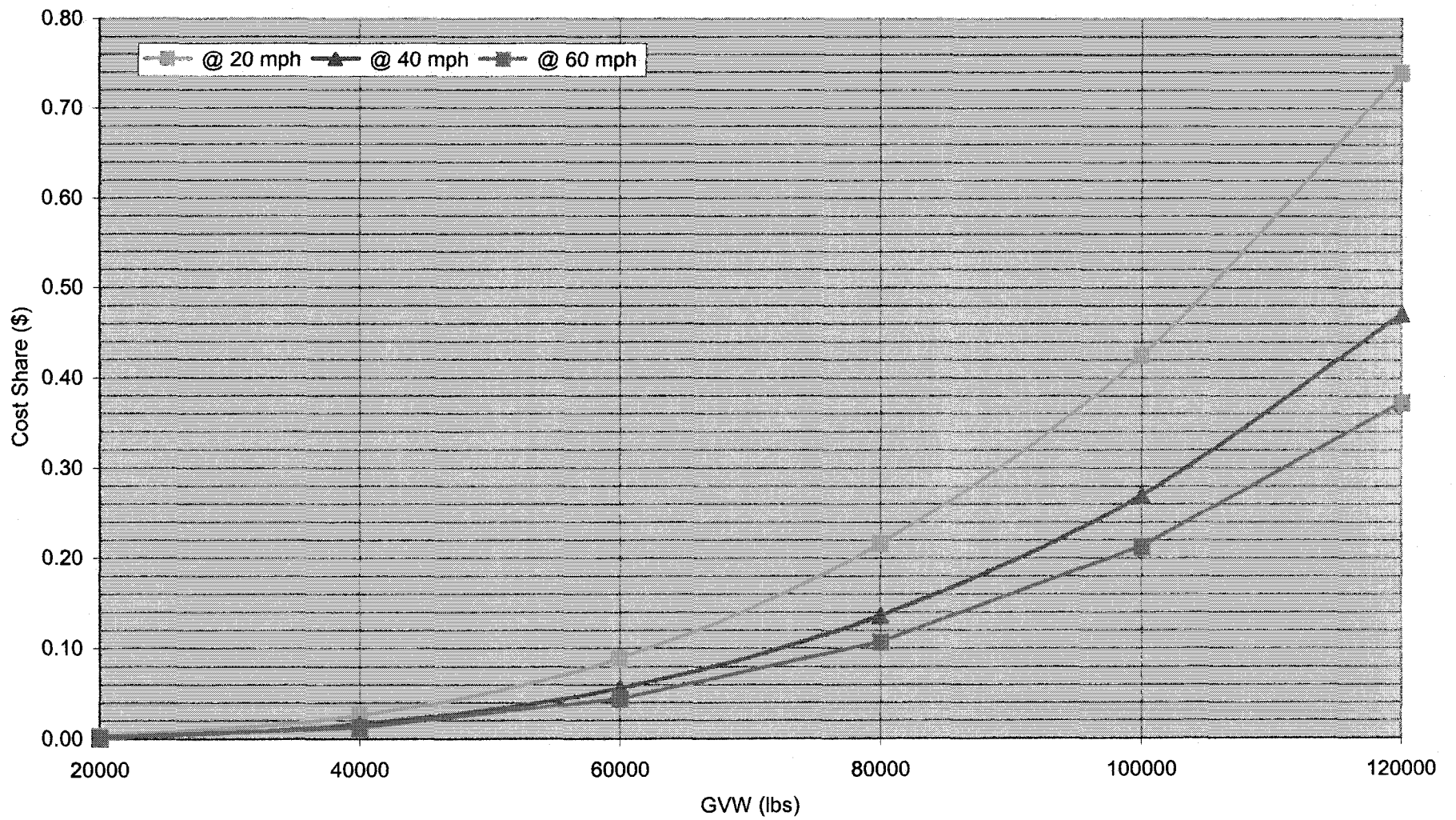


Figure 9-3: Cost responsibility for a class 9 truck at varying GVW, assuming equal distribution, at 20, 40 and 60 mph speed.

9.3 Comparison between Oregon and New Jersey Turnpike Tax Structures

Table 9-9 shows a comparison of computed taxes (proposed) with the Oregon DOT, and the NJ Turnpike tax structure. The NJ Turnpike charges vehicles based on the number of axles, regardless of vehicle weight. For example, a 5-axle truck traveling from exit 1 to 18W (over a 118-mile segment of road) must pay a total of \$23.20, or 19.66 cents per mile. Oregon state WDT is imposed on all trucks carrying a load of over 26,000 lbs. From 26,001 to 80,000 lbs. all type of trucks, regardless of the number of axles they have, pay the same rate depending on their Gross Vehicle Weight (GVW). For example, a truck carrying 60,000 lbs. pays 7.56 cents per mile (or a total of \$8.92 for driving over a 118-mile segment of public highway.)

Trucks carrying more than 80,000 lbs. in Oregon are charged on a declared weight, and the number of axles they have (refer to Table 8-2, in chapter 8). A 5-axle truck carrying 100,000 lbs. pays approximately 19.2 cent per mile (or a total cost of \$ 22.66 for driving over a 118-mile segment of public highway.) And although a 5-axle truck is not allowed to carry loads exceeding 100,000 lbs., Florida DOT WIM data shows that a good proportion of 5-axle truck do just that (refer to Appendix B).

Figure 9-4 shows the plot of total taxes charged for driving over a 118-mile segment of public roadway for NJ turnpike and the Oregon DOT, as well as the proposed procedure. The NJ Turnpike curve intercepts the proposed curve at 80,000 lbs., at 20 mph; and at 100,000 lbs., at 60 mph. The Oregon state curve follows the proposed curves more closely for speeds of 40 and 60 mph. At the lower end of the load spectrum, and up to 50,000 lbs., the Oregon tax structure charges a 5-axle truck more than the actual share. Note that the Oregon state tax structure does not differentiate between 4- or 5-axle trucks below 80,000 lbs. As shown in *Chapter 6*, a 4-axle

truck does much more damage than a 5-axle truck while carrying the same gross load. This implies that at the lower end of the load spectrum, a 5-axle truck may be overcharged by Oregon tax structure while a 3- or 4-axle truck carrying the same load may be undercharged. For trucks carrying more than 50,000 lbs., the results vary according to speed. At slower speeds, the Oregon DOT undercharges the trucks in question; while at higher speeds, it more closely follows the damage curve.

Table 9-9: Toll comparison for a Class 5 Truck
118 miles (Exit 1 to 18W NJ Turnpike)

GVW (lbs)	Damage Based @ 20 mph (\$)	Damage Based @ 40 mph (\$)	Damage Based @ 60 mph (\$)	NJ Turnpike (\$)	Oregon WDT (\$)
20000	0.34	0.21	0.16	23.20	0
40000	3.04	1.90	1.49	23.20	6.20
60000	10.56	6.63	5.21	23.20	8.92
80000	25.56	16.14	12.71	23.20	16.76
100000	50.16	31.86	25.15	23.20	22.66
120000	87.37	55.65	43.99	23.20	

NJ Turnpike: plus fuel taxes

Oregon:

< 26,000 lbs, fuel tax only

>26001<=80,000 lbs; declared weight only; exempt from fuel taxes

>80, 000 to 105,000 lbs declared weight + number of axles; exempt from fuel taxes

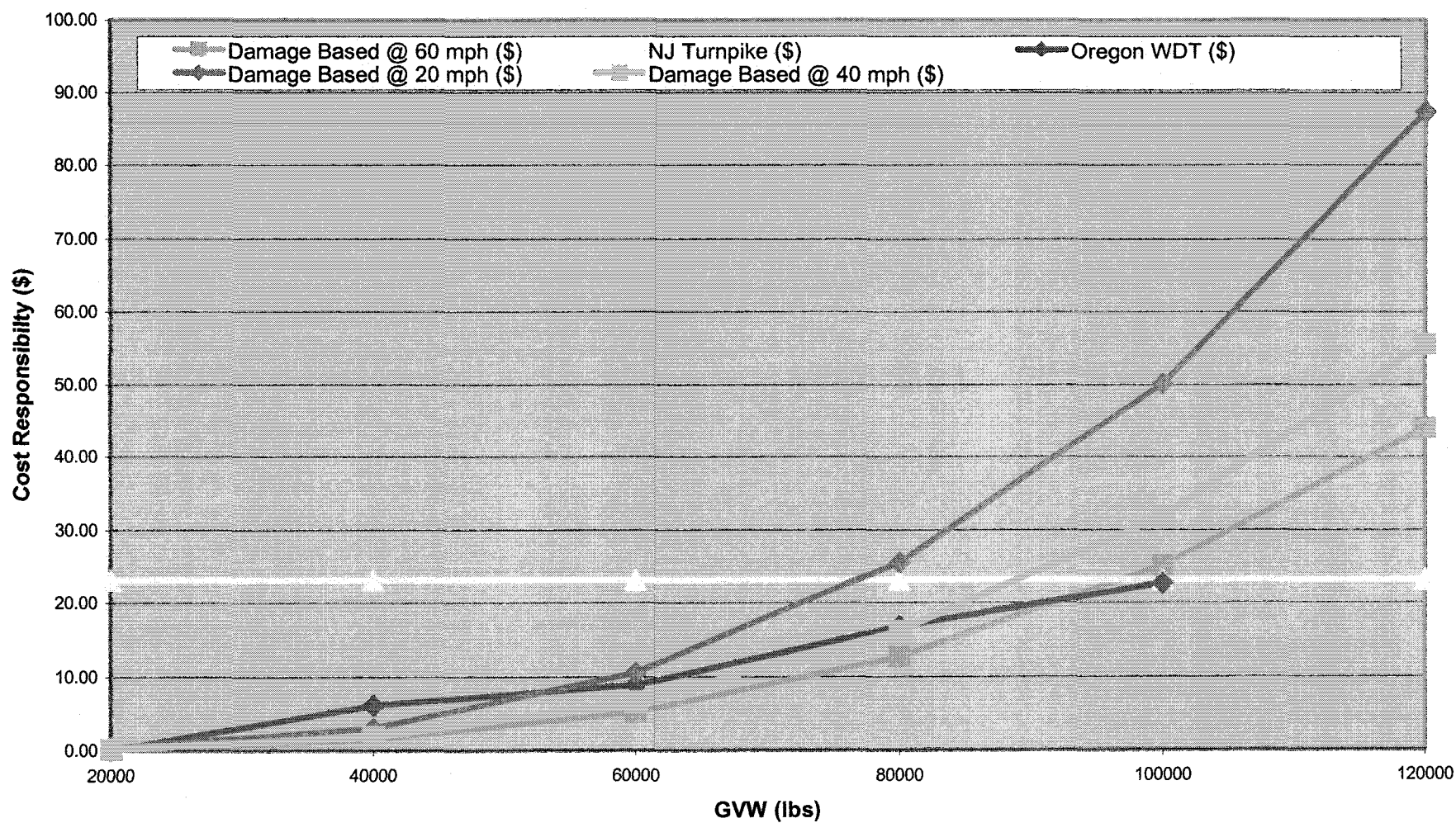


Figure 9-4: Comparison of cost responsibility for a 5-axle truck with NJ Turnpike and Oregon State tax structure for a 118-mile segment of road

CHAPTER 10

POLICY IMPLICATIONS

10.1 Assessment of Tolling Efficiency

Most funds for road construction and maintenance are raised by a variety of taxes related to vehicle use. The number and weight of the vehicles that will use a road significantly influence the cost of construction and maintenance. In particular, the number and configuration of heavy vehicles using the road affect both the initial construction costs and the need for maintenance. The federal government and various state governments conduct studies to determine the appropriate allocation of costs among classes of vehicles. These studies find that the fuel taxes and registration fees, which provide a substantial amount of the funds for construction and maintenance, are not levied in proportion to cost responsibility, as discussed in chapter 8. In particular, they conclude that heavy vehicles, typically, do not pay their share of the cost; while lighter vehicles tend to be taxed for more than their share. A variety of adjustments have been made at the federal level to try to bring a closer alignment between cost responsibility and taxes; but the most recent study finds that the heaviest trucks still do not pay their share of the cost. One suggestion for addressing this concern is to adopt a weight-distance tax at the federal level ⁽⁴⁾.

A major reason for this cost allocation problem is the nature of road finance relative to the cost structure. Road damage increases much more than proportionately with vehicle weight on a road surface, as discussed in chapter 6. While pavement damage goes up much more than proportionately with vehicle weight, fuel consumption does not vary

much with weight. Hence, a heavier truck would be expected to pay slightly higher fuel taxes than a lighter truck; but would cause much more road damage. Thus, there is a strong reliance on fuel taxes for apportioning the costs of road maintenance and construction. This leads to the result that heavier trucks do not pay for their cost responsibility.

In addition to the equity consideration, economic efficiency is more likely to result when vehicles pay the cost that they impose on the road system. If the cost is out of pocket, then the decision-maker takes that cost into account in determining whether a particular trip is worthwhile; whether the appropriate truck is being used; and also the time of the day it should travel, depending on congestion. If the cost is not paid directly by the decision-maker, then it is likely to be ignored; and the resulting decisions may impose costs that exceed their benefits. For example, high fuel taxes encourage conservation of fuel. This creates an incentive to use fewer axles to conserve fuel by minimizing pavement friction; but it increases road damage by increasing the weight per axle. Hence, this form of road financing can create inefficient incentives with respect to road damage. Also, failure to accurately price the use of roads for some heavy vehicles may divert commodities to trucks that could more efficiently be moved by rail or other forms of transportation. The railway industry always advocated imposing taxes on heavier trucks.

The above discussion combined with the quantitative analysis of actual pavement damage caused by the different loading characteristics of heavy vehicles in *Chapters 6, 7, 8 and 9* clearly shows that the current tax structures do a poor job of capturing pavement damage. The only method, among those investigated, that assesses tolls based upon load per axle

is the Oregon DOT weight-distance tax structure, which accounts for gross weight and distance traveled for trucks over 26,000 lbs and less than 80,000lbs. Oregon is the only state to try to discourage heavy axle loads by offering a tax reduction for trucks with additional axles, in weight classes above 80,000 lbs. Although this is an efficient policy of Third Structure taxes encouraging the trucking industry to add axles, the Oregon system does not capture the damage done by an individual truck because: it is based on a declared weight; the rationale is based on ESAL approximation; it does not consider the pavement characteristics and mechanistic response; and it does not account for speed and tire pressure. Moreover, it does not account for weight variations in vehicles weighing less than 26,000 lbs., aside from the increase in fuel tax associated with greater fuel consumption while hauling heavier loads. The following sections outline the proposed methods to determine real-time pavement damage and appropriate user charges.

10.2 Proposed Highway User Charges

We are now at a time when technology is rapidly advancing, providing us with an array of methods to determine appropriate user charges on a level that was impossible just 10 years ago. It is imperative that these systems be implemented in order to provide real-time information on which to assess tolls, according to the pavement damage caused by individual heavy vehicles. The following recommendations for modifying existing tolling methods include use of these evolving technologies:

- 1) Use electronic toll collection (ETC) technology, such as loop detectors, infrared light beams and weigh-in-motion (WIM) technology to instantaneously calculate the toll amount at tolling sites based upon axle

weight, speed and tire pressure. These variables will feed into a mechanistic model that calculates the pavement damage caused by this particular truck. Then, the damage caused by this truck will be weighed against the design life of the pavement and a fair share of the cost responsibility will be assigned.

Potential drawbacks: Truckers will need a system that can give them a good approximation of their toll amounts prior to each trip; otherwise they may criticize the system, when drivers are faced with a toll that exceeds their cash on hand. Although ETC debit systems, such as E-ZPass (NY) or I-Pass (Chicago) could eliminate the potential cash shortage problem, until there are ETC agencies whose tags function at all tolling facilities nationwide, the ETC debit tag is not a tenable solution for long-distance haulers. Additionally, high-speed toll collection lanes would allow collecting fees at highway speed.

- 2) Charging a vehicle on axle weight instead of gross weight will encourage the trucking industry to add axles and distribute load over all axles evenly. This will ultimately reduce the pavement damage, and increase the design life.
- 3) Incorporating load duration/speed into the damage model will encourage vehicles to travel in off-peak hours when speeds are higher, if possible. This will reduce the pavement damage that, in turn, will reduce the toll. The E-Z pass technology allows collection of varying tolls.
- 4) Incorporating tire pressure into the pavement damage model will encourage the trucking industry to operate at an optimum tire pressure distributing the load over a larger area, thereby lessening pavement damage and yielding longer pavement life.

- 5) Once a user charge based on axle weight has been established, the fuel taxes would need to be adjusted downward to avoid paying twice.

Other Proposed Actions to Support Proposed Tolling Methods

- 1) Advertise proposed toll structures, with an emphasis on savings for heavy trucks to distribute their loads evenly. Add axles for heavy loads. Maintain optimal tire pressure. And travel during off-peak hours.
- 2) More rational pavement models should be investigated to determine the appropriate toll charges based upon weight per unit contact area and speed (duration of loading). The ideal pavement analysis model should consider the dynamic nature of traffic loads and viscoelastic properties of the asphalt-concrete (AC) material.
- 3) Provide incentives for manufacturers to design trucks that minimize pavement damage through improved suspension, axle placement and other components. Technological improvements in vehicle design could substantially reduce the tax burden for the trucking industry under this proposal.
- 4) Provide incentives for manufacturers to incorporate universal ETC smart tags into the design of trucks.
- 5) Modify the existing road tax exemptions for publicly owned vehicles. If the present policy of tax exemptions continues to apply for vehicles operated by public agencies, on the grounds that such taxes only shift money from one government account to another, an imbalance will occur between the revenue collected and the costs to maintain the pavement structures. It is therefore essential for each public agency to pay their share of the road damage they

impose. An approximation of the total amount of pavement damage imposed by all vehicles operated by an agency would be logistically impossible, since each individual vehicle will operate on various highway systems across a range of different total weights, weights per axle, miles traveled, tire pressure, and speeds. It is more efficient to subject these vehicles to the same proposed tolling methods outlined above such that each tolling agency will receive direct payment for actual pavement damage. Additionally, since only the fuel and mileage taxes will capture the costs of maintaining untolled roads, it is imperative that these taxes be paid. In such cases, let the agency determine the best way to trade that cost against its other needs. Overall, this change would support the equitable division of highway user taxes and, simultaneously, provide a more accurate accounting of the true costs of government programs.

- 6) Since slower speeds cause more pavement damage, vehicle speed limits on limited access highways should not be restricted unnecessarily, although this must be balanced with geometric safety requirements.

10.3 Equity

In Chapter 8, we discussed that the Federal Highway Cost Allocation Study (HCAS) shows that the lighter vehicles have higher equity ratios, and pay more than their fair share; as compared to heavier vehicles within their vehicle class. The heavier vehicles underpay for the damage they inflict on the pavement system. The equity ratios indicates that the greater the weight of a vehicle within a vehicle class, the lower its equity ratio. Moreover, the study recommended implementation of weight-mile distance tax (WDT)

for the scenarios 5 and 6 (refer to Chapter 8). Table 10-1 presents the forecasted equity ratio estimated by HCAS for all 6 scenarios recommended under 1997 HCAS. Analyses of improvements in equity that could be achieved by imposing a weight distance tax (WDT) showed varying abilities to improve equity across vehicle classes. Federal HCAS show that the WDT options can produce greater improvements in equity than any of the modifications to existing user fees that were evaluated, because they reflect both vehicle weight and annual mileage. Scenario 5 and 6 exhibited equity ratios of 1 among all classes of trucks; indicating that each class pay their fare share for the damage they inflicts on the highway system.

It should be noted here that this dissertation views WDT differently. This dissertation advocates a WDT tax on an individual truck not a class of vehicle or group of vehicles. The issue is approached by imposing a WDT on an individual vehicle based on real-time axle weight (not the gross weight) that a particular truck carries at a particular time on a specific pavement system, traveling with a specific speed and tire pressure. In other words, the same truck may pay a different toll either traveling with a different weight, or even with the same weight but a different speed or tire pressure.

Table 10-1: Estimated ratios of user charges to allocated costs by vehicle class under alternative federal user charge structure [source: 1997 HCAS]

Vehicle Class / Registered Weight	Current Structure	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Auto	1.0	1.0	0.9	1.0	0.9	0.9	0.9
Pickups/Van	1.4	1.4	1.3	1.4	1.3	1.3	1.3
Buses	0.1	0.1	0.1	0.1	0.1	0.2	0.2
All Personal Use Vehicles	1.1	1.1	1.0	1.1	1.0	1.0	1.0
Single Unit Truck							
<25,000 pounds	1.5	1.6	1.7	1.5	1.4	1.2	1.2
25,001 - 50,000 pounds	0.7	0.7	0.8	0.7	0.8	1.0	1.0
>50,000 pounds	0.5	0.5	0.5	0.5	0.9	1.0	1.0
All Single Units	0.9	0.9	1.0	0.9	1.1	1.0	1.0
Combination Trucks							
<50,000 pounds	1.6	1.7	1.8	1.6	1.5	1.0	1.0
50,001 - 70,000 pounds	1.1	1.1	1.2	1.1	0.9	1.0	1.0
70,001 - 75,000 pounds	1.0	1.0	1.1	1.0	1.0	1.0	1.0
75,001 - 80,000 pounds	0.9	0.9	1.0	0.9	1.0	1.0	1.0
80,001-100,000 pounds	0.6	0.6	0.6	0.6	1.1	1.0	1.0
>100,001 pounds	0.5	0.5	0.5	0.6	1.1	1.0	1.0
All Combinations	0.9	0.9	1.0	0.9	1.0	1.0	1.0
All Trucks	0.9	0.9	1.0	0.9	1.0	1.0	1.0
All Vehicles	1.0	1.0	1.0	1.0	1.0	1.0	1.0

10.4 Effect of Adding Axles on Pavement Damage

Charging trucks by actual axle weight will encourage the trucking industry to haul heavy freight on more axles and distribute it evenly over the axles to minimize the per axle weight. This will ultimately reduce their toll. This will result in an increase in the design life of the pavement, and will delay the MR&R activities. A damage analysis was conducted using KENLAYER ⁽²¹⁾ to assess the effects of adding an axle on the design life of the pavement. The first part of the example used in chapter 9 to calculate the total damage was used here. Again, three classes of vehicles were chosen for the analysis: Class 8A (3-axle truck), Class 8B (4-axle truck) and class 9 (5-axle truck). The speed and tire pressure were kept constant for all trucks. For input data, refer to Table 9-1, 9-2, 9-3 and 9-4, in chapter 9.

The model was run with actual loading and axle configurations. The damage was computed for the base case. Then, one axle is added to each type of truck; that is, 3-axle was converted to 4-axle (class 8); 4-axle to 5-axle (class 9); and 5-axle to 6-axle (class 10) as shown in Figure 10-1. Table 10-2 presents the converted loading configuration for the KENLAYER model input. All other parameters, including the average gross loads and number of annual repetitions, remain unchanged. The model was rerun with modified axle configuration.

The results show a 5 % reduction in the tensile strain at the bottom of layer 1. A ½ year increase in the design life was observed (from 9.4 to 9.9 years). The actual reduction may be more than what is reported here because, for demonstration purposes, an average gross weight and axle distribution was used for the analysis, while the damage is exponentially

proportion to the load. For example, the Class 9 trucks gross weight ranged from 15,000 to 150,000 lbs., with an average of 68,864 lbs. If a vehicle weighs twice the average, the damage done to the road by the heavier vehicle would be far more than 2 times the damage done by an average vehicle. Moreover, it was found that the damage done by front axle is substantial, because it distributes the load over two tires and carries a significant proportion (about 20%) of the gross weight. The damage inflicted by the front axle almost remains the same with addition of one more axle. This suggests serious consideration for front axle redesign by the truck manufacturing industry. Even a 5 % increase in the design life of the pavement, as determined by this analysis, may have a substantial economical and financial value.

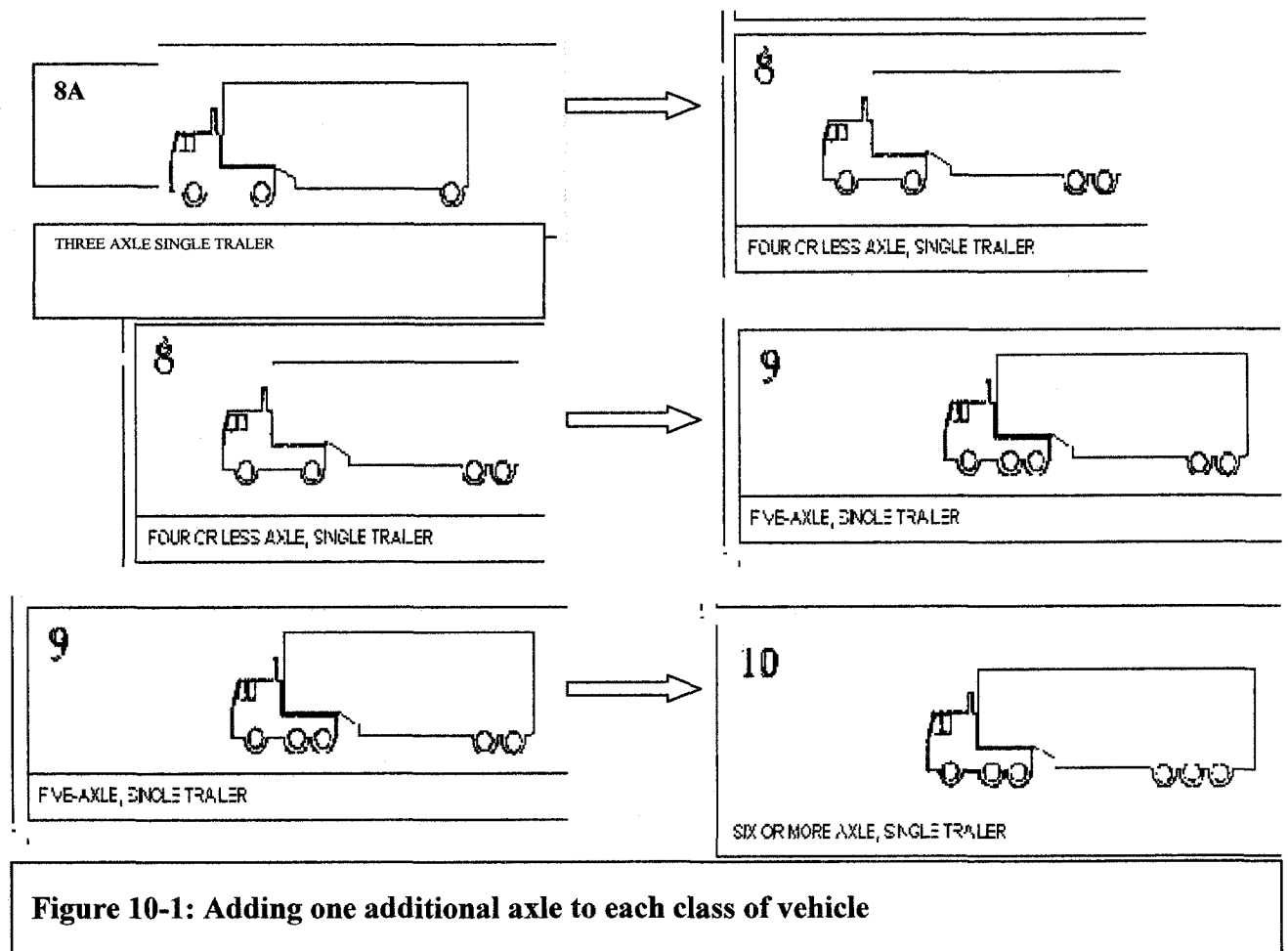


Table 10-2: Effect of adding one axle to each class: switching class 8A to 8B; 8B to class 9; and class 9 to class 10

Description	Type	Axle Share	Avg Weight (lbs)	Load per Tire (lbs)	TP=CP (psi)	Contact Area (sq-in)	Contact Radius (in)	XW (in)	YW (in)
Class 8B									
Axle 1	SASW	20%	8247	4123	80	51.54	4.05	0	0
Axle 2	SADW	40%	16494	4123	80	51.54	4.05	0	13.5
Axle 3&4	TA	40%	16494	2062	80	25.77	2.86	4.5	13.5
Class 9			41234						
Axle 1	SASW	20%	14655	7328	80	91.59	5.40	0	0
Axle 2&3	TA	40%	29310	3664	80	45.80	3.82	3.3	13.5
Axle 4&5	TA	40%	29310	3664	80	45.80	3.82	3.8	13.5
Class 9			73275						
Axle 1	SASW	15%	10330	5165	80	64.56	4.53	0	0
Axle 2&3	TA	35%	24102	3013	80	37.66	3.46	3.3	13.5
Axle 4,5 and 6	Tridem	50%	34432	2869	80	35.87	3.38	3.8	13.5
			68864						

SASW= single axle single wheel; SADW= single axle dual wheel; TA=tandem axle

Assumption: The gross load will be evenly distributed over the axles.

10.5 Policy Administration and Revenue Generation

The pavement damage and cost responsibility analyses thus far have demonstrated that the implementation of a weight-distance tax for an individual vehicle based on axle weight, load distribution, speed and tire pressure is achievable with the latest technology and mechanistic-empirical deterioration models. Data similar to that presented in chapter 9 could be generated for different combinations of vehicle classes, speeds and tire pressures, in a series of tables and mathematical curves. Although this approach is technologically possible, it may be complex from the policy administration point of view. This section will provide a simplified approach to estimate the annual revenue that could be generated as a result of this pricing policy. This section will also present a procedure for allocating a uniform cost responsibility for each class of vehicle in order to generate a required amount of revenue.

Figure 10-2 shows the GVW (gross vehicle weight) distribution for class 9 (5-axle) trucks at 10,000 lbs. interval for Florida DOT data used in this analysis. The data is approximately evenly distributed for the GVW of 40,000 lbs. to 100,000 lbs. The lower and upper ranges have a smaller frequency in the weight histogram. The mean of the entire population was 68,865 lbs. and the standard deviation was 22,093 lbs. The damage-based cost responsibility for each measurement class (interval) was obtained from Figure 9-3 for 60 mph speed and 80 psi tire pressure. The average daily truck traffic (ADTT) for each measurement class was extrapolated and converted into annual traffic to estimate the annual revenue as shown in Table 10-3. The estimated annual revenue that could be generated from class 9 trucks using the proposed pricing policy (assuming cost responsibility = price) would be \$139,254 per mile.

Administratively, a simplified approach could be used to establish a *uniform tax* on a particular class of vehicle in order to generate certain amounts of revenue. For example, the total revenue needed to fix the pavement damage caused by the fleet of class 9 truck divided by the predicted number of class 9 truck passes will establish a uniform cost responsibility.

$$\text{Cost Responsibility (class 9)} = \$139,254 / 1,244,183 = \$0.112 / \text{mile}$$

Although assigning a uniform cost responsibility will generate the required amounts of revenue, it will also create an imbalance in equity as shown in the last column of Table 10-3. The uniform cost responsibility corresponds to a measurement class of 70,001 – 80,000 lbs. All vehicles below this measurement class will be overpaying while all vehicles above this class will be underpaying. Moreover, as demonstrated in Chapter 6,

the load – damage curve follows a 3rd or 4th power relationship implying that doubling the load may increase the cost responsibility by as high as by 12-16 times. Table 10-3 shows the cost responsibility for each measurement class of 5-axle truck for a 118-mile segment of a roadway. If a uniform cost responsibility is assigned, all 5-axle trucks would pay \$12.98 for this segment of the roadway. However, the actual cost responsibility for a 5-axle truck carrying 30,000 lbs and 100,000 lbs. along this segment of the roadway would be \$1.77 and \$24.78, respectively. Therefore, assigning a cost responsibility or establishing a price based on actual axle weight, speed and tire pressure would be the most appropriate method to apportion the cost according to the actual damage each individual vehicle inflicts on the pavement.

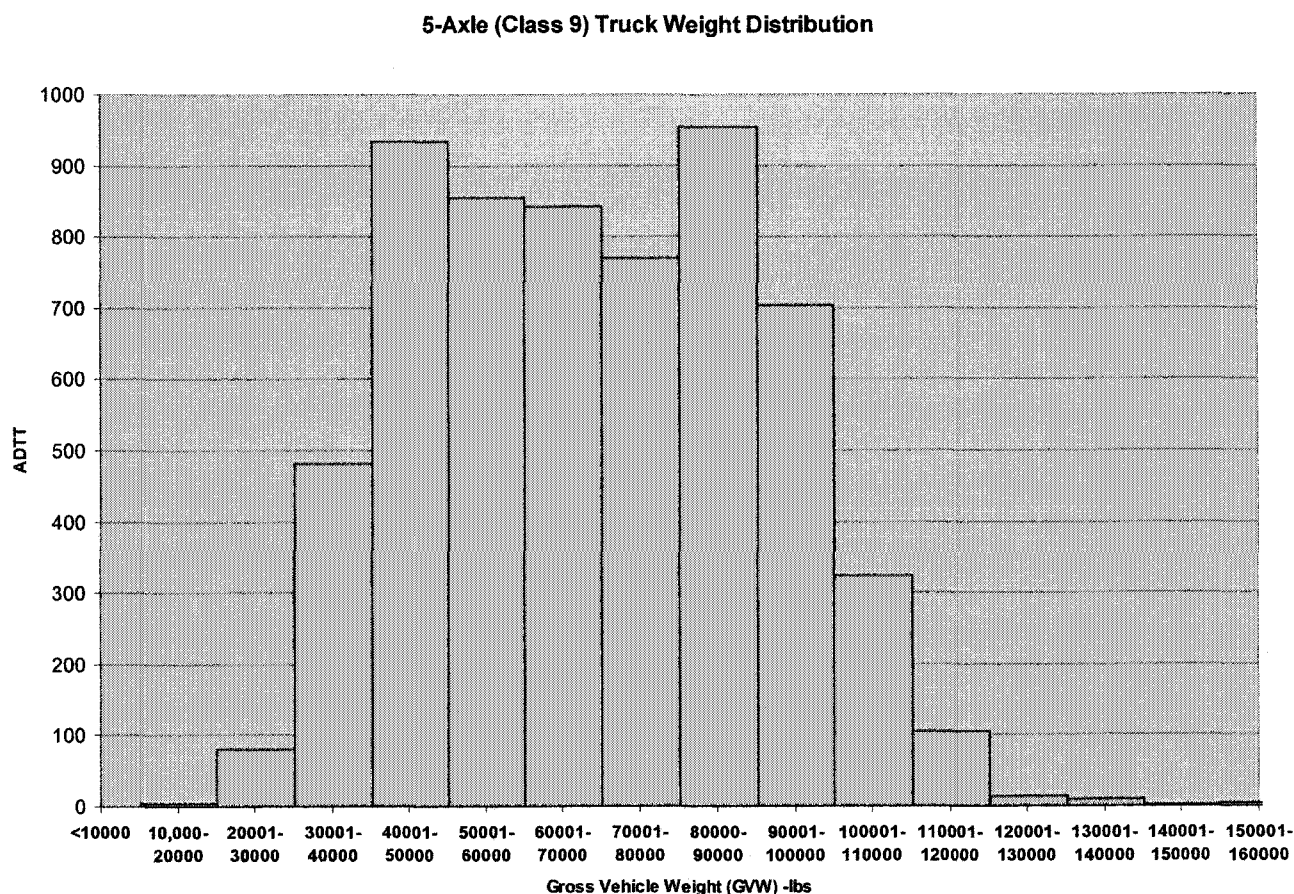


Figure 10-2: Average daily weight distribution for class 9 trucks

Table 10-3: Revenue generation model for Class 9 truck

GVW range (lbs)	ADTT	Direction split (56%)	Annual truck traffic	Cost share per mile ¹ (\$)	Annual revenue (\$ per mile)	Actual cost responsibility for 118 mile segment (\$)	Equity with uniform cost responsibility
<10000	0	0	0	0.000	-	-	Underpayment
10,000-20000	5	3	1022	0.010	10	1.18	
20001-30000	80	45	16352	0.015	245	1.77	
30001-40000	482	270	98521	0.020	1,970	2.36	
40001-50000	934	523	190910	0.030	5,727	3.54	
50001-60000	854	478	174558	0.040	6,982	4.72	
60001-70000	842	472	172105	0.080	13,768	9.44	
70001-80000	771	432	157592	0.110	17,335	12.98	AVERAGE
80000-90000	954	534	194998	0.160	31,200	18.88	Overpayment
90001-100000	703	394	143693	0.210	30,176	24.78	
100001-110000	324	181	66226	0.300	19,868	35.40	
110001-120000	105	59	21462	0.370	7,941	43.66	
120001-130000	15	8	3066	0.460	1,410	54.28	
130001-140000	11	6	2248	0.600	1,349	70.80	
140001-150000	2	1	409	0.760	311	89.68	
150001-160000	5	3	1022	0.940	961	110.92	
6087		3409	1,244,183		139,254		
Average cost responsibility for class 9 vehicles =					0.112		

1. Cost responsibility obtained from Figure 9-3, 60 mph curve; assuming 80 psi tire pressure and 20-40-40% distribution.

CHAPTER 11

CONCLUSION

This dissertation quantifies the damage inflicted by a particular truck traveling on a highway with a certain speed and tire pressure. The best way to economize on maintaining and using an existing road is to apply a user charge equal to the damage each vehicle inflicts on pavements, based on the damaging power of their axle loads, time of the day they travel (congestion and speed), and tire pressure. Cars, vans and buses cause minimal damage to the pavement, while trucks are primarily responsible for damage to the pavement structure. When a vehicle travels on a road, it causes some damage to the surface and advances the date at which the pavement needs to be repaired, rehabilitated or reconstructed. The damage vehicles do to the pavement depends on the characteristic of the vehicle, type of the pavement, axle load, tire pressure/contact area, and duration of load/congestion (speed). Table 11-1 summarizes the characteristics that influence the pavement damage. The following conclusions were drawn from this research.

11.1 Pavement Damage

1. The actual load repetitions (load spectra) results in 27% less damage than that calculated using standard ESALs.
2. The use of a uniform truck factor results in a 3.83 times higher damage estimate as compared to actual load spectra.
3. Use of ESAL or Truck Factor (TF) for design and rehabilitation, or predicting future damage may be misleading, and should be considered as an approximation only.

4. A 4-axle truck causes more pavement damage as compared to 5-axle trucks at any given load. Both tensile strain at the bottom of layer 1 and compressive strain at the top of layer 3 was substantially greater for identical loads from the 4-axle truck than the 5-axle truck.
5. When fitting a curve to the data set for both tensile strain and compressive strain, the compressive strain curve follows the AASHTO 4th power curve more closely while the tensile strain closely follows a 3rd power law. This is true for both 4-axle and 5-axle trucks. However, the 4-axle truck demonstrated a steeper curve; that is, caused more damage than a 5-axle truck.
6. The tensile strain governs the damage inflicted on the pavement until the load reaches 65,000 lbs. and 100,000 lbs. for Class 8 and Class 9 trucks, respectively. This occurs when the compressive strain begins to overtake the tensile strain, as the greater percentage of the total damage inflicted. Therefore, at loads greater than 65,000 lbs. (for a 4-axle truck) and 100,000 lbs. (for a 5-axle truck), the damage inflicted becomes increasingly more costly to repair as the pavement starts to fail at the top of the subgrade, instead of the bottom of the surface course.
7. This analysis clearly demonstrates two facts concerning differential damage: one, the extent of loading on the same truck, whether empty, partially loaded or fully loaded; and two, the distribution of the load over the axles. The same truck carrying 88,500 lbs. causes as high as 11 times more damage than a truck carrying 25,300 lbs.

8. A damage simulation demonstrates that an equal load distribution over the axles yields less pavement damage. An uneven load distribution produces significantly more strain, though the compressive strain is the most affected by weight share. At a load distribution of 10-10-80% (and 10-80-10%), the compressive strain was 435% higher than at 10-40-50%, and the tensile strain was 108%.
9. A 5-axle truck produced 16% overall less surface deflection than the 4-axle truck at similar gross weights.
10. The spread between two consecutive axles in a tandem- or tridem-axle group also affects pavement life or performance; the greater the spread the more each axle in a group acts as a single axle.
11. The analysis shows that increased exposure time (lower speed) reduces the design life of the viscoelastic material (flexible pavements). Theoretically, decreases in speed from 70 mph to 5 mph resulted in a reduction of design life from 15 years to 5 years, keeping all other loading and pavement parameters constant.
12. An analysis conducted to assess the effect of congestion on pavement damage demonstrates a reduction of 5 years in design life, if the reduced speed of 25 mph is considered during congestion periods (AM and PM peak hours); as compared to a constant off-peak speed of 58 mph.
13. An analysis was performed to quantify the damage with a constant and varying tire pressure. The results indicate that the pavement life reduced by 1.4 years when 1/3 of trucks were assumed to have tire pressures of 80, 100 and 120 psi each, as compared with a uniform tire pressure of 80 psi for all tires.

14. A damage analysis to assess the effects of adding one more axle to each class of vehicles exhibited a 5% reduction in the tensile strain at the bottom of layer 1.

11.2 Road Pricing

1. The cost allocation analysis across all levels of government showed that heavy vehicles typically do not pay their share of the cost, while lighter vehicles tend to be taxed for more than their share.
2. The current tax structures do a poor job of capturing the pavement damage. Charging by number of axles, instead of by axle load, encourages hauling heavy loads on too few axles. On the other hand, charging per axle weight instead of by total load would not only reduce the heaviest axle weights, by encouraging trucking companies to distribute the load more evenly, but also hold vehicles accountable for their true share of the pavement damage.
3. Establishing a cost responsibility based on ESAL or Truck Factor does not capture the actual pavement damage inflicted by individual vehicles or classes of vehicles; and should be considered only as an approximation.
4. Implementation of real-time weight-mile tax based on actual weight, speed and tire pressure promotes two distinct objectives. One is to apportion the cost of road construction and repair in an equitable manner among those who affect the standards needed for construction, and cause the need for repair. The second is to discourage the use of heavy axle-loads and thus, reduce the wear on the road system.

5. Changing from the current highway financing system to one based more on weight-mile charges would substantially reduce the amount of damage done by trucks carrying the same volume of freight on more axles.
6. The weight-mile tax provides for reduced taxes if the loads carried within a vehicle are evenly distributed over all axles. A shift away from the weight-mile tax could also remove these incentives and further increase road damage.
7. Adding one or two axles to a single axle to make a tandem-or tridem-axle group allows higher gross vehicle weights without increasing pavement damage.
8. Weigh-in-motion technology has the capability of measuring the weight on each axle, and the spacing between those axles; in addition to total weight. Moreover, the electronic toll collection (ETC) technology makes it convenient to impose varying tolls based on per axle weight and time of the day they travel (congestion).
9. Establishing a pavement damage tax based on speed will encourage the trucking industry to shift their time of travel towards off-peak hours, which would ultimately reduce congestion in typical peak hours, as well as the pavement damage.
10. Since slower speeds cause more pavement damage, vehicle speed limits on limited access highways should not be restricted unnecessarily, although this must be balanced with geometric safety requirements.
11. Publicly owned vehicles are often exempted from road taxes on the grounds that charging them just shifts money from one government account to another, but in this case exempting those vehicles will create an imbalance to establish an

optimum tax. Therefore, public vehicles should be charged for the damage they inflict on the pavement as well. The agency should determine the best way to trade off that cost against it's other needs.

12. The cost responsibility assignment analysis demonstrated that reducing the speed from 40 to 20 mph, at 80 psi tire pressure, increases the cost responsibility by 62%, that is, from 8 cent to 13 cent per mile.
13. A 20 psi increase in tire pressure caused only a 1 cent upward shift in the curve. Changing the tire pressure from 80 to 120 psi (for 20 mph speed) resulted in a 2 cent increase in cost responsibility (from 13 c to 15c), or a 15% increase.
14. The cost responsibility for a 5-axle truck when traveling empty was approximately 2 cent per mile. This cost increased significantly, to 21 cent per mile, when carrying 100,000 lbs. at 60 mph. The impact of same truck at slower speed was much more pronounced. Traveling at 20 mph will assign a cost responsibility of 42 cent per mile with same 100, 000 lbs. Gross vehicle weight (GVW.)
15. Comparing the proposed tax structure with current in use taxes, the Oregon state curve follows the proposed curves more closely for 40 and 60 mph speed. At the lower end, up to 50,000 lbs., the Oregon tax structure charges more than the actual share. For trucks carrying more than 50,000 lbs., the results vary with speed. At slower speed, the state of Oregon undercharges the truck; while, at a higher speed, it more closely follows the proposed tax structure.

11.3 Future Needs

1. Since it is evident from this research that speed and tire pressure play an important role in pavement damage, there is a further need of investigating more rational pavement models that would consider the dynamic nature of traffic loads and viscoelastic properties of the asphalt-concrete (AC) material.
2. This dissertation focused on minimizing the pavement damage inflicted by different type of trucks. However, minimizing pavement damage indirectly mitigates congestion by incorporating speed into pavement damage models. On the other hand, congestion itself represents a scarcity in the availability of road space. Congestion pricing is therefore a natural economic response to scarcity. By applying congestion pricing, the resulting increase in speed on the priced route will produce less pavement damage and less social costs upon other vehicles using the priced route. Since road investment is expensive, optimal investment involves minimizing the costs associated with both pavement damage and congestion. This establishes a need for further investigation, for combining both aspects of road pricing; that is, a pavement damage component and a congestion component, in order to determine the optimum toll or tax. Although this toll amount should be low enough to encourage those vehicles to shift to the priced route, it must also be high enough to discourage a shift for the majority of vehicles; otherwise, the congestion priced route will become congested as well, negating its benefit.
3. It is found from this research that the front axle of a truck causes a substantial amount of pavement damage because it takes approximately 15-25% of total load that is distributed over a single axle having only two tires. There is a need for further investigation to quantify the damage caused by front axles of the different type of trucks; and to improve

front axle design to optimize its load-taking share and distribution to a larger pavement area. This could be achieved by providing incentives for manufacturers to design trucks that minimize pavement damage through improved suspension, axle placement and other components. Technological improvements in vehicle design could substantially reduce the tax burden for the trucking industry.

4. Replacing current taxes with ones based on real-time axle weight, speed and tire pressure would lead to several responses by truckers. This may include switching their heavy loads on trucks with more axles; distributing load equally over the axles; and adjusting load sizes, dispatch schedule, and fleet sizes. A significant response may also include routing shifts, relocation of terminals, and modal shifts, such as railroads. This needs to be further investigated to estimate the change in demand due to a pricing policy. A study conducted by NJDOT demonstrates that the relationship between price and behavior of the trucking industry is inelastic ⁽⁶¹⁾. A change in price may not results a shift in demand.

TABLE 11-1: Summary of Characteristics Influencing Pavement Damage

Characteristic	Decrease in Pavement Damage	Increase in Pavement Damage
No. of Tires per Axle	<i>More Tires per Axle (Tandem Axle)</i> → Less Load per Tire → Less Load per Unit Contact Area → Decrease in Pavement Damage	<i>Fewer Tires per Axle (Single Axle)</i> → Greater Load per Tire → Greater Load per Unit Contact Area → Increase in Pavement Damage
No. of Axles	<i>More Axles</i> → Less Load per Axle → Less Load per Unit Contact Area → Decrease in Pavement Damage	<i>Fewer Axles</i> → Greater in Load per Axle → Greater Load per Unit Contact Area → Increase in Pavement Damage
Load Distribution	<i>Load Distributed Evenly Among Axles</i> → Less Load for the Most Heavily Loaded Axle Group → Decrease in Pavement Damage	<i>Load Not Distributed Evenly Among Axles</i> → Greater Load for the Most Heavily Loaded Axle Group → Increase in Pavement Damage
Speed / Congestion	<i>Higher Speeds</i> → Decrease in Load Duration → Decrease in Pavement Damage	<i>Lower speeds</i> → Greater Load Duration → Increased Pavement Damage
Tire Pressure	<i>Lower Tire Pressure</i> → Greater Surface Contact Area between Tire and Pavement → Less Load per Unit Contact Area → Decrease in Pavement Damage	<i>Higher Tire Pressure</i> → Smaller Surface Contact Area between Tire and Pavement → Greater Load per Unit Area → Increase in Pavement Damage

APPENDIX –A

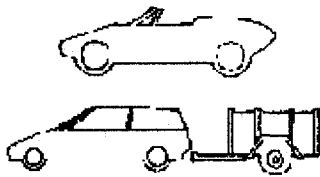
FHWA VEHICLE CLASSIFICATION SCHEME

1



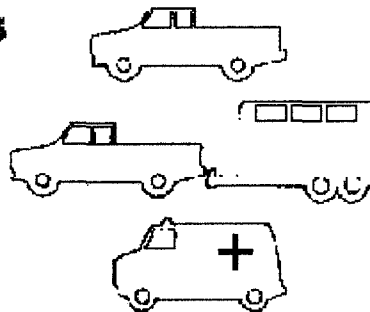
MOTORCYCLES

2



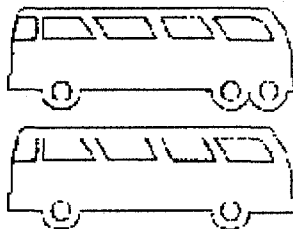
PASSENGER CARS

3



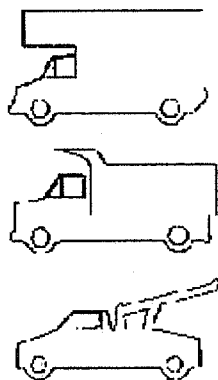
FOUR TIRE, SINGLE UNIT

4



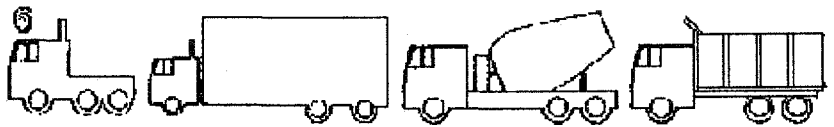
BUSES

5



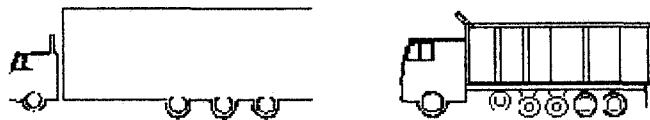
TWO AXLE, SIX TIRE SINGLE UNIT

6



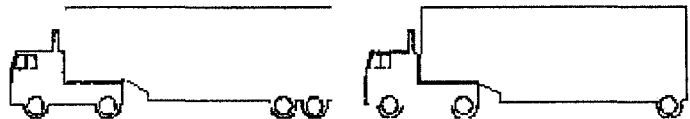
THREE AXLE, SINGLE UNIT

7



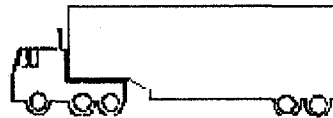
FOUR OR MORE AXLE, SINGLE UNIT

8



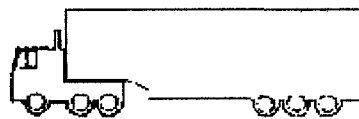
FOUR OR LESS AXLE, SINGLE TRAILER

9



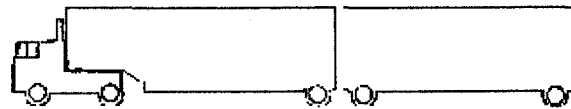
FIVE-AXLE, SINGLE TRAILER

10



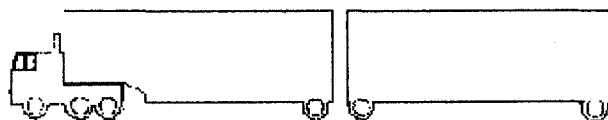
SIX OR MORE AXLE, SINGLE TRAILER

11



FIVE OR LESS AXLE, MULT-TRAILER

12



SIX AXLE, MULT-TRAILER

13



SEVEN OR MORE AXLE, MULT-TRAILER

Class 1- Motorcycles: All two- or three-wheeled motorized vehicles. Typical vehicles in this category have saddle type seats and are steered by handlebars rather than wheels. This category includes motorcycles, motor scooters, mopeds, motor-powered bicycles, and three-wheeled motorcycles.

Class 2- Passenger Cars: All sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers and including those passenger cars pulling recreational or other light trailers.

Class 3- Other Two-Axle, Four-Tire, Single Unit Vehicles: All two-axle, four-tire, vehicles other than passenger cars. Included in this classification are pickups, panels, vans, and other vehicles such as campers, motor homes, ambulances, hearses, carryalls, and minibuses. Other two-axle, four-tire single unit vehicles pulling recreational or other light trailers are included in this classification.

Class 4- Buses: All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses (including school buses) functioning as passenger-carrying vehicles. Modified buses should be considered to be trucks and be appropriately classified.

Note: In reporting information on trucks the following criteria should be used:

- a. Truck tractor units traveling without a trailer will be considered single unit trucks.
- b. A truck tractor unit pulling other such units in a "saddle mount" configuration will be considered as one single unit truck and will be defined only by axles on the pulling unit.
- c. Vehicles shall be defined by the number of axles in contact with the roadway. Therefore, "floating" axles are counted only when in the down position.
- d. The term "trailer" includes both semi- and full trailers.

Class 5- Two-Axle, Six-Tire, Single Unit Trucks: All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., having two axles and dual rear wheels.

Class 6- Three-axle Single unit Trucks: All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., having three axles.

Class 7- Four or More Axle Single Unit Trucks: All trucks on a single frame with four or more axles.

Class 8- Four or Less Axle Single Trailer Trucks: All vehicles with four or less axles consisting of two units, one of which is a tractor or straight truck power unit.

Class 9- Five-Axle Single Trailer Trucks: All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit.

Class 10- Six or More Axle Single Trailer Trucks: All vehicles with six or more axles consisting of two units, one of which is a tractor or straight truck power unit.

Class 11- Five or Less Axle Multi-Trailer Trucks: All vehicles with five or less axles consisting of three or more units, one of which is a tractor or straight truck power unit

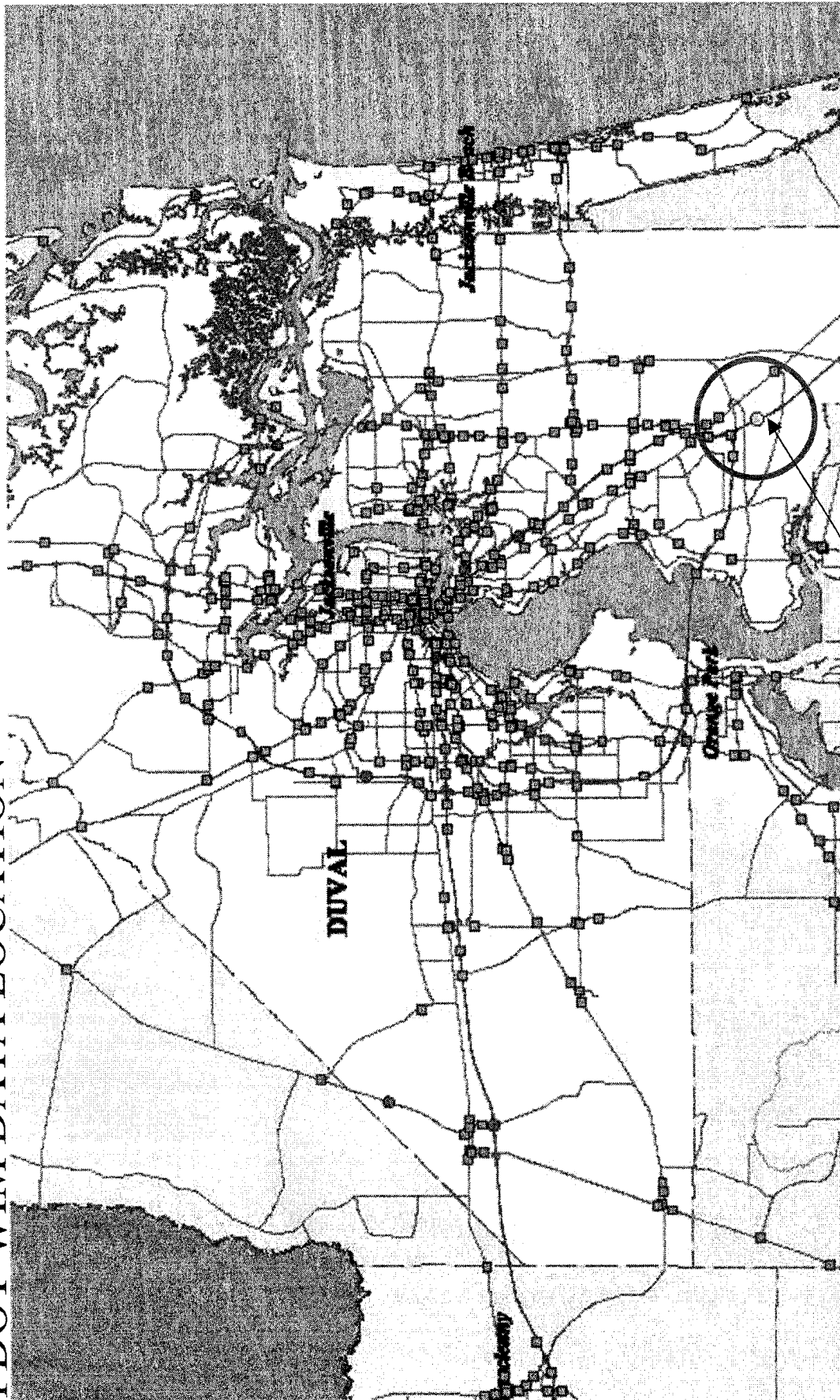
Class 12- Six-Axle Multi-Trailer Trucks: All six-axle vehicles consisting of three or more units, one of which is a tractor or straight truck power unit.

Class 13- Seven or More Axle Multi-Trailer Trucks: All vehicles with seven or more axles consisting of three or more units, one of which is a tractor or straight truck power unit.

APPENDIX –B

WEIGH-IN-MOTION (WIM) DATA

FDOT WIM DATA LOCATION



yellow dot on I-95, 2 miles
south of I-295 interchange

SUMMARY- FDOT December 01, 2004 Data

Description	# of Axles	Proportion (5-13 Trucks)	Avg Speed (mph)	Avg Length (ft)	Avg Gross Wt (lbs)	Min Wt. (lbs)	Max Wt. (lbs)	Bad Data ? (lbs)	# of Axle Spaces	ASP1 (ft)	ASP2 (ft)	ASP3 (ft)	ASP4 (ft)	ASP5 (ft)
Class 8 A	3	2%	67	47.6	41,235	12,370	83,980	145,670	2	14.3	25.8	0.0	0.0	0.0
Class 8 B	4	9%	64	56.6	74,262	12,020	221,480	472,670	3	15.8	26.7	4.5	0.0	0.0
Class 9	5	50%	53	50.2	68,865	14,840	157,510	196,140	4	12.9	3.3	25.1	3.8	0.0
Class 10	6	1%	48	45.4	81,145	30,180	149,860	-	5	11.9	3.1	20.4	7.8	2.9

CL	SPD LENGTH			GROWT			AXLE1			AXLE2			AXLE3			AXLE4			AXLE5			AXLE6			AXLE7			AXLE8			AXLE9			NS	NA	WHLB	ASPI	ASP2	ASP3	ASP4	ASP5	ASP6	ASP7	ASP8																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
	Vehicle Class (Scheme "F") Code	Speed (in mph)	Length of Vehicle From Bumper to Bumper (in ft)	Gross Weight (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Num Axles	Num Wheel distance from first axle (in ft)	Space 1-2 (in ft)	Space 2-3 (in ft)	Space 3-4 (in ft)	Space 4-5 (in ft)	Space 5-6 (in ft)	Space 6-7 (in ft)	Space 7-8 (in ft)	Space 8-9 (in ft)	Space 9-10 (in ft)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
8	77	4461	12370	6780	4970	620	0	0	0	0	0	0	0	2	3	3293	1423	1870	0	0	0	0	0	0	0	0	2	3	3293	1423	1870	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Vehicle Class (Scheme "P") Code	Speed of Vehicle (in mph)	Length of Vehicle From Bumper to Bumper (in)	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Num ber of Axles	Wheel base distance from first axle (in)	Axle 1 Weight (in lbs)	Axle 2 Weight (in lbs)	Axle 3 Weight (in lbs)	Axle 4 Weight (in lbs)	Axle 5 Weight (in lbs)	Axle 6 Weight (in lbs)	Axle 7 Weight (in lbs)	Axle 8 Weight (in lbs)	Axle 9 Weight (in lbs)
8	64	5429	57060	13870	21590	21600	0	0	0	0	0	2	3	4717	1332	3385	0	0	0	0	0	0
8	68	4632	57180	15490	23670	18020	0	0	0	0	0	2	3	3755	1263	2493	0	0	0	0	0	0
8	64	4166	57250	14370	25660	17250	0	0	0	0	0	2	3	3414	1249	2165	0	0	0	0	0	0
8	68	3884	57370	13530	19670	24170	0	0	0	0	0	2	3	3335	1364	1971	0	0	0	0	0	0
8	64	5305	58150	16260	21320	20570	0	0	0	0	0	2	3	4592	1269	3323	0	0	0	0	0	0
8	63	4104	58240	14210	26850	17180	0	0	0	0	0	2	3	3407	1236	2171	0	0	0	0	0	0
8	64	7473	58370	15660	21080	21430	0	0	0	0	0	2	3	5671	1853	3818	0	0	0	0	0	0
8	69	5173	58390	14550	21330	22510	0	0	0	0	0	2	3	4602	1561	3041	0	0	0	0	0	0
8	70	5873	58550	13440	23310	21800	0	0	0	0	0	2	3	5770	1971	3799	0	0	0	0	0	0
8	59	6122	58570	13890	22910	21770	0	0	0	0	0	2	3	5189	1312	3877	0	0	0	0	0	0
8	65	5679	58640	13820	23140	21660	0	0	0	0	0	2	3	5150	1722	3428	0	0	0	0	0	0
8	64	6515	58820	14930	21530	22460	0	0	0	0	0	2	3	5481	1663	3818	0	0	0	0	0	0
8	62	5290	59290	53990	4180	1120	0	0	0	0	0	2	3	2808	1017	1591	0	0	0	0	0	0
8	65	6643	59420	16350	21350	21720	0	0	0	0	0	2	3	5603	1696	3907	0	0	0	0	0	0
8	72	3766	59530	15970	20230	23330	0	0	0	0	0	2	3	3047	1233	1814	0	0	0	0	0	0
8	72	3756	59670	14480	21650	23530	0	0	0	0	0	2	3	3041	1230	1811	0	0	0	0	0	0
8	70	6450	59740	15320	22860	21560	0	0	0	0	0	2	3	5442	1545	3897	0	0	0	0	0	0
8	61	5334	59800	14260	21640	23900	0	0	0	0	0	2	3	4851	1253	3398	0	0	0	0	0	0
8	67	5245	60260	12990	24150	23120	0	0	0	0	0	2	3	4619	1263	3356	0	0	0	0	0	0
8	63	5908	60420	13070	20190	27160	0	0	0	0	0	2	3	4534	1660	3874	0	0	0	0	0	0
8	63	6532	60950	14100	23150	23700	0	0	0	0	0	2	3	5534	1660	3874	0	0	0	0	0	0
8	53	5459	61090	13780	25610	21700	0	0	0	0	0	2	3	4808	1528	3280	0	0	0	0	0	0
8	73	5229	61250	27470	22390	11400	0	0	0	0	0	2	3	5382	1774	3608	0	0	0	0	0	0
8	65	6555	63250	16430	23710	23110	0	0	0	0	0	2	3	3837	1633	2204	0	0	0	0	0	0
8	77	5141	63630	23890	18760	20980	0	0	0	0	0	2	3	3749	1571	2178	0	0	0	0	0	0
8	70	4432	64640	22800	22100	19740	0	0	0	0	0	2	3	3457	1236	2221	0	0	0	0	0	0
8	71	4809	78770	18430	33410	26930	0	0	0	0	0	2	3	3953	2034	1919	0	0	0	0	0	0
8	78	5321	79410	13500	26250	39660	0	0	0	0	0	2	3	4336	1351	2985	0	0	0	0	0	0
8	78	5088	82000	48120	17300	16580	0	0	0	0	0	2	3	4281	1555	2706	0	0	0	0	0	0
8	79	4717	83980	11200	35980	36800	0	0	0	0	0	2	3	3368	1407	1961	0	0	0	0	0	0
8	71	4977	145670	73470	56640	15560	0	0	0	0	0	2	3	3296	1217	1837	242	0	0	0	0	0
8	63	3927	12020	4240	4050	1270	2460	0	0	0	0	3	4	3286	1302	1673	311	0	0	0	0	0
8	64	3900	12060	4760	4300	1720	1280	0	0	0	0	3	4	3486	1177	2037	272	0	0	0	0	0
8	65	4478	12070	4010	4470	2290	1300	0	0	0	0	3	4	3210	1292	1640	278	0	0	0	0	0
8	71	3795	12200	4490	5280	1070	1360	0	0	0	0	3	4	3138	1259	1591	288	0	0	0	0	0
8	66	3651	12320	4560	3930	2350	1480	0	0	0	0	3	4	3903	1423	2211	269	0	0	0	0	0
8	63	4855	12400	5970	4180	1330	920	0	0	0	0	3	4	4385	1292	2769	324	0	0	0	0	0
8	74	5649	12460	4310	4580	1470	2100	0	0	0	0	3	4	3470	1538	1637	295	0	0	0	0	0
8	65	3753	12560	4530	5640	1410	980	0	0	0	0	3	4	3191	1282	1624	285	0	0	0	0	0
8	55	4576	12570	4370	3720	2260	2220	0	0	0	0	3	4	3447	1112	2063	272	0	0	0	0	0
8	65	4809	12580	4600	3960	2580	1440	0	0	0	0	3	4	3876	1279	2319	278	0	0	0	0	0
8	63	4829	12650	5460	4170	2020	1000	0	0	0	0	3	4	3969	1322	2375	272	0	0	0	0	0
8	64	3779	12790	6000	4700	1150	940	0	0	0	0	3	4	3339	1427	1643	269	0	0	0	0	0
8	76	4058	12950	4580	5070	1140	2160	0	0	0	0	3	4	3470	1538	1637	295	0	0	0	0	0
8	75	4708	12960	4460	5000	2020	1480	0	0	0	0	3	4	3752	1427	2043	282	0	0	0	0	0
8	64	3385	12960	4900	4990	1790	1280	0	0	0	0	3	4	2961	1256	1443	262	0	0	0	0	0
8	68	4048	12960	6220	4080	1380	1280	0	0	0	0	3	4	3152	1309	1578	265	0	0	0	0	0
8	63	3782	13060	4220	5340	1440	2060	0	0	0	0	3	4	2944	1095	1597	252	0	0	0	0	0
8	54	4950	13080	4630	4360	2200	1900	0	0	0	0	3	4	3746	1286	2188	272	0	0	0	0	0
8	68	4872	13150	5700	4740	1770	940	0	0	0	0	3	4	4113	1437	2404	272	0	0	0	0	0
8	60	4744	13220	4030	4750	2680	1760	0	0	0	0	3	4	3995	1312	2408	275	0	0	0	0	0
8	72	4773	13280	6560	3980	1060	1680	0	0	0	0	3	4	4217	1528	2427	262	0	0	0	0	0
8	62	4609	13490	4780	4040	2620	2050	0	0	0	0	3	4	3666	1302	2086	278	0	0	0	0	0
8	75	4763	13570	4180	4490	2360	2540	0	0	0	0	3	4	3515	1272	1955	288	0	0	0	0	0
8	78	4320	13650	5920	4360	1470	1880	0	0	0	0	3	4	3833	1259	2283	291	0	0	0	0	0
8	58	4744	13730	4320	5330	2560	1520	0	0	0	0	3	4	3949	1387	2280	282	0	0	0	0	0

Vehicle Class (Scheme "F") Code	Speed of Vehicle (in km/h)	Length of Vehicle From Bumper	Gross Weight of Vehicle (in lbs)	Total Axle 1 Total Weight (in lbs)	Total Axle 2 Total Weight (in lbs)	Total Axle 3 Total Weight (in lbs)	Total Axle 4 Total Weight (in lbs)	Total Axle 5 Total Weight (in lbs)	Total Axle 6 Total Weight (in lbs)	Total Axle 7 Total Weight (in lbs)	Total Axle 8 Total Weight (in lbs)	Num ber of Axles	Wheel base distance from first axle (in mm)	Axle 2 (format mm)	Axle 3 (format mm)	Axle 4 (format mm)	Axle 5 (format mm)	Axle 6 (format mm)	Axle 7 (format mm)	Axle 8 (format mm)	Axle 9 (format mm)
8	81	5026	18020	9420	5200	1800	1500	0	0	0	0	3	4	3850	1440	2063	347	0	0	0	0
8	76	4947	18070	6060	4760	3590	3660	0	0	0	0	3	4	3818	1440	2106	272	0	0	0	0
8	69	3658	18130	4970	5320	3970	3870	0	0	0	0	3	4	3033	1102	1646	285	0	0	0	0
8	64	5793	18140	5890	7270	2570	2410	0	0	0	0	3	4	4402	1292	2782	328	0	0	0	0
8	74	4609	18230	4620	6450	3000	4160	0	0	0	0	3	4	3715	1387	2040	288	0	0	0	0
8	56	4701	18250	4210	6460	4220	3360	0	0	0	0	3	4	3660	1420	1978	262	0	0	0	0
8	69	4701	18360	6290	9170	1640	1260	0	0	0	0	3	4	4241	1581	1840	820	0	0	0	0
8	64	4893	18570	5740	10490	1480	860	0	0	0	0	3	4	4674	1952	1830	892	0	0	0	0
8	58	3671	18700	4860	5800	4640	3400	0	0	0	0	3	4	3135	1158	1702	275	0	0	0	0
8	77	4379	18710	10790	4660	1640	1620	0	0	0	0	3	4	3542	1351	1870	321	0	0	0	0
8	61	4432	18800	4680	7400	3780	2940	0	0	0	0	3	4	3543	1414	1860	269	0	0	0	0
8	74	5144	18940	5850	10560	2030	500	0	0	0	0	3	4	4913	1751	2237	925	0	0	0	0
8	70	5643	18950	6100	4650	3360	4840	0	0	0	0	3	4	4326	1387	2644	295	0	0	0	0
8	57	4452	19040	4580	5720	4290	4450	0	0	0	0	3	4	3362	1312	1781	269	0	0	0	0
8	67	4711	19050	4320	6390	4640	3700	0	0	0	0	3	4	3558	1459	1814	288	0	0	0	0
8	65	4327	19100	4320	10320	2180	2280	0	0	0	0	3	4	3614	1338	1420	856	0	0	0	0
8	62	4110	19180	5190	10610	2940	440	0	0	0	0	3	4	3732	1325	2132	275	0	0	0	0
8	63	4514	19270	8090	7630	1820	1730	0	0	0	0	3	4	4047	807	2473	767	0	0	0	0
8	52	4652	19540	10210	3820	2680	2830	0	0	0	0	3	4	3692	774	2230	688	0	0	0	0
8	53	4143	19640	8010	3430	1840	6360	0	0	0	0	3	4	2712	1056	1240	416	0	0	0	0
8	28	3398	19680	4080	7880	3960	3760	0	0	0	0	3	4	3286	1305	1729	252	0	0	0	0
8	63	4383	19730	5110	5420	4450	4750	0	0	0	0	3	4	3951	1282	2391	278	0	0	0	0
8	69	4973	19740	6150	6680	3840	3070	0	0	0	0	3	4	3567	1272	2020	275	0	0	0	0
8	64	4685	19860	4740	7180	4380	3560	0	0	0	0	3	4	4523	1729	1981	813	0	0	0	0
8	68	5082	20040	5220	12150	1420	1250	0	0	0	0	3	4	3955	1440	2217	298	0	0	0	0
8	62	5160	20420	5650	7990	3620	3160	0	0	0	0	3	4	4290	1719	1689	882	0	0	0	0
8	61	4622	20500	7490	10870	1400	740	0	0	0	0	3	4	3834	1322	2198	314	0	0	0	0
8	63	5124	20550	4200	6060	7130	3160	0	0	0	0	3	4	3820	1377	2096	347	0	0	0	0
8	72	4517	20690	5720	7320	3950	3700	0	0	0	0	3	4	5196	1443	3353	400	0	0	0	0
8	69	5335	20730	4540	7790	4350	4050	0	0	0	0	3	4	3831	1322	2221	288	0	0	0	0
8	54	4891	20750	4660	7140	5290	3660	0	0	0	0	3	4	3108	1305	1541	262	0	0	0	0
8	74	3900	20760	8130	5490	3390	3750	0	0	0	0	3	4	3591	1469	1827	295	0	0	0	0
8	66	4373	20840	9120	8680	1760	1280	0	0	0	0	3	4	3676	1292	2119	265	0	0	0	0
8	62	4858	20860	4080	7900	4260	4620	0	0	0	0	3	4	4307	1158	2880	269	0	0	0	0
8	69	4022	21030	5320	10140	3510	2060	0	0	0	0	3	4	3391	1377	1745	269	0	0	0	0
8	67	4980	21110	7680	7960	3170	2300	0	0	0	0	3	4	3572	1299	2001	272	0	0	0	0
8	65	4878	21250	4270	7370	4550	5060	0	0	0	0	3	4	5108	1427	3330	351	0	0	0	0
8	67	6115	21260	4380	9290	4350	3240	0	0	0	0	3	4	4539	1811	1830	898	0	0	0	0
8	71	5059	21360	5540	12470	2300	1050	0	0	0	0	3	4	3368	1256	1814	298	0	0	0	0
8	76	4196	21390	10990	7660	1240	1500	0	0	0	0	3	4	4300	1158	2877	265	0	0	0	0
8	66	4950	21400	7880	7990	3130	2400	0	0	0	0	3	4	3624	1279	2076	269	0	0	0	0
8	67	4625	21570	5350	7530	5150	3540	0	0	0	0	3	4	3988	1309	2401	278	0	0	0	0
8	72	4750	21680	6830	7810	3630	3410	0	0	0	0	3	4	5284	2073	2152	1059	0	0	0	0
8	76	5633	21710	8090	4090	2850	6580	0	0	0	0	3	4	3755	1476	1965	314	0	0	0	0
8	76	4192	21790	5190	12180	2360	2060	0	0	0	0	3	4	3663	1289	2099	275	0	0	0	0
8	67	4517	21810	4480	8410	4480	4440	0	0	0	0	3	4	5159	1863	2919	377	0	0	0	0
8	68	6181	21900	5660	4620	5580	6040	0	0	0	0	3	4	2859	1115	1525	219	0	0	0	0
8	56	3398	22260	12440	6140	2200	1480	0	0	0	0	3	4	4259	1669	2276	314	0	0	0	0
8	69	4842	22350	10170	10060	1020	1100	0	0	0	0	3	4	3745	1295	2175	275	0	0	0	0
8	61	5521	22350	5790	6830	5070	4660	0	0	0	0	3	4	4641	1197	3097	347	0	0	0	0
8	61	5748	22520	9740	7120	2510	3150	0	0	0	0	3	4	3916	1427	2201	288	0	0	0	0
8	66	5124	22530	5220	5960	6410	4940	0	0	0	0	3	4	4887	2244	1784	859	0	0	0	0
8	59	5410	22690	7760	12050	1820	1060	0	0	0	0	3	4	3765	1476	2004	285	0	0	0	0
8	65	4642	22790	5820	11330	2960	2680	0	0	0	0	3	4	3686	1410	1988	288	0	0	0	0
8	63	4563	22880	4680	10180	4540	3480	0	0	0	0	3	4	3591	1473	1325	793	0	0	0	0
8	63	4032	22910	10740	9550	1480	1140	0	0	0	0	3	4					0	0	0	0

Vehicle Class (Scheme -PT)	Speed (in km/h)	Length of Vehicle From Bumper to Bumper	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Num ber of Axles	Wheel base distance from first axle (in ft)	Axle 2 from first axle (in ft)	Axle 3 from first axle (in ft)	Axle 4 from first axle (in ft)	Axle 5 from first axle (in ft)	Axle 6 from first axle (in ft)	Axle 7 from first axle (in ft)	Axle 8 from first axle (in ft)	Axle 9 from first axle (in ft)
8	65	5767	33490	10520	18550	2060	2360	0	0	0	0	0	3	4	4824	2106	2427	291	0	0	0	0
8	65	5449	33500	11740	10330	6050	5380	0	0	0	0	0	3	4	4860	1315	2952	393	0	0	0	0
8	73	5980	33760	11450	11990	7780	2540	0	0	0	0	0	3	4	5057	1292	3349	416	0	0	0	0
8	79	6312	33800	6110	4810	12660	10220	0	0	0	0	0	3	4	5428	1981	3008	439	0	0	0	0
8	68	4507	33820	11030	12490	7960	2340	0	0	0	0	0	3	4	4411	1217	2171	1023	0	0	0	0
8	49	3802	33900	9160	12050	12190	500	0	0	0	0	0	3	4	2613	1138	1243	232	0	0	0	0
8	72	4202	34300	15580	13360	2840	2520	0	0	0	0	0	3	4	3401	1227	1860	314	0	0	0	0
8	87	4734	34330	24850	5820	1760	1900	0	0	0	0	0	3	4	3621	1469	1811	341	0	0	0	0
8	58	4819	34650	11400	6800	9790	6660	0	0	0	0	0	3	4	3395	761	2870	364	0	0	0	0
8	55	4780	34670	12860	17090	2520	2200	0	0	0	0	0	3	4	4368	1958	1479	931	0	0	0	0
8	57	5465	34800	8120	12820	5980	7880	0	0	0	0	0	3	4	4664	1266	2995	403	0	0	0	0
8	72	6394	35020	7570	3950	11740	11760	0	0	0	0	0	3	4	5829	2093	3336	400	0	0	0	0
8	65	5226	35020	15450	5310	9280	4980	0	0	0	0	0	3	4	4950	1794	2769	387	0	0	0	0
8	72	6968	35120	14780	13380	4280	2680	0	0	0	0	0	3	4	5372	1650	3316	406	0	0	0	0
8	64	5344	35250	11980	10790	7260	5220	0	0	0	0	0	3	4	4558	1256	2906	396	0	0	0	0
8	68	5351	35270	9110	10870	8030	7260	0	0	0	0	0	3	4	4761	1236	3129	396	0	0	0	0
8	67	6446	35300	14670	11120	5250	4260	0	0	0	0	0	3	4	5786	1499	3897	390	0	0	0	0
8	74	5790	35310	13420	13250	4850	3790	0	0	0	0	0	3	4	4530	1309	2857	364	0	0	0	0
8	70	4022	35380	16170	11120	4760	3330	0	0	0	0	0	3	4	3489	1259	1827	413	0	0	0	0
8	60	5800	35470	14120	7920	2900	10530	0	0	0	0	0	3	4	4865	1473	436	2956	0	0	0	0
8	71	5803	35600	10820	13820	7960	3000	0	0	0	0	0	3	4	5179	1738	3038	403	0	0	0	0
8	59	5915	35710	9740	12870	5670	7430	0	0	0	0	0	3	4	4657	1204	3106	347	0	0	0	0
8	21	4619	35790	4700	14990	8040	8060	0	0	0	0	0	3	4	3099	1814	1164	121	0	0	0	0
8	65	5538	35890	8900	8360	8370	10260	0	0	0	0	0	3	4	4654	1223	3031	400	0	0	0	0
8	68	5830	35980	11410	11440	8270	4860	0	0	0	0	0	3	4	4723	1663	2775	285	0	0	0	0
8	64	6253	36010	10790	10270	8270	6880	0	0	0	0	0	3	4	5212	1276	3533	403	0	0	0	0
8	76	6217	36040	12890	10530	5910	6710	0	0	0	0	0	3	4	5438	1581	3454	403	0	0	0	0
8	61	4970	36050	6290	10050	11470	8240	0	0	0	0	0	3	4	4073	1305	2431	337	0	0	0	0
8	69	5137	36070	10710	19460	2990	2910	0	0	0	0	0	3	4	4581	2112	2194	275	0	0	0	0
8	72	5121	36330	27650	5980	1180	1520	0	0	0	0	0	3	4	3546	1335	1893	318	0	0	0	0
8	38	2876	36510	25800	2550	3580	4580	0	0	0	0	0	3	4	2876	1049	1614	213	0	0	0	0
8	62	5708	36590	11760	10930	7700	6200	0	0	0	0	0	3	4	5221	1279	3546	396	0	0	0	0
8	67	5554	36640	11940	13720	5690	5290	0	0	0	0	0	3	4	4845	1240	3202	403	0	0	0	0
8	70	5285	36720	8360	13560	8110	6890	0	0	0	0	0	3	4	4949	1213	3349	387	0	0	0	0
8	66	5961	36760	9970	11600	7040	8150	0	0	0	0	0	3	4	4798	1279	3116	403	0	0	0	0
8	60	5784	36820	15060	11650	4840	5270	0	0	0	0	0	3	4	4781	1269	3116	396	0	0	0	0
8	72	5600	36920	7460	4760	11320	13380	0	0	0	0	0	3	4	5372	1925	3090	357	0	0	0	0
8	66	6624	36940	13040	12770	4940	6190	0	0	0	0	0	3	4	6084	1761	3930	393	0	0	0	0
8	66	5383	37000	18260	15020	2720	1000	0	0	0	0	0	3	4	4726	2017	1886	823	0	0	0	0
8	68	4425	37120	27380	4860	2520	2360	0	0	0	0	0	3	4	3470	1220	1978	272	0	0	0	0
8	65	5039	37170	13160	17430	3060	3520	0	0	0	0	0	3	4	4509	2112	2119	278	0	0	0	0
8	69	7326	37300	13440	11250	4550	8060	0	0	0	0	0	3	4	6147	2047	3093	1007	0	0	0	0
8	76	6883	37310	10220	3750	11980	11360	0	0	0	0	0	3	4	6347	2273	3651	423	0	0	0	0
8	70	6650	37320	11330	12430	8040	5520	0	0	0	0	0	3	4	4822	1286	3126	410	0	0	0	0
8	72	5403	37360	10260	12160	8320	6820	0	0	0	0	0	3	4	4339	1302	2083	954	0	0	0	0
8	65	4642	37410	13070	13850	8370	2120	0	0	0	0	0	3	4	4365	1138	426	2801	0	0	0	0
8	51	5600	37550	13440	10540	3110	10460	0	0	0	0	0	3	4	5310	1709	3205	396	0	0	0	0
8	66	6246	37860	14030	13480	5410	4840	0	0	0	0	0	3	4	5080	1276	3398	406	0	0	0	0
8	65	5465	55720	12590	19510	12600	11020	0	0	0	0	0	3	4	6262	2096	3779	387	0	0	0	0
8	96	8474	55840	29080	13260	6500	7000	0	0	0	0	0	3	4	5444	1630	3467	347	0	0	0	0
8	73	6548	55940	12570	16080	13890	13400	0	0	0	0	0	3	4	5448	1971	3077	400	0	0	0	0
8	76	6633	55990	11730	9380	16140	18740	0	0	0	0	0	3	4	6275	2263	3556	456	0	0	0	0
8	76	8018	56080	22490	10890	11020	11680	0	0	0	0	0	3	4	3309	1181	1912	216	0	0	0	0
8	38	3487	56210	25640	18690	4380	6500	0	0	0	0	0	3	4	5257	1912	2962	383	0	0	0	0
8	72	5679	56300	9560	6520	18260	21960	0	0	0	0	0	3	4					0	0	0	0

Vehicle Class (Scheme 1-7) Code	Speed of Vehicle (in mi/hr)	Length of Vehicle From Bumper (in)	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Num of Axles	Wheel base distance from first axle (in)	Axle Space 1 2 (in)	Axle Space 2 3 (in)	Axle Space 3 4 (in)	Axle Space 4 5 (in)	Axle Space 5 6 (in)	Axle Space 6 7 (in)	Axle Space 7 8 (in)	Axle Space 8 9 (in)
8	64	5492	56390	13020	19400	11690	12280	0	0	0	0	0	3	4	5218	1220	3595	403	0	0	0	0
8	65	6036	56440	11730	16370	13500	14840	0	0	0	0	0	3	4	5081	1266	3415	400	0	0	0	0
8	64	6463	76000	36550	20930	8860	9660	0	0	0	0	0	3	4	5720	2053	3284	383	0	0	0	0
8	37	3546	76180	26230	16970	16600	16380	0	0	0	0	0	3	4	3397	1213	1958	226	0	0	0	0
8	56	4812	76260	39360	28860	5240	4800	0	0	0	0	0	3	4	4309	1551	2457	301	0	0	0	0
8	74	7011	76610	45710	15620	6080	9200	0	0	0	0	0	3	4	5486	1669	3398	419	0	0	0	0
8	71	6788	76710	24030	16000	17620	19060	0	0	0	0	0	3	4	6551	1955	3497	1099	0	0	0	0
8	71	6259	76790	16720	46490	6980	6600	0	0	0	0	0	3	4	5623	2034	3166	423	0	0	0	0
8	46	4058	76850	41170	27640	4260	3780	0	0	0	0	0	3	4	3627	1299	2073	255	0	0	0	0
8	74	7171	76900	32920	19340	11860	12780	0	0	0	0	0	3	4	5868	2112	3323	433	0	0	0	0
8	48	3982	77140	31810	28670	8540	8120	0	0	0	0	0	3	4	3732	1348	2112	272	0	0	0	0
8	38	3238	77380	31260	23160	13960	9000	0	0	0	0	0	3	4	2899	1043	1653	203	0	0	0	0
8	73	4209	77750	6410	22140	24560	24840	0	0	0	0	0	3	4	4024	1578	2030	416	0	0	0	0
8	76	5065	77770	16810	31660	18420	10880	0	0	0	0	0	3	4	4015	1535	2175	305	0	0	0	0
8	52	5554	77850	24650	15680	18160	19360	0	0	0	0	0	3	4	4520	1624	2601	295	0	0	0	0
8	45	4189	77980	43360	25020	4160	5440	0	0	0	0	0	3	4	3562	1279	2034	249	0	0	0	0
8	34	2797	77980	12700	32980	16580	15720	0	0	0	0	0	3	4	2797	1046	1561	190	0	0	0	0
8	25	4376	78100	9150	9880	45130	13940	0	0	0	0	0	3	4	2945	1624	1171	150	0	0	0	0
8	68	3996	78350	6690	27160	11240	33260	0	0	0	0	0	3	4	3804	1482	1952	370	0	0	0	0
8	35	3182	78380	42910	22090	6180	7200	0	0	0	0	0	3	4	2870	1030	1640	200	0	0	0	0
8	40	3910	78600	41030	24090	6760	6720	0	0	0	0	0	3	4	3808	1358	2198	252	0	0	0	0
8	43	3631	78760	33850	32410	5560	6940	0	0	0	0	0	3	4	3440	1233	1968	239	0	0	0	0
8	74	6200	78790	43790	14040	8100	12860	0	0	0	0	0	3	4	5054	1377	3251	426	0	0	0	0
8	48	4461	78910	41310	26820	5800	4980	0	0	0	0	0	3	4	3890	1397	2221	272	0	0	0	0
8	76	6801	79090	16160	12490	26740	23700	0	0	0	0	0	3	4	5953	2145	3385	423	0	0	0	0
8	79	4435	79280	7060	27340	21260	23620	0	0	0	0	0	3	4	4254	1656	2162	436	0	0	0	0
8	56	4186	79680	15160	22400	23400	18720	0	0	0	0	0	3	4	3860	1463	1984	413	0	0	0	0
8	64	5849	79820	14940	29850	17670	17360	0	0	0	0	0	3	4	4690	1689	2660	341	0	0	0	0
8	58	4957	80280	41410	27270	6300	5300	0	0	0	0	0	3	4	4074	1404	2267	403	0	0	0	0
8	46	4074	80380	35400	36040	5700	3240	0	0	0	0	0	3	4	4778	1341	3034	403	0	0	0	0
8	37	3638	80460	42270	22830	7300	8060	0	0	0	0	0	3	4	3381	1210	1952	219	0	0	0	0
8	37	3585	80650	32800	13150	16720	17980	0	0	0	0	0	3	4	5274	1886	3031	357	0	0	0	0
8	63	5554	80690	37570	30460	7120	5540	0	0	0	0	0	3	4	4303	1538	2477	288	0	0	0	0
8	48	4580	81430	11530	39820	16420	13660	0	0	0	0	0	3	4	5339	1935	2985	419	0	0	0	0
8	70	5935	81510	47390	20180	8020	5920	0	0	0	0	0	3	4	3920	1407	2244	269	0	0	0	0
8	114	6187	81660	58600	10480	6320	6260	0	0	0	0	0	3	4	4854	1758	2690	406	0	0	0	0
8	72	6998	81690	39820	18070	10420	13380	0	0	0	0	0	3	4	5750	2073	3267	410	0	0	0	0
8	35	3372	81830	47650	24560	4580	5040	0	0	0	0	0	3	4	3282	1171	1902	209	0	0	0	0
8	71	6338	81830	14170	51920	5360	10380	0	0	0	0	0	3	4	5940	2139	3398	403	0	0	0	0
8	34	3385	82060	43930	25310	6420	6400	0	0	0	0	0	3	4	3247	1164	1870	213	0	0	0	0
8	71	5961	82390	13920	44370	12460	11640	0	0	0	0	0	3	4	4913	1791	2732	390	0	0	0	0
8	38	3197	82400	41870	34010	2820	3700	0	0	0	0	0	3	4	3197	1151	1830	216	0	0	0	0
8	36	3238	82810	33380	28230	10540	10660	0	0	0	0	0	3	4	2972	1066	1706	200	0	0	0	0
8	39	3523	82820	43840	29660	3420	5900	0	0	0	0	0	3	4	3184	1141	1824	219	0	0	0	0
8	60	6181	83080	41280	26560	6020	9220	0	0	0	0	0	3	4	5133	1847	2926	360	0	0	0	0
8	76	6548	83080	13480	11840	28020	29740	0	0	0	0	0	3	4	5766	1873	2798	1095	0	0	0	0
8	48	4120	83100	39020	31880	4580	7620	0	0	0	0	0	3	4	3788	1358	2168	262	0	0	0	0
8	35	3412	83150	30910	34160	10220	7860	0	0	0	0	0	3	4	2829	1053	1673	203	0	0	0	0
8	64	4347	83200	12280	23470	21730	25710	0	0	0	0	0	3	4	3918	1528	1994	396	0	0	0	0
8	76	7565	83560	25770	42870	10960	3960	0	0	0	0	0	3	4	6400	1932	459	4009	0	0	0	0
8	79	5738	84000	14140	13280	30620	25960	0	0	0	0	0	3	4	5015	1673	2946	396	0	0	0	0
8	58	4727	84380	59980	13500	5700	5200	0	0	0	0	0	3	4	4142	961	2857	324	0	0	0	0
8	33	2847	84440	40570	30130	5960	7780	0	0	0	0	0	3	4	2824	1017	1614	193	0	0	0	0
8	38	3576	84520	31750	28990	11080	12700	0	0	0	0	0	3	4	3256	1167	1866	223	0	0	0	0
8	69	6305	84640	40830	26390	5960	11460	0	0	0	0	0	3	4	5435	1975	3034	426	0	0	0	0

Vehicle Class (Scheme "g") Code	Speed of Vehicle (in mi/hr)	Length of Vehicle From Bumper to Bumper	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Num ber of Axles	Wheel base distance from first axle (in ft)	Axle 1 Weight (in lbs)	Axle 2 Weight (in lbs)	Axle 3 Weight (in lbs)	Axle 4 Weight (in lbs)	Axle 5 Weight (in lbs)	Axle 6 Weight (in lbs)	Axle 7 Weight (in lbs)	Axle 8 Weight (in lbs)	Axle 9 Weight (in lbs)
8 79	79	7066	84730	9190	55480	10580	9480	0	0	0	0	0	0	4	5966	2148	3389	429	0	0	0	0	0
8 34	34	3008	84910	31900	25670	12820	14520	0	0	0	0	0	0	3	4	2862	1026	1646	190	0	0	0	0
8 59	59	5393	85020	38950	33270	6040	6760	0	0	0	0	0	0	3	4	4838	1735	2775	328	0	0	0	0
8 48	48	4304	85040	46330	46730	15100	15580	0	0	0	0	0	0	3	4	3887	1391	2227	269	0	0	0	0
8 37	37	3313	85350	25750	36320	10860	12420	0	0	0	0	0	0	3	4	2978	1069	1706	203	0	0	0	0
8 36	36	3384	85680	56730	12670	6460	9820	0	0	0	0	0	0	3	4	3384	1213	1942	229	0	0	0	0
8 35	35	2949	85700	43540	30320	5060	6780	0	0	0	0	0	0	3	4	2820	1010	1617	193	0	0	0	0
8 73	73	4386	85780	12730	26760	24180	22110	0	0	0	0	0	0	3	4	3912	1535	1981	396	0	0	0	0
8 80	80	6758	85830	18870	13420	26640	26900	0	0	0	0	0	0	3	4	5970	2168	3356	446	0	0	0	0
8 63	63	6246	85960	20840	45560	10820	8740	0	0	0	0	0	0	3	4	5239	1870	2992	377	0	0	0	0
8 64	64	6673	86000	48080	21660	8480	7780	0	0	0	0	0	0	3	4	5563	1998	3175	390	0	0	0	0
8 38	38	4337	86160	10250	27880	30430	17600	0	0	0	0	0	0	3	4	3391	1263	1919	209	0	0	0	0
8 61	61	4278	86470	11600	24470	25340	25060	0	0	0	0	0	0	3	4	3893	1463	2027	403	0	0	0	0
8 66	66	4097	86860	11550	28330	22480	24500	0	0	0	0	0	0	3	4	3808	1404	1998	406	0	0	0	0
8 66	66	4350	86940	14360	24760	13210	34610	0	0	0	0	0	0	3	4	3919	1538	1991	390	0	0	0	0
8 35	35	3064	87110	30400	42190	7200	7320	0	0	0	0	0	0	3	4	3010	1082	1722	206	0	0	0	0
8 35	35	3297	87270	49570	27940	3560	6200	0	0	0	0	0	0	3	4	4598	1125	3113	360	0	0	0	0
8 64	64	4835	87320	63840	15560	3660	4260	0	0	0	0	0	0	3	4	3630	1220	2014	396	0	0	0	0
8 65	65	3937	87470	13040	25050	23390	25990	0	0	0	0	0	0	3	4	3237	1177	1801	259	0	0	0	0
8 41	41	3441	87510	48910	24640	6260	7700	0	0	0	0	0	0	3	4	5594	2037	3277	380	0	0	0	0
8 69	69	6686	87720	45470	24710	8490	9060	0	0	0	0	0	0	3	4	5471	1978	3083	410	0	0	0	0
8 56	56	5380	87810	14670	45120	13580	14440	0	0	0	0	0	0	3	4	6498	2119	3300	1079	0	0	0	0
8 72	72	5125	88060	55700	21280	5860	5220	0	0	0	0	0	0	3	4	3877	1384	2060	433	0	0	0	0
8 73	73	7463	88180	44520	20740	10960	11960	0	0	0	0	0	0	3	4	4178	1492	2431	255	0	0	0	0
8 48	48	4494	88320	49870	7130	12840	18480	0	0	0	0	0	0	3	4	6360	2280	3641	439	0	0	0	0
8 74	74	7496	88700	44150	23130	12860	8560	0	0	0	0	0	0	3	4	3739	1456	1873	410	0	0	0	0
8 67	67	3927	88800	12370	24650	28060	23720	0	0	0	0	0	0	3	4	3899	1466	2020	413	0	0	0	0
8 65	65	4183	88970	14560	24690	24690	25030	0	0	0	0	0	0	3	4	4677	1696	2604	377	0	0	0	0
8 58	58	5793	106030	42920	43570	9960	9580	0	0	0	0	0	0	3	4	4555	1643	2591	321	0	0	0	0
8 56	56	5488	106120	42080	38180	11740	14120	0	0	0	0	0	0	3	4	5540	1988	3172	380	0	0	0	0
8 69	69	5698	106330	51550	41900	6020	6860	0	0	0	0	0	0	3	4	3201	1368	1633	200	0	0	0	0
8 32	32	4543	106330	10450	24260	52140	19480	0	0	0	0	0	0	3	4	5385	1938	3054	393	0	0	0	0
8 69	69	5698	106460	47280	36500	10820	11860	0	0	0	0	0	0	3	4	6134	2201	3517	416	0	0	0	0
8 72	72	6719	106460	53070	36040	7080	10740	0	0	0	0	0	0	3	4	3703	1030	2408	265	0	0	0	0
8 35	35	3451	107100	49920	43840	6880	6880	0	0	0	0	0	0	3	4	5972	2155	3398	419	0	0	0	0
8 47	47	4881	107260	8300	48610	42830	9520	0	0	0	0	0	0	3	4	5379	1932	3077	370	0	0	0	0
8 72	72	6046	107280	58680	34000	7060	7540	0	0	0	0	0	0	3	4	5863	2139	3395	429	0	0	0	0
8 74	74	6525	107310	27830	64980	7420	7080	0	0	0	0	0	0	3	4	5786	2096	3264	426	0	0	0	0
8 64	64	6463	107800	61940	23160	10860	11840	0	0	0	0	0	0	3	4	5255	1893	2972	390	0	0	0	0
8 34	34	3044	108020	43050	36130	13840	15000	0	0	0	0	0	0	3	4	5405	1938	3087	380	0	0	0	0
8 74	74	5958	108160	50550	40390	10260	6960	0	0	0	0	0	0	3	4	5510	1863	452	3195	0	0	0	0
8 74	74	5692	108310	50880	36870	11100	9460	0	0	0	0	0	0	3	4	2954	1056	1689	209	0	0	0	0
8 62	62	6473	108620	49680	31760	12860	14320	0	0	0	0	0	0	3	4	2876	1033	1640	203	0	0	0	0
8 77	77	6095	109250	58470	13260	18220	19300	0	0	0	0	0	0	3	4	3204	1151	1830	223	0	0	0	0
8 34	34	3349	109660	56200	35580	8760	8820	0	0	0	0	0	0	3	4	3594	1295	2050	249	0	0	0	0
8 36	36	3149	109680	38080	30920	20060	20820	0	0	0	0	0	0	3	4	6058	2162	3490	406	0	0	0	0
8 38	38	3828	109880	46320	26800	17860	18900	0	0	0	0	0	0	3	4	5760	2070	3277	413	0	0	0	0
8 44	44	3759	110000	53070	37690	9220	10020	0	0	0	0	0	0	3	4	5833	2132	3375	426	0	0	0	0
8 74	74	6213	110140	79420	12660	7540	10520	0	0	0	0	0	0	3	4	5477	1305	3746	209	0	0	0	0
8 75	75	6807	110570	51720	37690	10400	10760	0	0	0	0	0	0	3	4	3328	1190	1929	209	0	0	0	0
8 75	75	6807	110670	55720	39470	6940	9540	0	0	0	0	0	0	3	4	5833	2132	3375	426	0	0	0	0
8 76	76	7234	110670	51130	34520	11680	13340	0	0	0	0	0	0	3	4	5477	1305	3746	209	0	0	0	0
8 40	40	3779	110920	47410	31110	15620	16780	0	0	0	0	0	0	3	4	5477	1305	3746	209	0	0	0	0
8 74	74	6528	111070	50950	26840	17000	16280	0	0	0	0	0	0	3	4	5477	1305	3746	209	0	0	0	0
8 37	37	3382	111580	47030	32010	15700	16840	0	0	0	0	0	0	3	4	5477	1305	3746	209	0	0	0	0

Vehicle Class (Scheme "SP") Code	Speed of Vehicle (in km/h)	Length of Vehicle From Bumper to Bumper	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Num ber of Axles	Wheel base distance from first axle to last axle (in mm)	Axle 1 Weight (formal mm)	Axle 2 Weight (formal mm)	Axle 3 Weight (formal mm)	Axle 4 Weight (formal mm)	Axle 5 Weight (formal mm)	Axle 6 Weight (formal mm)	Axle 7 Weight (formal mm)	Axle 8 Weight (formal mm)	Axle 9 Weight (formal mm)
8 78	6555	121800	66420	36900	9000	9480	0	0	0	0	0	0	3	4	5827	2155	3310	462	0	0	0	0	0
8 78	7155	121830	64420	32350	11820	13240	0	0	0	0	0	0	3	4	5789	2099	3254	436	0	0	0	0	0
8 72	5629	121910	53520	41990	13960	12440	0	0	0	0	0	0	3	4	4651	1696	2575	380	0	0	0	0	0
8 32	4619	122320	10470	48350	45060	18440	0	0	0	0	0	0	3	4	3424	1368	1856	200	0	0	0	0	0
8 77	6053	122370	56260	42990	10280	12840	0	0	0	0	0	0	3	4	5212	1883	2929	400	0	0	0	0	0
8 76	7014	122570	57150	42180	10580	12660	0	0	0	0	0	0	3	4	6174	2234	3471	469	0	0	0	0	0
8 72	5689	122830	61560	40930	10740	9600	0	0	0	0	0	0	3	4	5113	1856	2854	403	0	0	0	0	0
8 71	6866	123000	59980	46520	8680	10820	0	0	0	0	0	0	3	4	6318	2257	3651	410	0	0	0	0	0
8 77	7483	123020	69710	40810	5980	6520	0	0	0	0	0	0	3	4	6537	2119	3326	1092	0	0	0	0	0
8 48	4356	123460	51690	39910	16360	15500	0	0	0	0	0	0	3	4	3998	1440	2267	291	0	0	0	0	0
8 37	3231	123520	55740	43900	12860	11020	0	0	0	0	0	0	3	4	2939	1053	1686	200	0	0	0	0	0
8 72	5889	123530	62240	49690	4740	6860	0	0	0	0	0	0	3	4	5241	1896	2942	403	0	0	0	0	0
8 77	6318	123570	65720	44490	5560	7800	0	0	0	0	0	0	3	4	6202	2230	3536	436	0	0	0	0	0
8 72	6837	124260	65530	39530	9000	10200	0	0	0	0	0	0	3	4	5750	2073	3274	403	0	0	0	0	0
8 74	6446	149840	67700	61360	8760	12020	0	0	0	0	0	0	3	4	5232	1893	2929	410	0	0	0	0	0
8 68	6000	150530	73940	59510	9000	8180	0	0	0	0	0	0	3	4	5445	1952	3116	377	0	0	0	0	0
8 56	4247	150970	59640	53750	17040	20540	0	0	0	0	0	0	3	4	4247	1535	2404	308	0	0	0	0	0
8 75	7103	151040	57700	66660	12620	14060	0	0	0	0	0	0	3	4	6068	2175	3477	416	0	0	0	0	0
8 72	6998	151240	66620	36520	25260	22840	0	0	0	0	0	0	3	4	6209	2227	3566	416	0	0	0	0	0
8 78	7811	151550	81920	40030	15900	13700	0	0	0	0	0	0	3	4	5829	2109	3274	446	0	0	0	0	0
8 74	4671	151940	57920	27000	35540	31480	0	0	0	0	0	0	3	4	4132	1610	2096	426	0	0	0	0	0
8 74	6945	152240	67830	66610	8600	9200	0	0	0	0	0	0	3	4	6239	2096	3274	869	0	0	0	0	0
8 81	7706	152250	23590	77380	25560	25720	0	0	0	0	0	0	3	4	6425	2299	3710	416	0	0	0	0	0
8 74	7040	152360	90130	11630	25240	25360	0	0	0	0	0	0	3	4	5566	2004	3162	400	0	0	0	0	0
8 63	5206	153500	68610	53450	16640	14800	0	0	0	0	0	0	3	4	4576	1640	2595	341	0	0	0	0	0
8 71	6975	153900	71470	62390	10280	9760	0	0	0	0	0	0	3	4	5723	2057	3270	396	0	0	0	0	0
8 67	6574	154130	75510	50080	13200	15340	0	0	0	0	0	0	3	4	5602	2030	3192	380	0	0	0	0	0
8 72	6184	154300	62610	47610	22540	21540	0	0	0	0	0	0	3	4	5842	2024	3238	380	0	0	0	0	0
8 74	7185	154890	74620	49750	15020	15500	0	0	0	0	0	0	3	4	5959	2145	3398	416	0	0	0	0	0
8 82	7670	155060	80750	51390	13760	9160	0	0	0	0	0	0	3	4	5582	2040	3090	452	0	0	0	0	0
8 69	7122	155060	69670	68030	10840	6520	0	0	0	0	0	0	3	4	5835	2080	3359	396	0	0	0	0	0
8 70	7165	155310	64240	38710	27180	25180	0	0	0	0	0	0	3	4	5851	2099	3333	419	0	0	0	0	0
8 76	7805	155520	68510	58810	13140	15060	0	0	0	0	0	0	3	4	5878	2119	3349	410	0	0	0	0	0
8 72	6735	155380	60370	46690	23440	24880	0	0	0	0	0	0	3	4	6386	2280	3677	429	0	0	0	0	0
8 74	7267	156260	74150	60250	10940	10920	0	0	0	0	0	0	3	4	6422	2299	3707	416	0	0	0	0	0
8 74	7578	156410	84360	15610	26560	29880	0	0	0	0	0	0	3	4	5939	2148	3362	429	0	0	0	0	0
8 74	6879	156740	85500	16980	32300	21960	0	0	0	0	0	0	3	4	5635	2037	3169	429	0	0	0	0	0
8 72	6758	157390	75390	46680	18360	16960	0	0	0	0	0	0	3	4	6094	2181	3503	410	0	0	0	0	0
8 74	7398	157710	86640	18350	25780	26940	0	0	0	0	0	0	3	4	6340	2263	3648	429	0	0	0	0	0
8 74	7214	158000	21790	71570	32840	31800	0	0	0	0	0	0	3	4	6317	2270	3605	442	0	0	0	0	0
8 77	7332	158140	57920	57200	20860	22160	0	0	0	0	0	0	3	4	6118	2201	3471	446	0	0	0	0	0
8 71	6663	158500	65190	47510	22040	23760	0	0	0	0	0	0	3	4	5867	2030	3244	383	0	0	0	0	0
8 72	6998	158690	77720	55070	12500	13400	0	0	0	0	0	0	3	4	6294	2247	3631	416	0	0	0	0	0
8 75	7185	159080	74940	53980	15100	15060	0	0	0	0	0	0	3	4	6157	1768	3953	436	0	0	0	0	0
8 73	7601	159180	41380	54620	46360	16820	0	0	0	0	0	0	3	4	5727	2050	3284	393	0	0	0	0	0
8 69	6610	159680	59980	51580	23120	25000	0	0	0	0	0	0	3	4	5497	1981	3100	416	0	0	0	0	0
8 76	6817	159810	66690	60940	17140	15040	0	0	0	0	0	0	3	4	6288	2260	3615	413	0	0	0	0	0
8 76	7368	159970	66060	35630	27900	30380	0	0	0	0	0	0	3	4	5378	1469	3480	429	0	0	0	0	0
8 74	6581	160000	35040	51390	49710	23860	0	0	0	0	0	0	3	4	6180	2221	3520	439	0	0	0	0	0
8 76	7667	160050	65980	68350	13780	11940	0	0	0	0	0	0	3	4	5442	1975	3054	413	0	0	0	0	0
8 69	6610	161460	76560	48640	18560	17700	0	0	0	0	0	0	3	4	5878	2109	3353	416	0	0	0	0	0
8 74	5807	161460	80050	63670	10320	7420	0	0	0	0	0	0	3	4	6101	2181	3540	380	0	0	0	0	0
8 69	6610	162180	64070	50050	22360	25700	0	0	0	0	0	0	3	4	5912	1181	1938	793	0	0	0	0	0
8 68	5570	163220	53200	35180	38100	36740	0	0	0	0	0	0	3	4	6340	2296	3536	508	0	0	0	0	0
8 87	7673	163450	70780	50590	21660	20420	0	0	0	0	0	0	3	4	5185	1879	2893	413	0	0	0	0	0
8 73	6663	164090	73570	65180	12840	12500	0	0	0	0	0	0	3	4	5185	1879	2893	413	0	0	0	0	0

Vehicle Class (Scheme "P") Code	Speed of Vehicle (in km/h)	Length of Vehicle Bumper to Bumper	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Num ber of Axles	Wheel base distance from first axle (in mm)	Axle Space 1 2 (format mm mm)	Axle Space 2 3 (format mm mm)	Axle Space 3 4 (format mm mm)	Axle Space 4 5 (format mm mm)	Axle Space 5 6 (format mm mm)	Axle Space 6 7 (format mm mm)	Axle Space 7 8 (format mm mm)	Axle Space 8 9 (format mm mm)
8 73	7027	164540	83000	58800	109800	11760	0	0	0	0	0	0	3	4	6170	2204	3543	423	0	0	0	0
8 72	7080	164640	88680	50100	117000	14160	0	0	0	0	0	0	3	4	6085	2188	3487	410	0	0	0	0
8 76	6916	164650	83940	59610	9640	11460	0	0	0	0	0	0	3	4	6108	2185	3520	403	0	0	0	0
8 72	6889	165190	63160	65460	17020	19560	0	0	0	0	0	0	3	4	5789	2086	3303	400	0	0	0	0
8 79	6807	165610	86180	58470	10800	10760	0	0	0	0	0	0	3	4	6373	2296	3628	449	0	0	0	0
8 72	6541	166510	73070	61220	15740	16480	0	0	0	0	0	0	3	4	6075	2185	3474	416	0	0	0	0
8 72	6830	166550	85670	57120	11900	11860	0	0	0	0	0	0	3	4	5992	2007	3202	383	0	0	0	0
8 64	6745	167080	73070	61390	17040	15580	0	0	0	0	0	0	3	4	5845	2103	3336	406	0	0	0	0
8 80	7276	167330	87490	54600	13280	11960	0	0	0	0	0	0	3	4	6432	2296	3700	436	0	0	0	0
8 76	7214	168680	74260	66880	12960	14580	0	0	0	0	0	0	3	4	6134	2208	3477	449	0	0	0	0
8 69	6532	169310	68260	45510	27300	28240	0	0	0	0	0	0	3	4	5783	2070	3333	380	0	0	0	0
8 77	7401	170200	67700	50580	26280	25640	0	0	0	0	0	0	3	4	6219	2234	3533	452	0	0	0	0
8 72	7381	170740	79050	57710	18540	15440	0	0	0	0	0	0	3	4	5923	2122	3385	416	0	0	0	0
8 84	6774	171330	39500	79370	25560	26900	0	0	0	0	0	0	3	4	5976	2171	3343	462	0	0	0	0
8 74	8169	171400	69570	57290	22320	22220	0	0	0	0	0	0	3	4	6107	2201	3454	452	0	0	0	0
8 74	6774	171680	73910	56310	20480	20980	0	0	0	0	0	0	3	4	6144	2208	3503	433	0	0	0	0
8 70	6453	172360	80720	63940	14540	13160	0	0	0	0	0	0	3	4	5521	1981	3166	374	0	0	0	0
8 74	8087	173690	74070	67140	13480	19000	0	0	0	0	0	0	3	4	6426	2224	3553	649	0	0	0	0
8 91	8316	175400	80620	63940	14900	15940	0	0	0	0	0	0	3	4	6268	2280	3477	511	0	0	0	0
8 70	6437	176570	66050	64720	21500	24300	0	0	0	0	0	0	3	4	5136	1847	2929	360	0	0	0	0
8 72	6420	176760	63970	62030	25420	25340	0	0	0	0	0	0	3	4	5104	1850	2874	380	0	0	0	0
8 78	7677	176850	89100	61030	13580	13140	0	0	0	0	0	0	3	4	6213	2234	3523	456	0	0	0	0
8 77	7230	177680	78190	56690	21540	21260	0	0	0	0	0	0	3	4	5586	2024	3126	436	0	0	0	0
8 69	6876	177780	69490	61090	24540	22860	0	0	0	0	0	0	3	4	5891	2096	3405	390	0	0	0	0
8 73	5938	179630	62530	48620	31820	36660	0	0	0	0	0	0	3	4	5455	1975	3077	403	0	0	0	0
8 77	5501	180390	67310	33460	34500	45120	0	0	0	0	0	0	3	4	4769	1873	2421	475	0	0	0	0
8 68	6961	181640	65570	67850	24260	23960	0	0	0	0	0	0	3	4	6320	2253	3667	400	0	0	0	0
8 108	7818	182020	82820	70020	14140	15040	0	0	0	0	0	0	3	4	4867	1899	2253	715	0	0	0	0
8 70	6318	183980	77060	51700	27660	15040	0	0	0	0	0	0	3	4	5530	2014	3083	433	0	0	0	0
8 75	7070	186050	91880	60390	16820	16960	0	0	0	0	0	0	3	4	6199	2230	3533	436	0	0	0	0
8 72	6118	189140	73870	62750	27400	25120	0	0	0	0	0	0	3	4	5674	2027	3270	377	0	0	0	0
8 81	7349	189260	79800	57560	26640	25260	0	0	0	0	0	0	3	4	6330	2299	3536	495	0	0	0	0
8 70	7473	189570	85710	52940	23940	26980	0	0	0	0	0	0	3	4	6258	2250	3569	439	0	0	0	0
8 69	6761	189710	86350	51660	25860	25840	0	0	0	0	0	0	3	4	5567	2001	3166	400	0	0	0	0
8 35	44844	190180	23039	64933	29730	32388	0	0	0	0	0	0	3	4	5320	2057	2509	754	0	0	0	0
8 130	8395	192190	10150	63410	12680	14800	0	0	0	0	0	0	3	4	5020	820	3380	820	0	0	0	0
8 79	4806	192850	39000	63230	54980	35840	0	0	0	0	0	0	3	4	4208	1650	2135	423	0	0	0	0
8 75	7086	192910	83510	70980	18660	19760	0	0	0	0	0	0	3	4	6108	2191	3517	400	0	0	0	0
8 74	7447	194590	76350	60640	27980	29620	0	0	0	0	0	0	3	4	6022	2155	3454	413	0	0	0	0
8 76	7014	194710	84510	54060	24980	31160	0	0	0	0	0	0	3	4	5900	2125	3362	413	0	0	0	0
8 76	7365	194760	68110	69090	29580	27980	0	0	0	0	0	0	3	4	6192	2224	3526	442	0	0	0	0
8 18	27700	195470	92896	95495	10519	11917	0	0	0	0	0	0	3	4	4102	820	2462	820	0	0	0	0
8 70	6141	198310	76000	26460	25060	25060	0	0	0	0	0	0	3	4	5304	1902	3028	374	0	0	0	0
8 131	8461	198630	11456	56850	13100	14120	0	0	0	0	0	0	3	4	5373	2073	2552	748	0	0	0	0
8 69	7030	199970	87740	63830	23480	24820	0	0	0	0	0	0	3	4	6315	2290	3546	479	0	0	0	0
8 84	7791	200390	75330	67960	30800	26300	0	0	0	0	0	0	3	4	4217	1656	2132	429	0	0	0	0
8 81	4717	202030	39740	60020	66970	35300	0	0	0	0	0	0	3	4	5494	1981	3120	393	0	0	0	0
8 73	7063	202130	82790	66560	24060	28720	0	0	0	0	0	0	3	4	5858	2116	3336	406	0	0	0	0
8 72	6876	202520	73620	71980	25260	31660	0	0	0	0	0	0	3	4	6242	2247	3549	446	0	0	0	0
8 77	7247	202550	87450	60680	22660	31760	0	0	0	0	0	0	3	4	6242	2247	3549	446	0	0	0	0
8 74	7365	204550	70420	75870	31260	27000	0	0	0	0	0	0	3	4	6064	2191	3431	442	0	0	0	0
8 77	6473	204680	96010	72890	15900	19880	0	0	0	0	0	0	3	4	5307	1932	2952	423	0	0	0	0
8 70	7398	206210	85670	65500	26920	28120	0	0	0	0	0	0	3	4	6292	2283	3517	492	0	0	0	0
8 78	7316	214450	83610	76900	27220	26660	0	0	0	0	0	0	3	4	6288	2260	3595	433	0	0	0	0
8 75	6673	215190	85450	72380	29080	28280	0	0	0	0	0	0	3	4	6019	2171	3392	456	0	0	0	0

Vehicle Class (Scheme "F") Code	Speed of Vehicle (in mi/hr)	Length of Vehicle From Bumper (in)	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Num ber of Axles	Wheel base distance from first axle (in)	Axle 1 Weight (in lbs)	Axle 2 Weight (in lbs)	Axle 3 Weight (in lbs)	Axle 4 Weight (in lbs)	Axle 5 Weight (in lbs)	Axle 6 Weight (in lbs)	Axle 7 Weight (in lbs)	Axle 8 Weight (in lbs)	Axle 9 Weight (in lbs)
8	78	7244	217290	87820	73410	30100	25960	0	0	0	0	0	3	4	6076	2185	3458	433	0	0	0	0	0
8	81	7667	221480	95200	69960	27860	28460	0	0	0	0	0	3	4	6232	2237	3556	439	0	0	0	0	0
8	132	8559	244580	13143	83450	14940	14760	0	0	0	0	0	3	4	5291	2070	2480	741	0	0	0	0	0
8	35	63290	256040	85755	93715	56066	52212	0	0	0	0	0	3	4	4711	820	3071	820	0	0	0	0	0
8	136	8500	273460	13526	10002	17600	20580	0	0	0	0	0	3	4	5419	2099	2559	781	0	0	0	0	0
8	96	6831	291040	38055	16697	19172	20716	0	0	0	0	0	3	4	4913	820	3273	820	0	0	0	0	0
8	96	10136	331370	55206	61065	84948	94062	0	0	0	0	0	3	4	4818	820	3178	820	0	0	0	0	0
8	120	32126	472670	83864	33451	31356	29668	0	0	0	0	0	3	4	4227	820	2587	820	0	0	0	0	0
9	36	4064	14840	4410	2560	2380	3210	2280	0	0	0	0	4	5	3013	974	213	1325	501	0	0	0	0
9	68	58081	14870	6520	2310	2480	2440	1120	0	0	0	0	4	5	5562	1729	419	3008	406	0	0	0	0
9	69	12857	17270	4630	2620	2890	3280	3850	0	0	0	0	4	5	5947	1788	423	3336	400	0	0	0	0
9	81	7526	18470	4920	2910	3730	4130	2780	0	0	0	0	4	5	6770	2109	449	3779	433	0	0	0	0
9	50	4746	19640	8550	4960	1220	2770	2140	0	0	0	0	4	5	4746	889	328	2775	754	0	0	0	0
9	39	2642	20590	13840	2770	1650	1340	990	0	0	0	0	4	5	2642	800	219	1420	203	0	0	0	0
9	64	6135	21160	10890	3180	3200	2320	1570	0	0	0	0	4	5	4712	1315	429	2562	406	0	0	0	0
9	64	6597	21530	8330	3810	3570	2450	3370	0	0	0	0	4	5	6113	1955	416	3349	393	0	0	0	0
9	64	5249	22820	9370	4620	4250	1860	2720	0	0	0	0	4	5	5044	1272	426	2946	400	0	0	0	0
9	69	5541	23720	12180	4550	1570	4050	1370	0	0	0	0	4	5	5146	1453	433	2847	413	0	0	0	0
9	64	5501	24000	8080	6500	1980	3610	3830	0	0	0	0	4	5	5444	1335	429	3280	400	0	0	0	0
9	68	5574	24380	12070	5400	1540	4010	1360	0	0	0	0	4	5	4735	1072	429	2831	403	0	0	0	0
9	70	5301	24990	11820	5170	1530	3550	2920	0	0	0	0	4	5	5106	1515	436	2759	396	0	0	0	0
9	74	6453	25350	12360	3820	2510	3020	3640	0	0	0	0	4	5	5854	1709	419	3326	400	0	0	0	0
9	66	5065	25500	11510	5890	2720	3940	1440	0	0	0	0	4	5	5020	1430	419	2752	419	0	0	0	0
9	37	3064	25780	9150	5700	4740	2850	3340	0	0	0	0	4	5	2885	853	213	1719	200	0	0	0	0
9	65	4058	25880	10180	4250	4350	3550	3560	0	0	0	0	4	5	3862	1233	426	1807	396	0	0	0	0
9	65	5577	25960	11250	4610	4160	3460	2480	0	0	0	0	4	5	5117	1364	433	2910	410	0	0	0	0
9	65	5849	26300	10100	5270	5300	1710	3920	0	0	0	0	4	5	5411	1135	419	3467	390	0	0	0	0
9	48	4146	26320	4660	5720	5420	5440	5080	0	0	0	0	4	5	4125	1259	272	1935	659	0	0	0	0
9	67	5406	26590	9440	5190	4490	3720	3750	0	0	0	0	4	5	5140	1335	423	2979	403	0	0	0	0
9	68	5751	26660	12080	4400	4250	3530	2400	0	0	0	0	4	5	5237	1351	419	3061	406	0	0	0	0
9	34	2954	26730	4970	8420	6360	2800	4180	0	0	0	0	4	5	2954	813	203	1459	479	0	0	0	0
9	67	5538	26770	13020	4020	3100	4030	2600	0	0	0	0	4	5	5142	1292	439	3015	396	0	0	0	0
9	64	4261	26850	13040	5560	2020	3330	2900	0	0	0	0	4	5	4148	1669	426	1653	400	0	0	0	0
9	65	5508	26870	12230	3500	4670	3710	2760	0	0	0	0	4	5	5169	1348	426	2992	403	0	0	0	0
9	66	6486	27040	12420	3860	4160	3370	3240	0	0	0	0	4	5	5859	1689	416	3454	400	0	0	0	0
9	71	5203	27050	11520	5920	2660	3650	3300	0	0	0	0	4	5	5081	1371	433	2877	400	0	0	0	0
9	56	4819	27100	10850	6260	1680	4420	3890	0	0	0	0	4	5	4723	1276	423	2631	393	0	0	0	0
9	68	5583	27150	12890	6280	1940	4250	1790	0	0	0	0	4	5	4811	1181	429	2795	406	0	0	0	0
9	58	4186	27170	11060	6050	1770	3540	4750	0	0	0	0	4	5	4069	1459	429	1781	390	0	0	0	0
9	66	5600	27250	11310	3170	4730	4520	3520	0	0	0	0	4	5	5156	1322	436	2995	403	0	0	0	0
9	65	5505	27310	11990	3210	3900	4890	3320	0	0	0	0	4	5	5152	1351	426	2972	403	0	0	0	0
9	67	5744	27390	13710	6030	1870	2940	2840	0	0	0	0	4	5	5461	1712	439	2910	400	0	0	0	0
9	66	5682	27390	10530	4750	4500	4440	3170	0	0	0	0	4	5	5238	1368	429	3031	410	0	0	0	0
9	67	5620	27420	12690	4040	4550	2590	3550	0	0	0	0	4	5	5332	1348	429	3159	396	0	0	0	0
9	31	2913	27430	7770	4290	4480	5520	5370	0	0	0	0	4	5	2697	793	600	616	888	0	0	0	0
9	61	5702	27500	10980	8250	2780	2950	2540	0	0	0	0	4	5	4872	1624	439	2516	393	0	0	0	0
9	63	5318	27520	12490	6270	2030	3840	2890	0	0	0	0	4	5	5186	1650	433	2700	403	0	0	0	0
9	65	5623	27570	6150	15440	3900	1350	730	0	0	0	0	4	5	4926	1581	400	2073	872	0	0	0	0
9	69	5334	27620	11700	5780	2880	4250	3210	0	0	0	0	4	5	5111	1519	433	2759	400	0	0	0	0
9	64	5344	27780	11420	5900	5300	2780	2740	0	0	0	0	4	5	5296	1709	419	2765	403	0	0	0	0
9	32	2463	27800	7250	5900	5110	5050	4490	0	0	0	0	4	5	5717	1328	436	3540	413	0	0	0	0
9	64	5741	27880	9870	8110	3330	4880	1590	0	0	0	0	4	5	2708	685	213	1361	449	0	0	0	0
9	37	2708	27970	10330	5420	3460	4300	4460	0	0	0	0	4	5	6294	1883	429	2972	1010	0	0	0	0
9	58	6653	28000	11180	5620	4550	3300	3350	0	0	0	0	4	5	6025	1919	426	3280	400	0	0	0	0
9	74	6604	28070	8450	7600	2610	4410	5000	0	0	0	0	4	5	5270	1318	426	3116	410	0	0	0	0
9	59	6030	28090	11560	6220	3510	4950	1850	0	0	0	0	4	5									

Vehicle Class (Scheme "F") Code	Speed of Vehicle (in mi/hr)	Length of Vehicle Bumper to Bumper	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Numb er of Axles	Wheel base distance from first axle (in ft)	Axle 1 (formal name)	Axle 2 (formal name)	Axle 3 (formal name)	Axle 4 (formal name)	Axle 5 (formal name)	Axle 6 (formal name)	Axle 7 (formal name)	Axle 8 (formal name)	Axle 9 (formal name)
9 64	5849	30610	10340	8560	2550	5660	3500	0	0	0	0	0	4	5	5753	1430	433	3494	396	0	0	0	0
9 68	5908	31930	12230	6650	3000	6050	4000	0	0	0	0	0	4	5	5448	1660	426	2969	393	0	0	0	0
9 66	5974	31940	11930	5200	5640	3840	5330	0	0	0	0	0	4	5	5535	1341	429	2965	800	0	0	0	0
9 61	5902	31980	12500	5410	5900	3140	5030	0	0	0	0	0	4	5	5506	1348	426	2929	803	0	0	0	0
9 66	6217	32000	12670	6150	6230	2890	4060	0	0	0	0	0	4	5	5776	1601	426	2946	803	0	0	0	0
9 76	6233	32020	6920	5060	8420	6600	5020	0	0	0	0	0	4	5	5887	1663	439	3369	416	0	0	0	0
9 62	5705	32050	13620	5860	1830	5140	5600	0	0	0	0	0	4	5	5113	1637	426	2660	390	0	0	0	0
9 56	6532	32120	14210	5160	5080	3670	4000	0	0	0	0	0	4	5	6065	1702	423	3133	807	0	0	0	0
9 66	5482	32160	15210	5620	6150	1910	3270	0	0	0	0	0	4	5	5106	1233	436	3047	390	0	0	0	0
9 57	6509	32180	12530	7140	2640	7460	2410	0	0	0	0	0	4	5	5739	1722	423	3188	406	0	0	0	0
9 62	6456	32240	11760	7150	7290	2980	3060	0	0	0	0	0	4	5	5663	1692	419	3156	396	0	0	0	0
9 64	5836	32250	10640	8810	2800	6120	3880	0	0	0	0	0	4	5	5723	1423	439	3471	390	0	0	0	0
9 60	6505	32270	10360	5440	4780	5830	5860	0	0	0	0	0	4	5	5460	1354	436	3264	406	0	0	0	0
9 58	5790	32330	12380	5220	6670	2870	5190	0	0	0	0	0	4	5	5388	1354	429	3202	403	0	0	0	0
9 67	6056	32390	11830	5130	5430	4970	5030	0	0	0	0	0	4	5	5572	1696	429	3044	403	0	0	0	0
9 36	2695	32400	11480	6930	5710	4000	4280	0	0	0	0	0	4	5	2695	682	213	1351	449	0	0	0	0
9 58	6630	32430	12780	5920	5060	4990	3680	0	0	0	0	0	4	5	5339	1341	429	3156	413	0	0	0	0
9 64	5360	32430	13800	5000	5590	3770	4270	0	0	0	0	0	4	5	4958	1341	429	2785	403	0	0	0	0
9 38	2691	37450	10280	8820	37450	3360	6000	0	0	0	0	0	4	5	2691	770	206	1515	200	0	0	0	0
9 67	5941	37470	13730	6320	6750	5250	5420	0	0	0	0	0	4	5	5474	1358	462	3228	426	0	0	0	0
9 69	5790	37560	12980	7110	9010	4710	3750	0	0	0	0	0	4	5	5451	1581	433	3024	413	0	0	0	0
9 60	6860	37560	15550	5770	6970	4370	4900	0	0	0	0	0	4	5	5323	1128	423	3369	403	0	0	0	0
9 72	6456	37570	13530	5450	5700	6600	6290	0	0	0	0	0	4	5	5492	1505	429	3152	406	0	0	0	0
9 62	6686	37590	14460	5800	6550	5100	5680	0	0	0	0	0	4	5	5258	1079	433	3346	400	0	0	0	0
9 67	6535	37610	14040	6130	5590	5470	6380	0	0	0	0	0	4	5	5182	1368	429	2979	406	0	0	0	0
9 60	5685	37660	14590	8140	6800	4500	3630	0	0	0	0	0	4	5	6327	1584	459	3205	1079	0	0	0	0
9 68	6886	37680	12900	9660	6540	4370	4210	0	0	0	0	0	4	5	6111	1729	423	3054	905	0	0	0	0
9 64	6561	37710	14640	6890	7400	3610	5170	0	0	0	0	0	4	5	5093	1555	426	2706	406	0	0	0	0
9 68	5597	37720	14700	6530	7630	5040	3820	0	0	0	0	0	4	5	5352	1656	426	2860	410	0	0	0	0
9 57	5646	37760	10620	10160	7490	3980	5510	0	0	0	0	0	4	5	5603	1729	426	4045	403	0	0	0	0
9 73	6345	37770	14390	6260	6050	5200	5870	0	0	0	0	0	4	5	5603	1729	426	4045	403	0	0	0	0
9 65	7001	37780	9160	9390	9160	4920	5150	0	0	0	0	0	4	5	5260	1148	419	3300	393	0	0	0	0
9 67	5505	37790	12120	8760	8690	3300	4920	0	0	0	0	0	4	5	5573	1351	433	3379	410	0	0	0	0
9 60	6594	37840	12320	6980	7060	7100	4380	0	0	0	0	0	4	5	5467	1348	429	3277	413	0	0	0	0
9 61	6489	37850	11630	7020	7030	7160	5010	0	0	0	0	0	4	5	5770	2034	446	2864	426	0	0	0	0
9 76	5984	37870	9640	5470	10500	5120	7140	0	0	0	0	0	4	5	5372	1158	416	3398	400	0	0	0	0
9 62	5590	37890	11250	8930	8950	3920	4840	0	0	0	0	0	4	5	5519	1341	439	3343	396	0	0	0	0
9 61	6692	37910	13560	7250	7440	4400	5260	0	0	0	0	0	4	5	5355	1138	426	3385	406	0	0	0	0
9 66	6374	37940	15260	6100	6770	5970	3840	0	0	0	0	0	4	5	5908	1683	436	3402	387	0	0	0	0
9 76	6482	37940	13150	8090	8190	4390	4120	0	0	0	0	0	4	5	5946	1827	426	2703	990	0	0	0	0
9 70	6105	37940	13570	6660	6000	5730	5980	0	0	0	0	0	4	5	6720	1855	429	3326	1010	0	0	0	0
9 66	7145	37950	13490	8230	6990	4570	4670	0	0	0	0	0	4	5	2886	872	213	1601	200	0	0	0	0
9 33	2998	37970	14090	7230	6840	5030	4780	0	0	0	0	0	4	5	5503	1348	423	2919	813	0	0	0	0
9 60	5958	37970	15040	6100	7210	4550	5070	0	0	0	0	0	4	5	5378	1761	416	2791	410	0	0	0	0
9 63	6459	37970	11800	12450	4270	4240	5210	0	0	0	0	0	4	5	5005	1410	426	2769	400	0	0	0	0
9 70	5698	37990	15250	8360	8800	4260	1320	0	0	0	0	0	4	5	5005	1410	426	2769	400	0	0	0	0
9 57	5879	38000	10140	8180	7340	5960	6380	0	0	0	0	0	4	5	4204	1351	436	2017	400	0	0	0	0
9 68	4537	38000	13290	8110	7190	5090	4320	0	0	0	0	0	4	5	2013	935	209	669	200	0	0	0	0
9 37	2013	38020	13990	7960	5730	4750	5590	0	0	0	0	0	4	5	5592	1528	426	3228	410	0	0	0	0
9 68	6683	38020	11720	5840	7290	6460	6710	0	0	0	0	0	4	5	3164	1043	426	1292	403	0	0	0	0
9 64	3435	38030	12760	4190	10010	8230	2840	0	0	0	0	0	4	5	5136	1089	426	3234	387	0	0	0	0
9 65	5472	38030	11380	8370	8110	4870	5300	0	0	0	0	0	4	5	5330	1341	433	3156	400	0	0	0	0
9 61	5695	38050	15110	7490	6280	4030	5140	0	0	0	0	0	4	5	5119	1148	429	3146	396	0	0	0	0
9 60	5449	38080	12370	8720	3500	5950	7540	0	0	0	0	0	4	5	5847	1774	426	3251	396	0	0	0	0
9 64	6597	38130	12720	8230	4800	6230	6150	0	0	0	0	0	4	5	5057	1092	423	3139	403	0	0	0	0
9 72	6123	38140	14250	5850	6440	6490	5110	0	0	0	0	0	4	5									

Vehicle Class (Scheme "F") Code	Speed of Vehicle (in mi/hr)	Length of Vehicle From Bumper to Bumper	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Num ber of Axles	Wheel base distance from first axle (in ft)	Axle 1 Weight (in lbs)	Axle 2 Weight (in lbs)	Axle 3 Weight (in lbs)	Axle 4 Weight (in lbs)	Axle 5 Weight (in lbs)	Axle 6 Weight (in lbs)	Axle 7 Weight (in lbs)	Axle 8 Weight (in lbs)	Axle 9 Weight (in lbs)
9	68	6466	38140	14060	7200	7330	4360	5190	0	0	0	0	4	5	6084	1699	423	3152	810	0	0	0	0
9	66	6476	38170	14000	6450	4330	5860	7530	0	0	0	0	4	5	5267	1105	416	3343	403	0	0	0	0
9	63	5521	38180	12380	7770	2770	8440	6820	0	0	0	0	4	5	4664	1125	433	2716	390	0	0	0	0
9	66	5764	38200	14930	6220	5510	6160	5380	0	0	0	0	4	5	5166	1368	429	2956	413	0	0	0	0
9	62	6437	38210	13840	6000	5910	10570	1890	0	0	0	0	4	5	6137	1699	423	2995	1020	0	0	0	0
9	64	6886	38220	13920	5390	5740	6230	6940	0	0	0	0	4	5	5897	1699	433	3362	403	0	0	0	0
9	68	5967	38240	14240	9370	7770	3310	3550	0	0	0	0	4	5	5497	1755	419	2923	400	0	0	0	0
9	66	6427	38240	15360	6950	5960	3930	6040	0	0	0	0	4	5	5972	1617	429	3126	800	0	0	0	0
9	67	6217	38260	12910	6800	6290	5480	6780	0	0	0	0	4	5	5747	1312	410	3015	1010	0	0	0	0
9	71	4491	38260	12100	7430	8810	5030	4890	0	0	0	0	4	5	4200	1469	419	1906	406	0	0	0	0
9	64	7040	38280	15070	5990	6590	6650	3980	0	0	0	0	4	5	5845	1729	416	3290	410	0	0	0	0
9	66	5482	38280	9650	8140	7680	6750	6060	0	0	0	0	4	5	5139	931	429	3379	400	0	0	0	0
9	64	6771	49440	14540	10440	10290	7060	7110	0	0	0	0	4	5	5970	1578	433	3556	403	0	0	0	0
9	65	6807	49450	14130	10690	9450	7420	7760	0	0	0	0	4	5	5763	1624	423	3313	403	0	0	0	0
9	68	6935	49450	16690	8610	8020	8520	7610	0	0	0	0	4	5	5765	1676	429	3257	403	0	0	0	0
9	70	5577	49460	16130	8080	9250	12290	3710	0	0	0	0	4	5	5080	1745	419	1981	935	0	0	0	0
9	71	6482	49460	11870	11660	11590	10370	3970	0	0	0	0	4	5	5795	2076	423	2880	416	0	0	0	0
9	69	6574	49470	19280	9270	8030	5760	7130	0	0	0	0	4	5	6241	1725	423	3080	1013	0	0	0	0
9	75	5757	49480	16710	10740	9130	6650	6250	0	0	0	0	4	5	5404	1505	429	3064	406	0	0	0	0
9	63	6391	49480	16110	10110	9540	8020	5700	0	0	0	0	4	5	5750	1624	423	3290	413	0	0	0	0
9	65	7093	49490	18940	7180	8400	7980	8990	0	0	0	0	4	5	6058	1804	423	3431	400	0	0	0	0
9	67	6269	49520	11930	9870	8560	9590	9570	0	0	0	0	4	5	5519	1177	426	3510	406	0	0	0	0
9	35	3069	49530	12250	10900	10590	7540	8250	0	0	0	0	4	5	3069	1033	213	1627	196	0	0	0	0
9	72	6998	49530	16150	9530	8970	7460	7420	0	0	0	0	4	5	6000	1755	423	3412	410	0	0	0	0
9	37	2824	49560	16420	9650	11260	5570	6660	0	0	0	0	4	5	2824	984	213	1427	200	0	0	0	0
9	26	3082	49570	18910	10390	7750	5100	7780	0	0	0	0	4	5	3082	869	216	1492	505	0	0	0	0
9	62	6811	49580	14410	9480	10890	7050	7750	0	0	0	0	4	5	6028	1492	433	3700	403	0	0	0	0
9	32	2846	49600	15740	9150	9130	8170	7410	0	0	0	0	4	5	2846	892	209	1545	209	0	0	0	0
9	73	6591	49620	13770	8950	7920	10260	8720	0	0	0	0	4	5	5582	1689	426	3061	406	0	0	0	0
9	66	6627	49620	15440	8210	9590	8480	7600	0	0	0	0	4	5	5651	1584	423	3238	406	0	0	0	0
9	66	7283	49630	14140	10390	7510	9210	8380	0	0	0	0	4	5	6252	2096	433	3320	403	0	0	0	0
9	73	6751	49690	17500	7310	7470	7580	9830	0	0	0	0	4	5	5453	1505	419	3136	393	0	0	0	0
9	66	6692	49700	14260	9710	10180	7940	7610	0	0	0	0	4	5	5526	1115	423	3585	403	0	0	0	0
9	75	7408	49700	15050	10250	9300	6640	8460	0	0	0	0	4	5	6549	1860	442	3818	429	0	0	0	0
9	65	6715	49720	14940	9910	10300	6930	7640	0	0	0	0	4	5	5900	1499	426	3572	403	0	0	0	0
9	64	6322	49740	13040	6060	6360	10080	14200	0	0	0	0	4	5	5021	1450	426	2742	403	0	0	0	0
9	69	6108	49760	15410	9540	9780	7040	7990	0	0	0	0	4	5	5454	1722	429	2900	403	0	0	0	0
9	37	3141	49760	13140	12210	12020	5710	6680	0	0	0	0	4	5	3141	971	213	1459	498	0	0	0	0
9	61	6889	49770	15990	8780	10690	7070	7240	0	0	0	0	4	5	5956	1738	423	3395	400	0	0	0	0
9	60	4589	49780	14030	7670	9680	9520	8880	0	0	0	0	4	5	4148	2001	429	1315	403	0	0	0	0
9	63	6781	49780	16480	8860	8420	7770	8250	0	0	0	0	4	5	5740	1673	426	3238	403	0	0	0	0
9	37	2985	49810	13680	9250	8140	9910	8930	0	0	0	0	4	5	2902	853	209	1640	200	0	0	0	0
9	62	5734	49810	17340	11200	9480	6620	5170	0	0	0	0	4	5	5024	1102	433	3083	406	0	0	0	0
9	35	2598	49820	14500	9000	8230	9380	8710	0	0	0	0	4	5	2580	807	209	1361	203	0	0	0	0
9	65	6338	49820	13050	11450	11860	7110	6350	0	0	0	0	4	5	5605	1568	426	3205	406	0	0	0	0
9	65	6712	49830	15480	8750	6800	9000	9800	0	0	0	0	4	5	5539	1502	429	3205	403	0	0	0	0
9	76	7047	49840	16350	11090	11550	5780	5070	0	0	0	0	4	5	6719	2007	452	3198	1062	0	0	0	0
9	69	6354	49850	16140	11090	11210	5130	6280	0	0	0	0	4	5	5280	1837	449	2565	429	0	0	0	0
9	36	3113	49850	13450	9280	10360	8680	8080	0	0	0	0	4	5	3098	974	209	1715	200	0	0	0	0
9	72	6952	49860	6420	10860	11640	9960	10980	0	0	0	0	4	5	6045	1620	446	3566	413	0	0	0	0
9	70	6870	49860	17980	9360	9030	4610	8860	0	0	0	0	4	5	5986	1699	426	3474	387	0	0	0	0
9	34	2995	49870	15060	10140	10510	6140	8020	0	0	0	0	4	5	2905	807	213	1689	196	0	0	0	0
9	66	6771	49890	15580	7130	7250	9560	10370	0	0	0	0	4	5	5828	1719	423	3280	406	0	0	0	0
9	37	2960	49910	12840	5200	10640	10900	10330	0	0	0	0	4	5	2960	833	209	1715	203	0	0	0	0
9	68	5971	49920	14630	8690	8610	10080	7910	0	0	0	0	4	5	4995	1118	433	3038	406	0	0	0	0
9	35	2794	49920	14060	9200	10180	8080	8400	0	0	0	0	4	5	2794	813	213	1568	200	0	0	0	0

Vehicle Class (Scheme "P") Code	Speed of Vehicle (in km/h)	Length of Vehicle Bumper to Bumper	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Num ber of Axles	Wheel base (in)	Distance from first axle (in)	Axle 2 (format mm mm)	Axle 3 (format mm mm)	Axle 4 (format mm mm)	Axle 5 (format mm mm)	Axle 6 (format mm mm)	Axle 7 (format mm mm)	Axle 8 (format mm mm)	Axle 9 (format mm mm)
9 37	33	2646	49930	15680	9870	9740	7790	6850	0	0	0	0	4	5	2646	895	206	1345	200	0	0	0	0
9 33	2952	49930	13870	10940	10940	8050	8140	8930	0	0	0	0	4	5	2942	830	229	1683	200	0	0	0	0
9 36	2772	49940	13740	11630	11630	8950	6700	8920	0	0	0	0	4	5	2620	705	213	1502	200	0	0	0	0
9 35	3061	49940	13550	10160	10870	7560	7800	8920	0	0	0	0	4	5	3025	977	209	1643	196	0	0	0	0
9 68	6860	49970	16230	8670	8360	7860	8850	8850	0	0	0	0	4	5	6127	1735	436	3553	403	0	0	0	0
9 66	6902	49990	16100	8760	8760	10000	6830	8300	0	0	0	0	4	5	5661	1673	423	3162	403	0	0	0	0
9 77	6981	49990	13260	7230	7230	6530	10760	12210	0	0	0	0	4	5	5752	1715	472	3139	426	0	0	0	0
9 30	2651	49990	17910	10270	9640	6640	5530	0	0	0	0	0	4	5	2651	846	209	1400	196	0	0	0	0
9 62	7073	50020	18660	8900	8750	7730	5980	0	0	0	0	0	4	5	5921	1719	426	3366	410	0	0	0	0
9 69	6784	50050	16010	7630	9030	9240	8140	0	0	0	0	0	4	5	5962	1656	419	3487	400	0	0	0	0
9 67	6932	50050	15810	11230	10520	5580	6910	0	0	0	0	0	4	5	6612	1958	439	3208	1007	0	0	0	0
9 36	3123	50060	13600	10400	10620	8710	6730	0	0	0	0	0	4	5	3039	997	209	1630	203	0	0	0	0
9 64	6653	50070	16750	10150	9020	6490	7660	0	0	0	0	0	4	5	5881	1965	436	3074	406	0	0	0	0
9 35	3169	50080	13800	10600	8520	8620	8540	0	0	0	0	0	4	5	3020	869	209	1742	200	0	0	0	0
9 71	7053	50120	17500	7420	10010	7350	7840	0	0	0	0	0	4	5	5995	1843	426	3233	403	0	0	0	0
9 64	5633	50120	14000	7240	8490	10390	10000	0	0	0	0	0	4	5	4493	1227	423	2440	403	0	0	0	0
9 81	6935	50140	17630	7330	9140	6610	9430	0	0	0	0	0	4	5	5979	1801	423	3349	406	0	0	0	0
9 64	7103	50220	17110	9590	8730	6390	8400	0	0	0	0	0	4	5	6097	1965	426	3303	403	0	0	0	0
9 78	5872	50230	15290	7290	8460	6410	8850	12390	0	0	0	0	4	5	4761	1013	416	2929	403	0	0	0	0
9 73	6961	50250	18230	8460	9350	7320	6890	0	0	0	0	0	4	5	5924	1778	423	3313	410	0	0	0	0
9 66	6286	50270	12590	12970	5340	10130	9240	0	0	0	0	0	4	5	5474	1020	436	3612	406	0	0	0	0
9 32	2895	50270	11870	9420	12830	8480	7670	0	0	0	0	0	4	5	5126	1384	426	2906	410	0	0	0	0
9 65	5725	50270	19080	10700	9170	5640	5680	0	0	0	0	0	4	5	2862	856	209	1601	196	0	0	0	0
9 35	2862	50270	6290	11650	11720	9670	10940	0	0	0	0	0	4	5	2720	862	209	1446	203	0	0	0	0
9 34	2720	50290	17590	10710	10330	6480	5180	0	0	0	0	0	4	5	5405	1650	436	2906	413	0	0	0	0
9 64	6085	50300	10420	13650	5060	14890	6280	0	0	0	0	0	4	5	5901	1673	436	3389	403	0	0	0	0
9 63	5751	50310	14080	11320	11200	9650	7060	0	0	0	0	0	4	5	5375	1213	433	3326	403	0	0	0	0
9 71	6801	50310	14860	10730	8880	8530	7310	0	0	0	0	0	4	5	5949	1692	426	3428	403	0	0	0	0
9 62	6807	50320	17170	7950	9770	7690	7740	0	0	0	0	0	4	5	2849	849	209	1391	200	0	0	0	0
9 33	2649	50330	14950	11010	11420	6540	6410	0	0	0	0	0	4	5	2928	877	213	1548	190	0	0	0	0
9 36	2928	50330	11730	10010	10310	9400	8880	0	0	0	0	0	4	5	5983	1709	433	3438	403	0	0	0	0
9 80	6932	50340	16710	10400	9260	5390	8580	0	0	0	0	0	4	5	6149	1811	429	3503	406	0	0	0	0
9 62	7011	50350	16270	9930	8510	7760	7880	0	0	0	0	0	4	5	2806	790	209	1614	193	0	0	0	0
9 37	2806	50350	14970	11140	10630	6670	6940	0	0	0	0	0	4	5	2849	990	209	1450	200	0	0	0	0
9 35	2849	50360	13450	10030	10860	7660	8360	0	0	0	0	0	4	5	5710	1840	423	3051	396	0	0	0	0
9 67	6935	50370	15010	8800	8400	8540	9620	0	0	0	0	0	4	5	2846	826	213	1607	200	0	0	0	0
9 62	6381	50380	17860	11300	9690	6210	5320	0	0	0	0	0	4	5	5743	1709	426	3198	410	0	0	0	0
9 39	3028	50380	13400	9840	7670	10000	9470	0	0	0	0	0	4	5	2846	826	213	1607	200	0	0	0	0
9 33	2979	50400	15610	8400	9110	7460	9820	0	0	0	0	0	4	5	2830	866	213	1558	193	0	0	0	0
9 66	6482	50420	13700	11400	11280	8550	5490	0	0	0	0	0	4	5	5558	1722	419	3011	406	0	0	0	0
9 76	6356	50420	16050	7870	8550	9740	8210	0	0	0	0	0	4	5	5329	1174	433	3316	406	0	0	0	0
9 64	5751	50420	13630	11090	10790	7630	7280	0	0	0	0	0	4	5	6540	2004	426	3093	1017	0	0	0	0
9 70	6650	50420	17030	8700	8700	7020	8070	9600	0	0	0	0	4	5	6113	1984	429	3290	410	0	0	0	0
9 65	6879	50430	16500	10070	11190	5850	8820	0	0	0	0	0	4	5	2479	744	213	1309	213	0	0	0	0
9 69	6666	50440	16770	10620	10600	5310	7140	0	0	0	0	0	4	5	2454	777	209	1272	196	0	0	0	0
9 70	7158	50450	13930	9400	11030	8100	7990	0	0	0	0	0	4	5	2952	830	216	1706	200	0	0	0	0
9 31	2479	50460	12430	9730	10190	9650	8460	0	0	0	0	0	4	5	2977	856	209	1712	200	0	0	0	0
9 33	2703	50460	13650	9090	9770	7070	10880	0	0	0	0	0	4	5	2522	777	209	1272	196	0	0	0	0
9 34	2975	50470	7990	10670	13600	9390	8820	0	0	0	0	0	4	5	2952	830	216	1706	200	0	0	0	0
9 36	2977	50470	15710	10080	9740	7880	7060	0	0	0	0	0	4	5	2977	856	209	1712	200	0	0	0	0
9 67	7043	50470	14270	9640	12670	8270	5620	0	0	0	0	0	4	5	6259	1975	423	3451	410	0	0	0	0
9 68	6935	50490	16440	9310	9390	6570	8780	0	0	0	0	0	4	5	5899	1738	419	3336	406	0	0	0	0
9 65	6873	50500	17790	11100	11330	5690	4590	0	0	0	0	0	4	5	5919	1564	423	3526	406	0	0	0	0
9 35	2709	50510	13000	11330	10450	7460	8270	0	0	0	0	0	4	5	6117	1640	449	3605	423	0	0	0	0
9 74	7230	50540	15210	6510	12530	8030	8260	0	0	0	0	0	4	5	2797	974	213	1410	200	0	0	0	0
9 33	2797	50540	14840	9910	10720	6350	8720	0	0	0	0	0	4	5	2797	974	213	1410	200	0	0	0	0

Vehicle Class (Scheme "P") Code	Speed of Vehicle (in km/h)	Length of Vehicle From Bumper to Bumper (in mm)	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Num ber of Axles	Wheel base distance from first axle (in mm)	Axle 1 (formal mm)	Axle 2 (formal mm)	Axle 3 (formal mm)	Axle 4 (formal mm)	Axle 5 (formal mm)	Axle 6 (formal mm)	Axle 7 (formal mm)	Axle 8 (formal mm)	Axle 9 (formal mm)
9 36	2721	50560	15340	10330	9240	8580	7070	0	0	0	0	4	5	2721	856	213	1446	206	0	0	0	0
9 64	50560	17290	9930	8710	4680	0	0	0	0	0	0	4	5	5972	1676	429	3454	413	0	0	0	0
9 34	3011	50560	13450	8840	8830	9760	9680	0	0	0	0	4	5	2931	875	206	1650	200	0	0	0	0
9 71	6866	50570	16250	10440	6840	9190	8760	0	0	0	0	4	5	5802	1725	429	3238	410	0	0	0	0
9 35	3011	50580	12400	8560	11730	9600	8290	0	0	0	0	4	5	2938	846	206	1683	203	0	0	0	0
9 62	7227	50590	15200	9240	8740	8910	8500	0	0	0	0	4	5	6038	2001	429	3198	410	0	0	0	0
9 70	6391	50590	17410	9320	10960	5940	6960	0	0	0	0	4	5	5424	1696	429	2903	396	0	0	0	0
9 64	6315	50590	14640	10290	10770	8500	6390	0	0	0	0	4	5	5615	1174	428	3612	403	0	0	0	0
9 35	2716	50620	11070	11080	8100	10750	9620	0	0	0	0	4	5	6097	1706	429	3559	403	0	0	0	0
9 57	7024	50620	16560	12960	10750	3550	6800	0	0	0	0	4	5	5972	1587	429	3546	410	0	0	0	0
9 69	7171	50640	15340	10110	10840	6170	8180	0	0	0	0	4	5	5984	1774	429	3385	396	0	0	0	0
9 69	6945	50640	16530	7020	6650	10230	10210	0	0	0	0	4	5	5972	1587	429	3546	410	0	0	0	0
9 36	2747	50660	12900	10540	9400	9590	8230	0	0	0	0	4	5	2747	856	209	1482	200	0	0	0	0
9 74	7198	50660	14810	10070	9420	8650	7710	0	0	0	0	4	5	5844	1781	449	3195	419	0	0	0	0
9 66	6046	50670	15310	11760	12330	4890	6580	0	0	0	0	4	5	5086	1292	429	2858	406	0	0	0	0
9 67	6404	50680	14400	7510	6590	11260	10920	0	0	0	0	4	5	5569	1755	426	2988	400	0	0	0	0
9 69	7129	50700	17150	10440	10200	6070	6840	0	0	0	0	4	5	6024	1807	419	3392	406	0	0	0	0
9 35	38750	50710	11410	8330	13070	9530	8370	0	0	0	0	4	5	3046	787	209	1545	505	0	0	0	0
9 32	3054	50730	8500	12350	10700	10750	8430	0	0	0	0	4	5	3053	1017	209	1624	203	0	0	0	0
9 34	2860	50730	11070	11110	11380	8450	8720	0	0	0	0	4	5	2860	810	213	1637	200	0	0	0	0
9 73	4931	50740	20350	8020	9440	3110	9820	0	0	0	0	4	5	4222	1640	436	2050	396	0	0	0	0
9 67	6853	50740	16540	10440	11040	5880	7040	0	0	0	0	4	5	5458	1965	433	3047	1013	0	0	0	0
9 70	5912	50750	18180	11670	10780	6540	3580	0	0	0	0	4	5	5460	1738	423	2883	416	0	0	0	0
9 78	7519	50770	15890	9570	10220	6730	8360	0	0	0	0	4	5	6412	1896	449	3638	429	0	0	0	0
9 69	5872	50780	13830	7190	15250	7920	6590	0	0	0	0	4	5	5455	1706	433	2910	406	0	0	0	0
9 64	7030	50790	14570	10750	9390	7180	8900	0	0	0	0	4	5	5917	1719	423	3372	403	0	0	0	0
9 37	2982	50790	12080	12000	11300	7960	7180	0	0	0	0	4	5	2941	849	209	1683	200	0	0	0	0
9 66	6843	50840	15110	10200	9300	8310	7920	0	0	0	0	4	5	6051	1683	429	3533	406	0	0	0	0
9 34	3034	50850	12770	10530	12520	7410	7620	0	0	0	0	4	5	2908	816	213	1679	200	0	0	0	0
9 76	7043	50860	16180	9330	7950	8860	8540	0	0	0	0	4	5	6098	1919	423	3346	410	0	0	0	0
9 61	7014	50860	16010	11730	10720	6120	6280	0	0	0	0	4	5	5940	1811	488	3231	410	0	0	0	0
9 64	6998	50880	15210	8550	9320	8020	9780	0	0	0	0	4	5	5992	1729	419	3438	406	0	0	0	0
9 61	5830	50880	14540	13350	10610	5950	6430	0	0	0	0	4	5	5884	1807	423	3254	400	0	0	0	0
9 65	7103	50900	15510	9780	11190	8540	5780	0	0	0	0	4	5	6291	1975	449	3454	413	0	0	0	0
9 66	7022	50910	18760	13340	4560	9450	4800	0	0	0	0	4	5	5316	1233	426	3251	406	0	0	0	0
9 36	3030	50920	12710	9780	10400	9170	8860	0	0	0	0	4	5	6078	1761	423	3494	400	0	0	0	0
9 74	6879	50940	15130	9590	10240	8910	7070	0	0	0	0	4	5	5759	1722	423	3211	403	0	0	0	0
9 70	6361	50940	16640	10930	10710	5830	6830	0	0	0	0	4	5	6001	1686	419	3490	406	0	0	0	0
9 51	5403	50970	19800	10610	11390	5550	3620	0	0	0	0	4	5	4328	1492	439	1994	403	0	0	0	0
9 70	6965	50980	15760	8310	10370	8910	7630	0	0	0	0	4	5	5316	1233	426	3251	406	0	0	0	0
9 66	6427	50990	16720	7560	8350	9130	9230	0	0	0	0	4	5	5861	1679	423	3356	403	0	0	0	0
9 65	7096	51000	15310	8610	9130	8430	9520	0	0	0	0	4	5	2921	849	209	1663	200	0	0	0	0
9 32	2988	51040	19070	10420	10220	4500	5830	0	0	0	0	4	5	2708	895	206	1407	200	0	0	0	0
9 34	2708	51070	14130	10930	11180	6210	8620	0	0	0	0	4	5	3029	921	216	1692	200	0	0	0	0
9 32	3031	51080	14360	12540	10930	4910	6790	0	0	0	0	4	5	2767	856	209	1499	203	0	0	0	0
9 35	2992	51100	15260	10920	10330	7680	6910	0	0	0	0	4	5	5368	1528	446	3011	403	0	0	0	0
9 58	5741	51150	17160	10590	10860	6390	6150	0	0	0	0	4	5	6189	1755	426	2995	1013	0	0	0	0
9 75	6538	51170	18140	8660	9780	7770	6820	0	0	0	0	4	5	5418	1325	456	3241	396	0	0	0	0
9 64	5908	51180	16690	11580	9900	6140	6870	0	0	0	0	4	5	6386	1876	429	3064	1017	0	0	0	0
9 66	6788	51180	16270	10750	10570	9020	4570	0	0	0	0	4	5	2964	879	209	1676	200	0	0	0	0
9 36	3067	51190	13850	10440	9930	8070	8900	0	0	0	0	4	5	5776	1568	423	3379	406	0	0	0	0
9 65	6807	51200	17300	9780	9960	7340	6820	0	0	0	0	4	5	2964	879	209	1676	200	0	0	0	0
9 63	6364	51210	15080	11370	10880	5480	8400	0	0	0	0	4	5	5976	1610	433	3123	810	0	0	0	0
9 33	3021	51230	14660	9360	10000	8370	8840	0	0	0	0	4	5	2998	889	203	1706	200	0	0	0	0
9 60	6873	51240	11890	9830	10280	10710	8530	0	0	0	0	4	5	6035	1514	423	3595	403	0	0	0	0
9 69	5590	51250	14840	11610	11190	5810	7800	0	0	0	0	4	5	5087	1151	449	3064	423	0	0	0	0

Vehicle Class (Scheme 1P) Code	Speed of Vehicle (in mi/hr)	Length of Vehicle Bumper to Bumper (in)	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Num of Axles	Wheel base (in)	Distance from first axle (in)	Axle 1 Weight (in lbs)	Axle 2 Weight (in lbs)	Axle 3 Weight (in lbs)	Axle 4 Weight (in lbs)	Axle 5 Weight (in lbs)	Axle 6 Weight (in lbs)	Axle 7 Weight (in lbs)	Axle 8 Weight (in lbs)	Axle 9 Weight (in lbs)
9	68	6843	51250	14860	10040	9640	8990	7720	0	0	0	0	4	5	5929	1610	436	3480	403	0	0	0	0	0
9	70	6824	51250	16800	7900	8270	9430	8850	0	0	0	0	4	5	5535	1715	419	2995	406	0	0	0	0	0
9	36	2937	51260	13470	11640	11510	6750	7890	0	0	0	0	4	5	2937	990	213	1538	196	0	0	0	0	0
9	32	2946	51260	12880	11730	10540	7400	8710	0	0	0	0	4	5	2884	764	209	1715	196	0	0	0	0	0
9	71	5731	51290	15540	12030	11970	6350	5400	0	0	0	0	4	5	5444	1725	426	2893	400	0	0	0	0	0
9	34	2847	51300	12620	9970	7990	9850	10870	0	0	0	0	4	5	2839	892	209	1538	200	0	0	0	0	0
9	34	2335	51330	16410	9320	10840	7080	7680	0	0	0	0	4	5	2328	688	213	1227	200	0	0	0	0	0
9	69	6433	51330	12350	11860	12150	11650	3320	0	0	0	0	4	5	6018	1706	419	3474	419	0	0	0	0	0
9	31	2754	51350	14530	10050	11340	8820	8610	0	0	0	0	4	5	5231	1135	419	3274	403	0	0	0	0	0
9	64	5912	51370	15180	9720	12360	8640	5470	0	0	0	0	4	5	6402	1856	446	3671	429	0	0	0	0	0
9	65	7437	51380	16080	10640	8380	7720	8560	0	0	0	0	4	5	2786	803	209	1571	203	0	0	0	0	0
9	35	2786	51380	13330	10310	11120	8420	8200	0	0	0	0	4	5	5759	1650	426	3280	403	0	0	0	0	0
9	63	7050	51390	18470	10690	9840	7680	5630	0	0	0	0	4	5	3965	1158	456	1909	442	0	0	0	0	0
9	73	4274	51390	16810	10040	10250	7840	6450	0	0	0	0	4	5	5303	1686	426	2778	413	0	0	0	0	0
9	74	6453	51390	15370	9780	8760	9420	8060	0	0	0	0	4	5	5969	1784	423	3359	403	0	0	0	0	0
9	70	6909	51400	17400	10400	10100	6850	7830	0	0	0	0	4	5	2738	744	213	1581	200	0	0	0	0	0
9	37	2887	51410	12780	12110	11430	7770	7320	0	0	0	0	4	5	6226	1876	433	3517	400	0	0	0	0	0
9	70	7011	51410	13840	10600	10210	7670	9090	0	0	0	0	4	5	2662	790	209	1463	200	0	0	0	0	0
9	33	2662	51420	13010	11580	11190	7810	7830	0	0	0	0	4	5	2977	820	219	1738	200	0	0	0	0	0
9	34	2977	51430	13320	12630	11350	6540	7590	0	0	0	0	4	5	5231	1548	436	2834	413	0	0	0	0	0
9	76	5875	51440	5240	11220	10380	12260	12340	0	0	0	0	4	5	6334	2139	459	3310	426	0	0	0	0	0
9	34	2939	51450	11540	10080	10100	9150	10580	0	0	0	0	4	5	2849	853	209	1591	196	0	0	0	0	0
9	70	7634	51450	15650	10410	9340	7170	8880	0	0	0	0	4	5	5120	1135	436	3143	406	0	0	0	0	0
9	64	5984	51460	16060	9490	8020	10090	7800	0	0	0	0	4	5	6278	1968	429	3471	410	0	0	0	0	0
9	73	7198	51460	14170	10420	10280	7740	8850	0	0	0	0	4	5	5304	1122	433	3343	406	0	0	0	0	0
9	65	5905	51460	15330	11540	10240	8200	6150	0	0	0	0	4	5	5674	1545	429	3297	403	0	0	0	0	0
9	70	6896	51500	17860	10050	7400	7840	8350	0	0	0	0	4	5	2745	682	213	1650	200	0	0	0	0	0
9	66	6318	51520	17230	8510	9150	8080	8550	0	0	0	0	4	5	5655	1601	426	3218	410	0	0	0	0	0
9	34	2745	51520	14270	9520	10180	9150	8400	0	0	0	0	4	5	2944	787	216	1748	193	0	0	0	0	0
9	37	3080	51520	10760	10320	9850	10350	10440	0	0	0	0	4	5	5860	1702	419	3339	400	0	0	0	0	0
9	65	6919	51530	14420	9080	10180	9260	8590	0	0	0	0	4	5	5854	1719	426	3303	406	0	0	0	0	0
9	67	6971	51540	17080	7550	6870	9550	10490	0	0	0	0	4	5	5884	1660	426	3398	400	0	0	0	0	0
9	71	6784	51550	16050	9180	10410	6650	9260	0	0	0	0	4	5	6228	1958	423	3444	403	0	0	0	0	0
9	65	7073	51590	15470	11170	8930	8160	7860	0	0	0	0	4	5	5271	1171	433	3264	403	0	0	0	0	0
9	66	6335	51590	14180	11290	10440	6920	8760	0	0	0	0	4	5	3203	1000	209	1496	498	0	0	0	0	0
9	39	3203	51600	12070	12950	12850	7340	6590	0	0	0	0	4	5	4884	1017	423	2844	400	0	0	0	0	0
9	60	6509	51620	11170	12840	12200	7150	8260	0	0	0	0	4	5	5860	1702	419	3339	400	0	0	0	0	0
9	64	5016	51630	13980	10210	10190	9750	7500	0	0	0	0	4	5	5627	1184	429	3608	406	0	0	0	0	0
9	64	6276	51650	18580	9280	10050	6890	8850	0	0	0	0	4	5	2455	606	209	1440	200	0	0	0	0	0
9	35	2578	51650	13870	11150	10580	7510	8540	0	0	0	0	4	5	6034	1574	426	3638	396	0	0	0	0	0
9	66	6456	51650	15650	12700	12880	5070	5550	0	0	0	0	4	5	5674	1601	426	3241	406	0	0	0	0	0
9	65	6715	51660	18270	9170	10150	8040	6030	0	0	0	0	4	5	2896	679	200	1817	200	0	0	0	0	0
9	32	2896	51660	12630	9410	13140	8480	8000	0	0	0	0	4	5	2812	895	209	1512	196	0	0	0	0	0
9	36	2812	51670	10120	11940	13440	10840	5330	0	0	0	0	4	5	6448	1610	436	3904	498	0	0	0	0	0
9	36	2933	51670	13270	8910	11740	10490	7260	0	0	0	0	4	5	5971	1761	419	3398	393	0	0	0	0	0
9	67	7260	51680	16850	9400	11320	7080	7030	0	0	0	0	4	5	5303	1128	426	3343	406	0	0	0	0	0
9	67	6482	51680	20570	8690	8030	7400	6990	0	0	0	0	4	5	5943	1719	423	3395	406	0	0	0	0	0
9	68	5833	51690	15660	10250	10120	9470	6190	0	0	0	0	4	5	6032	1660	429	3540	403	0	0	0	0	0
9	66	6843	51690	13390	10200	9020	9870	9210	0	0	0	0	4	5	5863	1541	429	3310	403	0	0	0	0	0
9	69	6870	51690	16980	11260	12780	6930	9420	0	0	0	0	4	5	2649	803	216	1430	200	0	0	0	0	0
9	66	6827	51690	16480	10680	8180	6900	4670	0	0	0	0	4	5	5960	1702	433	3425	400	0	0	0	0	0
9	34	2649	51700	15140	10380	10410	8400	7370	0	0	0	0	4	5	6784	2070	456	3182	1076	0	0	0	0	0
9	66	7096	51710	16540	8780	8420	8810	9160	0	0	0	0	4	5	6054	1784	423	3444	403	0	0	0	0	0
9	67	6217	51720	16390	10060	11090	8100	6080	0	0	0	0	4	5	5860	1702	433	3425	400	0	0	0	0	0
9	77	7322	51730	18720	11230	9430	6080	6270	0	0	0	0	4	5	6054	1784	423	3444	403	0	0	0	0	0
9	64	6991	51740	15390	10100	10420	9020	6810	0	0	0	0	4	5										

Vehicle Class (Scheme "F") Code	Speed of Vehicle (in km/h)	Length of Vehicle From Rear Bumper (in mm)	Gross Weight of Vehicle (in lbs)	Total Axle 1 Total Axle 2 Total Axle 3 Total Axle 4 Total Axle 5 Total Axle 6 Total Axle 7 Total Axle 8 Total Axle 9 Num ber of Axles										Axle 1- 2 from first base distance										Axle 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872 873 874 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889 890 891 892 893 894 895 896 897 898 899 900 901 902 903 904 905 906 907 908 909 910 911 912 913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930 931 932 933 934 935 936 937 938 939 940 941 942 943 944 945 946 947 948 949 950 951 952 953 954 955 956 957 958 959 960 961 962 963 964 965 966 967 968 969 970 971 972 973 974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992 993 994 995 996 997 998 999 1000
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Vehicle Class (Scheme "P") Code	Speed of Vehicle (in m.p.h.)	Length of Vehicle From Bumper to Bumper	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Num ber of Axles	Wheel base - from first axle to last axle (in inches)	Axle 2 (format axle num over axle num)	Axle 3 (format axle num over axle num)	Axle 4 (format axle num over axle num)	Axle 5 (format axle num over axle num)	Axle 6 (format axle num over axle num)	Axle 7 (format axle num over axle num)	Axle 8 (format axle num over axle num)	Axle 9 (format axle num over axle num)
9 32	2985	52800	15700	9710	10140	8340	8910	0	0	0	0	0	4	5	2812	764	209	1643	196	0	0	0
9 35	2995	52810	15440	12760	12910	7020	4680	0	0	0	0	0	4	5	2914	882	209	1627	196	0	0	0
9 35	2972	52830	13330	11030	10010	9280	9180	0	0	0	0	0	4	5	2869	787	209	1673	200	0	0	0
9 65	7096	52860	15270	12100	13020	7850	4820	0	0	0	0	0	4	5	6008	1794	423	3385	406	0	0	0
9 75	6496	52860	17110	8400	8120	9120	10110	0	0	0	0	0	4	5	5655	1414	426	3415	400	0	0	0
9 66	6587	52860	16150	8680	10600	9210	8220	0	0	0	0	0	4	5	5631	1437	426	3362	406	0	0	0
9 32	2721	52870	14200	11630	10690	10010	6340	0	0	0	0	0	4	5	2721	889	209	1423	200	0	0	0
9 29	2939	52880	5700	12230	13520	11180	10250	0	0	0	0	0	4	5	2899	853	206	1637	203	0	0	0
9 65	5879	52900	13920	8660	9000	10460	10860	0	0	0	0	0	4	5	5242	1135	423	3274	410	0	0	0
9 33	3008	52910	14050	9760	10500	8990	9810	0	0	0	0	0	4	5	2871	892	209	1574	196	0	0	0
9 84	7329	52910	17570	10010	11460	7120	6750	0	0	0	0	0	4	5	6264	1817	446	3572	429	0	0	0
9 33	2858	52920	14840	10620	10670	7480	9310	0	0	0	0	0	4	5	2858	862	209	1587	200	0	0	0
9 34	2816	52950	11510	12060	10890	9050	9440	0	0	0	0	0	4	5	2816	623	209	1784	200	0	0	0
9 61	7165	52950	18090	11140	11120	6080	6520	0	0	0	0	0	4	5	6206	2057	433	3313	403	0	0	0
9 62	6371	52960	18870	11430	9810	6600	6250	0	0	0	0	0	4	5	5533	1584	429	3120	400	0	0	0
9 65	6358	52960	11560	11250	10830	13070	12620	0	0	0	0	0	4	5	5772	1666	439	3264	403	0	0	0
9 76	6853	52970	16310	10540	10830	7880	7410	0	0	0	0	0	4	5	5687	1669	456	3136	426	0	0	0
9 64	6459	52980	16950	9450	9500	9360	7720	0	0	0	0	0	4	5	5038	1568	426	2641	403	0	0	0
9 76	6686	52990	14470	11430	8130	9520	9440	0	0	0	0	0	4	5	5818	1584	426	3402	406	0	0	0
9 66	6896	53000	19920	8570	7090	10100	7320	0	0	0	0	0	4	5	5825	1732	429	3254	410	0	0	0
9 68	6837	53000	17130	13070	9970	5520	7310	0	0	0	0	0	4	5	6471	1965	429	3070	1007	0	0	0
9 37	2613	53000	11770	11860	11880	9010	8480	0	0	0	0	0	4	5	2613	774	213	1423	203	0	0	0
9 65	6988	53030	15350	10190	8090	9850	9550	0	0	0	0	0	4	5	5735	1679	419	3231	406	0	0	0
9 75	7608	53040	14310	12180	11130	7440	7980	0	0	0	0	0	4	5	6717	2135	452	3697	433	0	0	0
9 66	6978	53100	15730	10690	11360	7250	8420	0	0	0	0	0	4	5	6018	1633	452	3507	426	0	0	0
9 65	6811	53120	19490	8570	8520	7390	7970	0	0	0	0	0	4	5	5809	1624	429	3343	410	0	0	0
9 36	2965	53120	13710	11770	10590	9170	7880	0	0	0	0	0	4	5	2822	849	209	1661	203	0	0	0
9 37	3008	53150	15160	9760	6700	10380	11150	0	0	0	0	0	4	5	2938	807	209	1722	200	0	0	0
9 67	7253	53170	16810	11600	10940	6210	7610	0	0	0	0	0	4	5	6435	2007	423	3582	423	0	0	0
9 35	3039	53170	14880	10730	10340	8830	8390	0	0	0	0	0	4	5	3039	803	213	1522	501	0	0	0
9 69	7152	53200	15400	10690	9850	7880	9380	0	0	0	0	0	4	5	6084	2073	426	3185	400	0	0	0
9 62	6584	53230	15790	9090	10090	8440	9820	0	0	0	0	0	4	5	5549	1417	423	3303	406	0	0	0
9 65	6971	53240	13390	10180	10240	10860	8570	0	0	0	0	0	4	5	5759	1614	419	3326	400	0	0	0
9 70	6935	53240	19080	8250	8240	8260	9410	0	0	0	0	0	4	5	5753	1719	433	3195	406	0	0	0
9 68	6912	53240	16260	11010	9080	8090	8800	0	0	0	0	0	4	5	5534	1522	436	3166	410	0	0	0
9 64	6345	53240	10450	12370	4320	11540	14560	0	0	0	0	0	4	5	6028	1614	433	3585	396	0	0	0
9 37	2825	53260	7880	12200	12100	10370	10700	0	0	0	0	0	4	5	2825	856	209	1564	196	0	0	0
9 66	5761	53260	13560	10700	8920	7850	12230	0	0	0	0	0	4	5	4952	1171	446	2906	429	0	0	0
9 66	6420	53270	13380	11180	12910	6220	9580	0	0	0	0	0	4	5	5575	1535	429	3205	406	0	0	0
9 33	2926	53270	14360	8420	10000	10110	10380	0	0	0	0	0	4	5	2922	764	213	1745	200	0	0	0
9 61	5954	53660	11180	12390	10240	12120	7730	0	0	0	0	0	4	5	5047	1643	426	2572	406	0	0	0
9 68	6305	53670	17270	13070	10530	6940	5860	0	0	0	0	0	4	5	5862	1640	433	3366	423	0	0	0
9 64	7303	60860	15450	11950	11990	11930	9540	0	0	0	0	0	4	5	5729	1551	416	3346	416	0	0	0
9 32	2910	60860	14460	12960	11630	11070	10740	0	0	0	0	0	4	5	2910	849	209	1351	501	0	0	0
9 70	6916	60880	16060	12630	11030	9850	11310	0	0	0	0	0	4	5	6012	1620	423	3566	403	0	0	0
9 68	5954	60880	10160	10260	10900	15320	14240	0	0	0	0	0	4	5	4680	1148	429	2700	403	0	0	0
9 54	6020	60910	12490	9840	10770	12610	15200	0	0	0	0	0	4	5	5030	1505	416	2703	406	0	0	0
9 34	2881	60940	11530	13780	13770	11050	10810	0	0	0	0	0	4	5	2881	862	209	1610	200	0	0	0
9 78	7368	60940	18240	12170	10780	9630	10120	0	0	0	0	0	4	5	6177	1893	446	3415	423	0	0	0
9 70	6056	60940	13440	15030	14790	9140	8540	0	0	0	0	0	4	5	5657	1955	426	2870	406	0	0	0
9 75	6788	60950	16830	11820	12280	10590	9330	0	0	0	0	0	4	5	5966	1876	423	2670	987	0	0	0
9 70	6213	60950	15030	15900	14100	6220	9700	0	0	0	0	0	4	5	5748	2043	429	2880	396	0	0	0
9 36	3137	60980	13490	13020	12520	10730	11220	0	0	0	0	0	4	5	3137	908	213	1515	501	0	0	0
9 72	6961	60990	19390	12520	11240	9360	8480	0	0	0	0	0	4	5	6035	1968	423	3238	406	0	0	0
9 63	6722	61000	13240	10380	10350	13970	13060	0	0	0	0	0	4	5	5806	1673	423	3300	410	0	0	0

Vehicle Class (Scheme "P") Code	Speed of Vehicle (in mph)	Length of Vehicle From Bumper (in)	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Num ber of Axles	Wheel base distance from first axle (in)	Axle 1 Weight (in lbs)	Axle 2 Weight (in lbs)	Axle 3 Weight (in lbs)	Axle 4 Weight (in lbs)	Axle 5 Weight (in lbs)	Axle 6 Weight (in lbs)	Axle 7 Weight (in lbs)	Axle 8 Weight (in lbs)	Axle 9 Weight (in lbs)
9 64	7057	61020	19610	10320	11100	9780	10210	0	0	0	0	0	4	5	5939	1748	426	3369	396	0	0	0	0
9 69	7007	61050	15680	11080	11080	11410	12800	0	0	0	0	0	4	5	6068	1778	426	3471	393	0	0	0	0
9 68	7578	61050	17070	11500	11470	10720	10290	0	0	0	0	0	4	5	6432	1817	446	3769	400	0	0	0	0
9 35	2834	61090	14420	12400	13460	11050	9760	0	0	0	0	0	4	5	2798	889	213	1486	200	0	0	0	0
9 70	6909	61100	17590	11030	12220	10690	9570	0	0	0	0	0	4	5	5851	1692	423	3333	403	0	0	0	0
9 62	6817	61110	14890	12130	13230	10370	10490	0	0	0	0	0	4	5	5782	1620	439	3320	403	0	0	0	0
9 33	2847	61120	16280	11820	11860	9490	11670	0	0	0	0	0	4	5	2708	682	209	1614	203	0	0	0	0
9 72	6256	61130	15680	7680	9120	14030	14620	0	0	0	0	0	4	5	4995	1092	426	3077	400	0	0	0	0
9 68	6784	61170	17860	8850	8380	12010	14070	0	0	0	0	0	4	5	5451	1709	423	2923	396	0	0	0	0
9 36	3195	61180	13090	14290	12980	9310	11510	0	0	0	0	0	4	5	3059	885	209	1765	200	0	0	0	0
9 35	2887	61180	14500	10040	11690	11920	10300	0	0	0	0	0	4	5	2883	807	213	1663	200	0	0	0	0
9 35	3011	61180	11810	11770	12270	12850	12480	0	0	0	0	0	4	5	2892	912	206	1578	196	0	0	0	0
9 36	2916	61180	13400	12790	11910	11190	11890	0	0	0	0	0	4	5	2803	869	216	1515	203	0	0	0	0
9 67	7080	61200	16340	11380	11870	11180	10430	0	0	0	0	0	4	5	5766	1745	433	3182	406	0	0	0	0
9 36	3121	61210	15250	13560	13070	9060	10270	0	0	0	0	0	4	5	3121	862	216	1817	226	0	0	0	0
9 34	2947	69950	14280	13400	13130	15140	14000	0	0	0	0	0	4	5	2827	846	193	1601	187	0	0	0	0
9 37	2851	69960	13000	12720	13560	14080	16600	0	0	0	0	0	4	5	5939	1692	488	3353	406	0	0	0	0
9 32	2616	69980	14220	14670	14480	13540	13070	0	0	0	0	0	4	5	2616	784	213	1423	196	0	0	0	0
9 34	2938	69990	14550	14250	13880	13740	13570	0	0	0	0	0	4	5	2938	853	209	1676	200	0	0	0	0
9 34	2875	70020	14150	15180	14010	13530	13150	0	0	0	0	0	4	5	2875	859	209	1607	200	0	0	0	0
9 66	7142	70050	17170	13610	12710	12910	13650	0	0	0	0	0	4	5	5959	1699	436	3428	396	0	0	0	0
9 36	3100	70060	14340	14450	14220	14070	12980	0	0	0	0	0	4	5	3063	1026	213	1624	200	0	0	0	0
9 35	2916	70100	15270	14640	13690	12790	13710	0	0	0	0	0	4	5	2833	977	216	1440	200	0	0	0	0
9 33	2992	70100	13200	14370	14570	13850	14110	0	0	0	0	0	4	5	2901	826	209	1666	200	0	0	0	0
9 68	6223	70140	12870	15930	16230	12050	13060	0	0	0	0	0	4	5	5903	1571	426	3500	406	0	0	0	0
9 32	2965	70150	15030	14750	14430	12760	13180	0	0	0	0	0	4	5	2828	826	209	1591	200	0	0	0	0
9 37	2596	70150	13960	13500	14120	14250	14320	0	0	0	0	0	4	5	2596	836	209	1351	200	0	0	0	0
9 68	6853	70180	15280	15270	15970	11470	12190	0	0	0	0	0	4	5	6008	1522	429	3654	403	0	0	0	0
9 70	6289	70180	14630	15840	16500	11310	11900	0	0	0	0	0	4	5	5037	1220	426	2985	406	0	0	0	0
9 37	2773	70190	12260	15910	15750	12210	14060	0	0	0	0	0	4	5	2773	892	209	1469	203	0	0	0	0
9 69	5990	70200	14210	15510	15120	12600	12760	0	0	0	0	0	4	5	4803	1200	426	2877	400	0	0	0	0
9 32	2803	70220	14920	14720	15840	13020	11720	0	0	0	0	0	4	5	2803	764	209	1630	200	0	0	0	0
9 76	7073	70230	14950	12290	13760	14250	14980	0	0	0	0	0	4	5	6130	1771	439	3487	433	0	0	0	0
9 62	6998	70250	18320	13480	14560	11180	12730	0	0	0	0	0	4	5	5845	1729	429	3287	400	0	0	0	0
9 32	3154	70260	14160	16810	14450	12620	12210	0	0	0	0	0	4	5	3154	915	213	1528	498	0	0	0	0
9 34	2942	70260	16220	14610	15510	11680	12240	0	0	0	0	0	4	5	2875	895	209	1568	203	0	0	0	0
9 65	7139	70280	18150	14430	14000	11780	11920	0	0	0	0	0	4	5	6104	1755	426	3520	403	0	0	0	0
9 70	6729	70290	16470	15730	16770	11300	10020	0	0	0	0	0	4	5	6113	1715	426	3566	406	0	0	0	0
9 34	2929	70300	14820	13030	12180	14690	15580	0	0	0	0	0	4	5	2773	853	209	1515	196	0	0	0	0
9 37	3418	70310	15220	14080	14050	13330	13430	0	0	0	0	0	4	5	3048	944	196	1899	209	0	0	0	0
9 77	7076	70330	15890	14610	16000	11440	12390	0	0	0	0	0	4	5	5838	1669	436	3333	400	0	0	0	0
9 35	2851	70340	11540	14500	13300	15510	15490	0	0	0	0	0	4	5	2587	666	213	1512	196	0	0	0	0
9 69	4747	70380	15570	13290	12420	15210	13890	0	0	0	0	0	4	5	4060	1112	429	2116	403	0	0	0	0
9 65	6893	70380	16520	11640	12470	14560	15190	0	0	0	0	0	4	5	5808	1696	429	3280	403	0	0	0	0
9 66	6276	70390	14670	15450	15820	12890	11760	0	0	0	0	0	4	5	5329	1066	436	3421	406	0	0	0	0
9 34	2691	70410	14630	12270	12350	14820	16340	0	0	0	0	0	4	5	2891	603	209	1679	200	0	0	0	0
9 30	2899	70410	19030	13990	14670	12120	10600	0	0	0	0	0	4	5	2899	849	213	1637	200	0	0	0	0
9 64	6391	70420	17830	14150	14720	12340	11380	0	0	0	0	0	4	5	5852	1699	426	3421	406	0	0	0	0
9 66	6774	70430	16600	13970	13000	13460	13400	0	0	0	0	0	4	5	6139	1876	429	3418	416	0	0	0	0
9 66	7368	70440	16570	13870	15660	11330	13010	0	0	0	0	0	4	5	5927	1804	426	3297	400	0	0	0	0
9 64	6945	70440	17320	13700	14230	11800	13390	0	0	0	0	0	4	5	5808	1696	429	3280	403	0	0	0	0
9 37	2836	70450	17540	11940	14670	12690	13610	0	0	0	0	0	4	5	2853	807	213	1637	196	0	0	0	0
9 71	7007	70810	20050	17420	14930	9240	9170	0	0	0	0	0	4	5	5975	1692	433	3444	406	0	0	0	0
9 37	2795	70820	15490	14220	12950	14220	14730	0	0	0	0	0	4	5	2831	839	209	1387	196	0	0	0	0
9 74	6860	70840	15080	14080	12980	14300	14400	0	0	0	0	0	4	5	5748	1715	419	3208	406	0	0	0	0

Vehicle Class (Scheme "P") Code	Speed of Vehicle (in mi/hr)	Length of Vehicle Bumper to Bumper (in ft)	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Number of Axles	Wheel base distance from first axle (in ft)	Axle 2 Weight (in lbs)	Axle 3 Weight (in lbs)	Axle 4 Weight (in lbs)	Axle 5 Weight (in lbs)	Axle 6 Weight (in lbs)	Axle 7 Weight (in lbs)	Axle 8 Weight (in lbs)	Axle 9 Weight (in lbs)
9 36	3243	70850	12520	16020	13530	15470	13310	0	0	0	0	0	4	5	3243	994	213	1535	501	0	0	0
9 36	3034	70860	13880	13280	13620	14530	15550	0	0	0	0	0	4	5	2992	885	209	1702	196	0	0	0
9 35	2863	70880	16190	14640	14170	11720	14160	0	0	0	0	0	4	5	2863	1053	216	1391	203	0	0	0
9 33	3162	70910	16680	16050	16450	10690	11040	0	0	0	0	0	4	5	3101	1010	209	1686	196	0	0	0
9 66	6535	70910	17610	13540	10570	15090	14100	0	0	0	0	0	4	5	5572	1601	439	3129	403	0	0	0
9 33	2964	70930	17150	13460	13550	13360	13410	0	0	0	0	0	4	5	2964	846	209	1709	200	0	0	0
9 36	2827	70930	16410	14450	13270	12970	13830	0	0	0	0	0	4	5	2827	751	213	1680	203	0	0	0
9 38	3144	70940	11820	15670	12960	15280	15210	0	0	0	0	0	4	5	3144	971	209	1469	495	0	0	0
9 36	3015	70950	11820	15080	15020	13120	15910	0	0	0	0	0	4	5	3013	856	216	1745	196	0	0	0
9 65	7001	70960	13490	15260	14080	14550	13580	0	0	0	0	0	4	5	6133	1791	419	3517	406	0	0	0
9 33	2655	70960	15210	14940	15290	11340	14180	0	0	0	0	0	4	5	5782	1624	429	3336	403	0	0	0
9 67	6942	70970	16490	10980	11480	15580	16440	0	0	0	0	0	4	5	777	213	1676	203	0	0	0	0
9 36	2869	70990	6340	14610	14980	17930	17130	0	0	0	0	0	4	5	2869	807	209	1453	200	0	0	0
9 37	2934	70990	15550	16990	16070	11890	10690	0	0	0	0	0	4	5	5096	1171	429	3090	406	0	0	0
9 63	5757	71010	20210	12610	13440	11870	12880	0	0	0	0	0	4	5	2869	807	209	1453	200	0	0	0
9 36	2834	71050	16450	12830	13330	14380	14060	0	0	0	0	0	4	5	2834	967	216	1551	200	0	0	0
9 33	2685	71080	18210	14290	14260	13990	12330	0	0	0	0	0	4	5	2686	843	213	1430	200	0	0	0
9 62	6118	71090	15260	15140	14370	12360	13960	0	0	0	0	0	4	5	5024	1368	429	2824	403	0	0	0
9 35	2988	71120	15980	14880	14400	13070	12790	0	0	0	0	0	4	5	2879	856	206	1617	200	0	0	0
9 35	2775	71130	13990	14950	13730	16540	11920	0	0	0	0	0	4	5	5327	1053	423	3458	393	0	0	0
9 66	6555	71180	14930	16190	15920	12050	12090	0	0	0	0	0	4	5	2583	569	209	1505	200	0	0	0
9 32	2583	71190	6370	15100	13010	17520	19190	0	0	0	0	0	4	5	2583	569	209	1505	200	0	0	0
9 34	2882	71190	12370	15700	10550	16430	16140	0	0	0	0	0	4	5	2882	803	223	1450	406	0	0	0
9 33	2998	71230	17530	12540	11830	14420	14910	0	0	0	0	0	4	5	2948	777	213	1758	200	0	0	0
9 61	5616	71230	14380	17110	17130	11630	10980	0	0	0	0	0	4	5	5109	1492	436	2778	403	0	0	0
9 34	3011	71240	19450	14990	15160	10910	10730	0	0	0	0	0	4	5	2849	849	209	1591	200	0	0	0
9 37	3372	71240	13940	14140	14640	13840	10730	0	0	0	0	0	4	5	3023	928	213	1676	206	0	0	0
9 37	3074	71270	15410	14520	14410	14620	12310	0	0	0	0	0	4	5	2977	869	213	1699	196	0	0	0
9 35	3064	82540	16400	16170	15680	16880	17410	0	0	0	0	0	4	5	3064	895	209	1459	501	0	0	0
9 32	2959	82560	17870	16970	17240	13980	16480	0	0	0	0	0	4	5	2852	830	209	1610	203	0	0	0
9 72	5360	82590	8610	17620	17620	19840	19480	0	0	0	0	0	4	5	5130	1437	433	2854	406	0	0	0
9 60	6509	82600	13590	17700	22720	14960	13630	0	0	0	0	0	4	5	6186	1958	426	3392	410	0	0	0
9 70	5518	82650	17470	19270	18750	14010	13150	0	0	0	0	0	4	5	4729	997	426	2900	406	0	0	0
9 37	2919	82690	14260	19620	19780	14640	14390	0	0	0	0	0	4	5	2917	846	209	1361	501	0	0	0
9 34	2764	82690	12800	15370	15070	19600	19850	0	0	0	0	0	4	5	2764	748	209	1309	498	0	0	0
9 35	2764	82690	14050	15590	15200	19160	18690	0	0	0	0	0	4	5	6094	1906	449	3336	403	0	0	0
9 72	7303	82690	15270	15110	14100	18580	19630	0	0	0	0	0	4	5	2799	846	209	1548	196	0	0	0
9 34	2949	82720	13700	16570	15990	18030	18430	0	0	0	0	0	4	5	2887	623	213	1351	200	0	0	0
9 37	2387	82720	11120	15920	16020	19730	19930	0	0	0	0	0	4	5	3125	1020	213	1692	200	0	0	0
9 33	2865	82730	14620	20920	19120	10350	17720	0	0	0	0	0	4	5	2865	823	213	1633	196	0	0	0
9 35	3169	82750	15360	16180	16310	17030	17870	0	0	0	0	0	4	5	2895	846	213	1640	196	0	0	0
9 33	3008	82750	14930	18420	17800	14770	16830	0	0	0	0	0	4	5	3083	1017	223	1345	498	0	0	0
9 37	3120	82760	14740	17390	18060	16780	15790	0	0	0	0	0	4	5	3033	974	209	1650	200	0	0	0
9 33	3100	82760	14940	16030	16660	17650	17480	0	0	0	0	0	4	5	3036	990	213	1328	505	0	0	0
9 36	3036	82770	13520	17540	18180	16640	16890	0	0	0	0	0	4	5	2783	875	213	1492	203	0	0	0
9 34	2821	82810	12930	17190	16080	20000	16610	0	0	0	0	0	4	5	6055	1748	433	3471	403	0	0	0
9 76	7322	82820	15580	17300	17450	16130	16360	0	0	0	0	0	4	5	3035	859	209	1748	219	0	0	0
9 38	3035	82830	12980	16860	17650	16340	17430	0	0	0	0	0	4	5	2823	823	213	1522	403	0	0	0
9 37	2961	82830	13610	16860	17320	17390	17650	0	0	0	0	0	4	5	6364	1968	433	3517	446	0	0	0
9 69	7145	82840	16880	14680	12540	17060	21680	0	0	0	0	0	4	5	5493	1486	429	3172	406	0	0	0
9 66	5912	82850	17280	14570	14840	17260	18900	0	0	0	0	0	4	5	5070	1423	429	2808	410	0	0	0
9 56	6181	82880	16200	14710	15020	17290	19660	0	0	0	0	0	4	5	2904	688	213	1502	501	0	0	0
9 33	2904	82880	13430	15680	16210	19670	17890	0	0	0	0	0	4	5	2872	836	206	1627	203	0	0	0
9 38	2872	82880	13430	19900	19630	16150	13770	0	0	0	0	0	4	5								

Vehicle Class (Scheme 4 th) Code	Speed of Vehicle (in km/h)	Length of Vehicle Bumper to Bumper (in mm)	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Num ber of Axles	Wheel base - from first axle (in mm)	Axle 2 formal dist. (mm)	Axle 3 formal dist. (mm)	Axle 4 formal dist. (mm)	Axle 5 formal dist. (mm)	Axle 6 formal dist. (mm)	Axle 7 formal dist. (mm)	Axle 8 formal dist. (mm)	Axle 9 formal dist. (mm)
9 35	3015	82890	13850	16200	16290	17800	18750	0	0	0	0	0	4	5	2917	892	209	1620	196	0	0	0
9 35	2924	82890	15370	17520	17310	17040	15650	0	0	0	0	0	4	5	2924	826	206	1692	200	0	0	0
9 39	2704	82900	11040	15660	17140	17730	21330	0	0	0	0	0	4	5	2704	688	213	1610	193	0	0	0
9 34	3303	82910	14170	16310	16790	17610	18030	0	0	0	0	0	4	5	2912	958	213	1541	200	0	0	0
9 37	3012	82920	11750	18280	17160	16750	18980	0	0	0	0	0	4	5	3012	846	209	1761	196	0	0	0
9 36	3467	82930	13510	17390	19570	16530	15930	0	0	0	0	0	4	5	3029	892	206	1630	301	0	0	0
9 34	3011	82940	15770	16190	16080	17440	17480	0	0	0	0	0	4	5	2898	856	209	1633	200	0	0	0
9 35	2969	82950	18060	15330	14630	17040	17890	0	0	0	0	0	4	5	2894	836	209	1653	196	0	0	0
9 33	2977	82950	17320	15140	16220	16870	16400	0	0	0	0	0	4	5	2977	862	213	1699	203	0	0	0
9 34	3001	82980	21180	14030	14410	16390	16970	0	0	0	0	0	4	5	2983	889	209	1689	196	0	0	0
9 72	6315	82980	5940	25260	17920	15680	18180	0	0	0	0	0	4	5	5822	1817	426	3179	400	0	0	0
9 36	3156	83010	13160	16150	15600	18310	18790	0	0	0	0	0	4	5	3004	987	213	1604	200	0	0	0
9 35	3240	83010	14660	16100	16960	16650	18640	0	0	0	0	0	4	5	3240	1000	213	1827	200	0	0	0
9 36	3077	83010	13400	15800	15480	17910	20420	0	0	0	0	0	4	5	2928	807	209	1712	200	0	0	0
9 37	3019	83020	13910	17100	17750	17030	17230	0	0	0	0	0	4	5	3019	803	216	1502	498	0	0	0
9 36	2708	83020	14000	18240	18050	16820	16910	0	0	0	0	0	4	5	2708	866	216	1430	196	0	0	0
9 69	7306	83020	15150	18510	17030	16800	15530	0	0	0	0	0	4	5	6429	1755	459	3776	439	0	0	0
9 34	1950	83020	10230	14410	14600	20760	23020	0	0	0	0	0	4	5	1950	639	206	905	200	0	0	0
9 37	3152	83030	13710	17170	16310	17870	17970	0	0	0	0	0	4	5	3017	967	213	1637	200	0	0	0
9 34	2982	83040	11500	17930	19560	16930	17120	0	0	0	0	0	4	5	2974	839	213	1722	200	0	0	0
9 37	2941	83050	14280	17850	18340	15600	17180	0	0	0	0	0	4	5	2941	964	213	1568	196	0	0	0
9 35	3099	83050	12880	16350	16480	14950	22390	0	0	0	0	0	4	5	3099	853	209	1545	492	0	0	0
9 37	2884	83100	15470	15780	16690	18290	16870	0	0	0	0	0	4	5	2884	780	209	1692	203	0	0	0
9 64	7024	83110	10560	21030	14480	19320	17720	0	0	0	0	0	4	5	6143	1745	449	3543	406	0	0	0
9 35	3008	83130	16480	15250	16110	17130	18160	0	0	0	0	0	4	5	2853	816	213	1624	200	0	0	0
9 35	3157	83130	13380	16760	16870	18570	17550	0	0	0	0	0	4	5	3157	964	216	1479	498	0	0	0
9 34	2985	83150	12810	16850	18320	17640	17530	0	0	0	0	0	4	5	2911	830	206	1679	196	0	0	0
9 35	3152	83150	15670	18760	16890	15250	16580	0	0	0	0	0	4	5	3117	987	219	1715	196	0	0	0
9 38	2858	83170	12170	15850	16260	18810	20080	0	0	0	0	0	4	5	2858	849	209	1604	196	0	0	0
9 75	6627	83170	17380	17970	17530	13390	16900	0	0	0	0	0	4	5	5950	1955	426	3166	403	0	0	0
9 34	3042	83200	15060	14720	14470	20110	18840	0	0	0	0	0	4	5	3164	931	213	1814	206	0	0	0
9 37	3638	83210	14540	17400	16970	17620	16680	0	0	0	0	0	4	5	5952	1784	426	3336	406	0	0	0
9 65	6351	83220	15440	19140	18120	13700	15820	0	0	0	0	0	4	5	2944	908	209	1627	200	0	0	0
9 35	3126	83220	11570	18150	18150	17040	18310	0	0	0	0	0	4	5	2754	800	213	1538	203	0	0	0
9 32	2754	83230	13750	18200	18330	16650	16300	0	0	0	0	0	4	5	2824	885	209	1630	200	0	0	0
9 37	2924	83270	12530	17060	18640	17650	17390	0	0	0	0	0	4	5	2865	800	216	1446	403	0	0	0
9 34	2865	83280	13180	16280	16430	19790	17600	0	0	0	0	0	4	5	3213	1033	209	1771	200	0	0	0
9 37	3215	83290	12880	17620	17480	17110	18200	0	0	0	0	0	4	5	2987	767	213	1515	492	0	0	0
9 35	2987	83310	11230	16650	17000	15810	22620	0	0	0	0	0	4	5	3043	928	213	1696	206	0	0	0
9 31	3494	83310	16680	17090	15520	16890	17130	0	0	0	0	0	4	5	5768	436	3188	419	0	0	0	0
9 59	6994	83350	14100	20850	6870	23770	17760	0	0	0	0	0	4	5	2951	843	213	1397	498	0	0	0
9 68	5843	83380	14240	22030	18310	13340	15460	0	0	0	0	0	4	5	5428	1732	439	2864	393	0	0	0
9 36	2951	83380	11390	17570	15130	19750	19540	0	0	0	0	0	4	5	4781	1085	426	2867	403	0	0	0
9 63	5810	83380	14020	15630	18360	15650	19720	0	0	0	0	0	4	5	5965	1502	462	3139	862	0	0	0
9 73	6423	83410	31640	30730	10920	3960	6160	0	0	0	0	0	4	5	2872	869	216	1584	203	0	0	0
9 36	3031	83420	15340	15060	14630	19050	19340	0	0	0	0	0	4	5	6258	1807	456	3592	403	0	0	0
9 71	7326	83430	15320	15700	14950	17410	20060	0	0	0	0	0	4	5	2990	971	209	1610	200	0	0	0
9 36	3139	83450	12640	17980	16470	17930	18430	0	0	0	0	0	4	5	4118	1463	416	1833	406	0	0	0
9 67	4458	84260	11470	13390	13350	23520	22530	0	0	0	0	0	4	5	2814	728	213	1673	200	0	0	0
9 34	2814	84260	12310	18610	17390	19160	16780	0	0	0	0	0	4	5	2902	971	213	1515	203	0	0	0
9 33	2902	84260	14470	17180	16210	17520	18880	0	0	0	0	0	4	5	2714	810	209	1492	203	0	0	0
9 34	2714	84270	16780	15380	15500	18790	17820	0	0	0	0	0	4	5	5149	1207	429	3110	403	0	0	0
9 73	5675	84280	16660	20750	21320	13040	12510	0	0	0	0	0	4	5	4845	1217	429	2896	403	0	0	0
9 70	6236	84290	14720	20420	19230	15910	14010	0	0	0	0	0	4	5	6481	1827	419	3835	400	0	0	0
9 65	6824	84290	14890	19540	17620	15110	17130	0	0	0	0	0	4	5								

Vehicle Class (Scheme "F") Code	Speed of Vehicle (in m.p.h.)	Length of Vehicle From Bumper to Bumper	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Num ber of Axles	Wheel base (in)	Axle distance from first axle (in)	Axle Space 1 (formal mm max)	Axle Space 2 (formal mm max)	Axle Space 3 (formal mm max)	Axle Space 4 (formal mm max)	Axle Space 5 (formal mm max)	Axle Space 6 (formal mm max)	Axle Space 7 (formal mm max)	Axle Space 8 (formal mm max)	Axle Space 9 (formal mm max)
9	72	6761	88990	19540	20590	9960	19140	19760	0	0	0	0	4	5	5852	1755	459	3228	410	0	0	0	0	0
9	33	3159	89010	16210	16800	18200	18510	19290	0	0	0	0	4	5	3043	971	209	1663	200	0	0	0	0	0
9	31	2982	89030	14070	19140	18640	18460	18720	0	0	0	0	4	5	2964	826	206	1732	200	0	0	0	0	0
9	33	2938	89040	14030	18220	17760	20210	18820	0	0	0	0	4	5	2938	853	209	1673	203	0	0	0	0	0
9	35	2904	89050	17210	17860	17730	18260	17990	0	0	0	0	4	5	2904	826	209	1669	200	0	0	0	0	0
9	34	3117	89060	16630	17110	16780	19550	18990	0	0	0	0	4	5	3117	902	209	1505	501	0	0	0	0	0
9	34	3070	89060	13110	18130	17120	20640	20060	0	0	0	0	4	5	3070	879	213	1486	492	0	0	0	0	0
9	62	5374	89060	14980	23360	20710	15910	14100	0	0	0	0	4	5	4966	1253	433	2870	410	0	0	0	0	0
9	33	3183	89070	14200	17780	19550	17990	19550	0	0	0	0	4	5	3183	875	213	1594	501	0	0	0	0	0
9	37	2724	89070	15150	17530	19950	18180	18260	0	0	0	0	4	5	2724	636	206	1686	196	0	0	0	0	0
9	37	2653	89080	14760	20380	20030	16530	17380	0	0	0	0	4	5	2653	807	213	1430	203	0	0	0	0	0
9	72	7043	89080	17740	17910	18170	17930	17330	0	0	0	0	4	5	5756	1745	433	3172	406	0	0	0	0	0
9	34	2859	89090	16050	16820	16340	20830	19050	0	0	0	0	4	5	2859	797	216	1443	403	0	0	0	0	0
9	33	2567	89110	14760	18560	19080	18140	18570	0	0	0	0	4	5	2567	662	216	1489	200	0	0	0	0	0
9	37	3392	89110	14710	18390	19140	18100	18770	0	0	0	0	4	5	3062	931	213	1709	209	0	0	0	0	0
9	34	2841	89120	13600	18840	18560	18780	19340	0	0	0	0	4	5	2897	839	209	1453	196	0	0	0	0	0
9	36	2980	89120	14000	17000	18360	20000	19760	0	0	0	0	4	5	2980	764	213	1505	498	0	0	0	0	0
9	65	6145	89130	12600	20660	21060	17190	17620	0	0	0	0	4	5	5806	1345	413	3638	410	0	0	0	0	0
9	37	2600	89140	14070	17160	18410	19300	19840	17720	0	0	0	4	5	2600	672	213	1519	196	0	0	0	0	0
9	35	3024	89160	15070	17160	16860	21920	18150	0	0	0	0	4	5	2850	787	213	1650	200	0	0	0	0	0
9	67	6509	89160	14210	20650	20250	16910	17140	0	0	0	0	4	5	6126	1624	429	3070	1003	0	0	0	0	0
9	35	3139	89170	12860	17090	18740	20130	20350	0	0	0	0	4	5	2941	974	209	1558	200	0	0	0	0	0
9	69	6197	89180	18050	20150	18550	15360	17070	0	0	0	0	4	5	5326	1791	435	2703	396	0	0	0	0	0
9	34	2877	89190	12710	17860	19720	20080	18820	0	0	0	0	4	5	2832	757	206	1673	196	0	0	0	0	0
9	36	2805	89190	14430	18300	18940	19010	18510	0	0	0	0	4	5	2800	859	213	1528	200	0	0	0	0	0
9	62	6210	89210	13300	22520	18720	17230	17440	0	0	0	0	4	5	5870	1440	429	2998	1003	0	0	0	0	0
9	33	3079	89230	13550	18120	19750	18710	19100	0	0	0	0	4	5	3079	974	213	1692	200	0	0	0	0	0
9	34	3392	89230	18450	17870	17260	18220	17430	0	0	0	0	4	5	3039	938	216	1679	206	0	0	0	0	0
9	36	2830	89240	15220	17570	17810	18570	20070	0	0	0	0	4	5	2830	784	213	1338	495	0	0	0	0	0
9	33	2999	89240	15790	17210	16320	19970	19950	0	0	0	0	4	5	2999	839	209	1551	400	0	0	0	0	0
9	57	6899	89240	16160	18790	19870	17080	17340	0	0	0	0	4	5	6107	1735	423	3549	400	0	0	0	0	0
9	34	2980	89260	17200	16980	16590	20270	18220	0	0	0	0	4	5	2980	803	213	1558	406	0	0	0	0	0
9	35	2986	89260	12580	17850	18230	20370	20370	0	0	0	0	4	5	2986	784	209	1492	501	0	0	0	0	0
9	34	2826	89270	17950	17870	15390	16570	21490	0	0	0	0	4	5	2826	928	213	1489	196	0	0	0	0	0
9	68	6784	89270	17420	19040	18680	17980	16150	0	0	0	0	4	5	6084	2076	429	3169	410	0	0	0	0	0
9	34	2826	89280	16550	18610	18310	18100	17710	0	0	0	0	4	5	2826	748	206	1676	196	0	0	0	0	0
9	34	3221	89300	15540	17820	17540	18690	19710	0	0	0	0	4	5	2927	839	209	1673	206	0	0	0	0	0
9	34	2894	89310	17660	16590	18880	18030	18150	0	0	0	0	4	5	2894	898	209	1587	200	0	0	0	0	0
9	65	6407	89310	16850	17810	18900	18180	17570	0	0	0	0	4	5	6081	1706	426	3513	436	0	0	0	0	0
9	80	7283	89320	17730	20220	20240	15470	15660	0	0	0	0	4	5	6409	1843	446	3697	423	0	0	0	0	0
9	37	2990	89340	11940	19320	17300	20840	19940	0	0	0	0	4	5	2990	971	209	1614	196	0	0	0	0	0
9	32	3067	89340	15290	16910	17220	20540	19380	0	0	0	0	4	5	2862	849	206	1601	206	0	0	0	0	0
9	33	2975	89340	15480	18300	17720	19170	18670	0	0	0	0	4	5	2868	833	206	1646	203	0	0	0	0	0
9	76	6968	89350	7890	18800	19620	20700	22340	0	0	0	0	4	5	6264	1994	442	3415	413	0	0	0	0	0
9	34	2961	89420	17180	18120	19040	16880	18200	0	0	0	0	4	5	2961	889	209	1663	200	0	0	0	0	0
9	36	3356	89430	12560	19990	19700	18830	18350	0	0	0	0	4	5	3124	931	213	1771	209	0	0	0	0	0
9	33	3131	89500	14720	17860	17320	19240	20360	0	0	0	0	4	5	3131	872	209	1850	200	0	0	0	0	0
9	74	6837	89540	18860	19160	21340	15550	14630	0	0	0	0	4	5	5854	1624	429	3198	403	0	0	0	0	0
9	32	2980	89570	16530	17440	16430	19540	19630	0	0	0	0	4	5	2980	810	213	1459	498	0	0	0	0	0
9	32	2982	89570	13080	20800	18960	19290	17440	0	0	0	0	4	5	2869	800	216	1653	200	0	0	0	0	0
9	54	4498	89580	16900	14320	15310	20390	22660	0	0	0	0	4	5	4088	1423	429	1840	396	0	0	0	0	0
9	76	6210	89580	6860	19320	18160	21000	24240	0	0	0	0	4	5	5674	1597	400	3300	377	0	0	0	0	0
9	34	2966	89580	12080	18750	17710	20210	20830	0	0	0	0	4	5	2966	967	209	1594	196	0	0	0	0	0
9	65	4553	89590	12340	13300	12460	25350	26140	0	0	0	0	4	5	4128	1341	426	1955	406	0	0	0	0	0

Vehicle Class (Scheme "F") Code	Speed of Vehicle (in km/h)	Length of Vehicle From Bumper to Bumper	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Num ber of Axles	Wheel base distance from first axle (in mm)	Axle 2 (format mm)	Axle 3 (format mm)	Axle 4 (format mm)	Axle 5 (format mm)	Axle 6 (format mm)	Axle 7 (format mm)	Axle 8 (format mm)	Axle 9 (format mm)
9 31	3366	89600	18050	19410	16660	17900	17580	0	0	0	0	4	5	3033	935	216	1676	206	0	0	0
9 36	2938	89610	14880	18860	19530	18410	17930	0	0	0	0	4	5	2938	856	213	1666	203	0	0	0
9 61	6669	89650	17880	15940	16250	20000	19580	0	0	0	0	4	5	5628	1348	429	3448	403	0	0	0
9 37	3003	89660	17220	17940	17940	18080	18480	0	0	0	0	4	5	3003	882	213	1407	501	0	0	0
9 35	3034	89660	17580	17700	17630	17950	18800	0	0	0	0	4	5	3030	856	206	1768	200	0	0	0
9 32	2528	89660	13860	18760	18340	18750	19950	0	0	0	0	4	5	2528	672	213	1440	203	0	0	0
9 34	3049	89710	15070	19280	18490	19360	17510	0	0	0	0	4	5	3049	862	213	1774	200	0	0	0
9 35	3001	89720	16110	18950	17820	16820	20020	0	0	0	0	4	5	2992	862	209	1725	196	0	0	0
9 66	8860	89770	20250	14580	15000	20190	19750	0	0	0	0	4	5	5847	1538	426	3477	406	0	0	0
9 59	6952	89810	16280	20490	19720	16120	17200	0	0	0	0	4	5	5880	1715	423	3336	406	0	0	0
9 35	2866	89810	13460	17910	18890	18540	21010	0	0	0	0	4	5	2866	741	216	1414	495	0	0	0
9 35	3054	89810	18090	16500	17100	20020	18100	0	0	0	0	4	5	2889	866	216	1607	200	0	0	0
9 60	5646	89820	13210	18610	19470	19690	18840	0	0	0	0	4	5	5225	1089	429	3307	400	0	0	0
9 67	6053	89820	15920	16700	17370	20030	19800	0	0	0	0	4	5	5499	1348	419	2919	813	0	0	0
9 67	6463	89830	6730	19480	18620	21860	23140	0	0	0	0	4	5	6186	1742	436	3595	413	0	0	0
9 35	2876	89850	14700	19050	20540	17580	17980	0	0	0	0	4	5	2876	797	193	1381	505	0	0	0
9 33	3173	89850	16170	18530	20070	17430	17650	0	0	0	0	4	5	3173	931	209	1535	498	0	0	0
9 69	5898	91920	54220	10380	11520	7620	8180	0	0	0	0	4	5	5707	1804	377	2660	866	0	0	0
9 36	2734	91930	16290	19910	20440	18370	16920	0	0	0	0	4	5	2734	639	213	1676	206	0	0	0
9 33	3582	91930	16460	20060	20820	17600	16990	0	0	0	0	4	5	3043	928	213	1696	206	0	0	0
9 69	5898	91930	15820	20600	19270	16290	19950	0	0	0	0	4	5	5405	1709	436	2864	396	0	0	0
9 67	6837	91970	16270	19420	20110	17710	18460	0	0	0	0	4	5	6464	2053	426	2975	1010	0	0	0
9 80	6847	91980	9620	23680	20480	18720	19480	0	0	0	0	4	5	6117	1929	485	3257	446	0	0	0
9 35	3041	91980	18320	18480	18420	18090	18670	0	0	0	0	4	5	2844	849	213	1679	203	0	0	0
9 34	3146	91980	15920	19890	18660	18930	18580	0	0	0	0	4	5	3112	994	216	1709	193	0	0	0
9 36	2901	91990	14730	18920	18180	21510	18650	0	0	0	0	4	5	2901	826	209	1663	203	0	0	0
9 35	2999	92030	12200	19960	18310	20070	21490	0	0	0	0	4	5	2999	895	216	1387	501	0	0	0
9 67	5856	92060	20160	17650	16710	18510	19030	0	0	0	0	4	5	4814	1000	429	2982	403	0	0	0
9 32	2663	92060	18560	17990	17870	19390	18250	0	0	0	0	4	5	2663	761	213	1489	200	0	0	0
9 64	5482	92110	15570	18970	18690	19470	19410	0	0	0	0	4	5	5120	1309	426	2982	403	0	0	0
9 34	2731	92110	14440	19790	18700	19500	19680	0	0	0	0	4	5	2731	639	213	1679	200	0	0	0
9 32	3022	92140	17130	17920	17940	18290	20860	0	0	0	0	4	5	3022	816	209	1797	200	0	0	0
9 34	3143	92150	13190	19300	19830	20080	19750	0	0	0	0	4	5	2991	918	213	1660	200	0	0	0
9 65	6151	92170	13330	20940	18640	18630	17730	0	0	0	0	4	5	5848	1351	416	3671	410	0	0	0
9 71	6952	92170	16930	18740	18640	19750	18110	0	0	0	0	4	5	6136	1797	423	3513	403	0	0	0
9 33	3127	92170	16210	17520	17250	19490	21700	0	0	0	0	4	5	3127	1000	209	1420	498	0	0	0
9 69	7034	92180	19410	18170	17930	17380	19290	0	0	0	0	4	5	5982	1797	423	3366	396	0	0	0
9 66	5206	92180	13070	22230	22480	16760	17640	0	0	0	0	4	5	4818	1876	419	2204	419	0	0	0
9 60	6761	92190	15670	18490	19180	22980	15870	0	0	0	0	4	5	6448	1991	429	3005	1023	0	0	0
9 63	6535	92190	18400	18180	17530	18140	19940	0	0	0	0	4	5	5847	1712	423	3106	406	0	0	0
9 55	6482	92200	15820	22330	20280	16350	17420	0	0	0	0	4	5	6087	1916	429	3339	403	0	0	0
9 68	6328	92210	12710	19470	21160	17660	21190	0	0	0	0	4	5	5618	1574	429	3215	400	0	0	0
9 34	3020	92210	15500	19790	20280	18390	19390	0	0	0	0	4	5	3020	820	239	1765	196	0	0	0
9 35	2679	92230	15400	19880	18160	19300	19490	0	0	0	0	4	5	2679	757	226	1496	200	0	0	0
9 65	5006	92230	13760	14160	7610	22800	33900	0	0	0	0	4	5	4480	1650	472	1925	433	0	0	0
9 65	6125	92230	11980	21380	20440	19170	19260	0	0	0	0	4	5	5850	1715	419	3313	403	0	0	0
9 62	6938	92230	14710	19960	19590	17320	20650	0	0	0	0	4	5	2756	869	209	1482	196	0	0	0
9 35	2756	92240	16360	17600	18350	20200	19730	0	0	0	0	4	5	5907	1696	436	3372	403	0	0	0
9 68	6325	92280	16270	24360	23870	12720	15060	0	0	0	0	4	5	2038	764	209	869	196	0	0	0
9 36	2961	92280	14600	19300	19690	18260	20430	0	0	0	0	4	5	5907	1696	436	3372	403	0	0	0
9 36	2896	92280	17250	18440	18330	18740	19520	0	0	0	0	4	5	2896	846	213	1637	200	0	0	0
9 34	2725	92290	12330	18440	19450	20150	21920	0	0	0	0	4	5	2725	836	213	1463	213	0	0	0
9 35	3113	92300	14510	20630	21300	17530	18330	0	0	0	0	4	5	2934	964	213	1561	196	0	0	0
9 35	3015	92310	15580	18440	17950	19270	21070	0	0	0	0	4	5	2991	866	213	1712	200	0	0	0

Vehicle Class (Scheme-F)	Speed of Vehicle (in km/hr)	Length of Vehicle Bumper to Bumper (in mm)	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Num ber of Axles	Wheel base (in)	Distance from first axle (in)	Axle 1 (format mm)	Axle 2 (format mm)	Axle 3 (format mm)	Axle 4 (format mm)	Axle 5 (format mm)	Axle 6 (format mm)	Axle 7 (format mm)	Axle 8 (format mm)	Axle 9 (format mm)
9	35	3633	92340	19720	18300	18570	18170	17580	0	0	0	0	4	5	3633	967	213	2257	196	0	0	0	0	0
9	59	6894	92340	14560	17900	20590	19400	18990	0	0	0	0	4	4	5	6077	1722	426	3526	403	0	0	0	0
9	65	5971	92340	13490	18450	17950	21440	21010	0	0	0	0	4	5	4903	1095	429	2979	400	0	0	0	0	0
9	70	7290	92350	44930	12080	14580	10360	10400	0	0	0	0	4	5	6744	1978	452	3248	1066	0	0	0	0	0
9	61	6975	92350	19100	18170	18910	18250	17920	0	0	0	0	4	5	6501	1765	426	3900	410	0	0	0	0	0
9	34	2757	92370	16090	17600	17460	23330	17890	0	0	0	0	4	5	2757	823	213	1515	206	0	0	0	0	0
9	30	2737	92370	15850	18600	18830	20570	18520	0	0	0	0	4	5	2737	662	216	1459	400	0	0	0	0	0
9	35	3164	92380	15120	19870	20830	18970	17490	0	0	0	0	4	5	3164	971	209	1476	508	0	0	0	0	0
9	75	6692	92400	15730	20300	22020	17600	16750	0	0	0	0	4	5	6126	1745	416	2962	1003	0	0	0	0	0
9	35	2666	92420	13000	19780	18760	20460	20420	0	0	0	0	4	5	2866	738	216	1512	200	0	0	0	0	0
9	36	2508	92420	11230	21230	19640	21160	19160	0	0	0	0	4	5	2508	633	216	1456	203	0	0	0	0	0
9	36	2780	92440	15040	19360	20450	18680	18890	0	0	0	0	4	5	2780	918	219	1443	200	0	0	0	0	0
9	36	3047	92450	15090	19140	19160	19090	19970	0	0	0	0	4	5	2997	974	213	1610	200	0	0	0	0	0
9	69	6263	92480	12380	16180	16430	19260	18350	22300	0	0	0	4	5	4893	1197	433	2867	396	0	0	0	0	0
9	64	7011	92500	16120	17560	20000	19900	18920	0	0	0	0	4	5	6070	1784	419	3467	400	0	0	0	0	0
9	68	6233	92500	14480	17830	18110	22790	19290	0	0	0	0	4	5	5264	1545	416	2900	403	0	0	0	0	0
9	33	2885	92510	17840	18160	18500	19180	18830	0	0	0	0	4	5	2885	820	213	1354	498	0	0	0	0	0
9	34	3216	92520	11960	18100	18670	20270	23520	0	0	0	0	4	5	3216	984	206	1525	501	0	0	0	0	0
9	36	2949	92530	13880	15840	20650	20180	21980	0	0	0	0	4	5	2837	833	213	1591	200	0	0	0	0	0
9	56	6994	92550	16180	16430	19260	18350	22300	0	0	0	0	4	5	5828	1722	419	3287	400	0	0	0	0	0
9	65	6955	99920	17470	18660	19030	21570	23190	0	0	0	0	4	5	5989	1732	429	3428	400	0	0	0	0	0
9	65	7037	100030	18910	20870	20470	16920	22760	0	0	0	0	4	5	6167	1788	423	3553	403	0	0	0	0	0
9	32	2787	99960	18280	20490	21250	19440	20500	0	0	0	0	4	5	2787	964	213	1397	213	0	0	0	0	0
9	65	2993	100040	19500	19310	19650	20840	20740	0	0	0	0	4	5	2993	839	209	1745	200	0	0	0	0	0
9	34	2885	100050	16920	22680	20260	19110	21080	0	0	0	0	4	5	2885	797	209	1683	196	0	0	0	0	0
9	62	6151	100070	18970	20270	20850	18640	21340	0	0	0	0	4	5	4982	1368	423	2798	393	0	0	0	0	0
9	74	5892	100080	16610	18890	18880	23480	22220	0	0	0	0	4	5	5473	1729	419	2919	406	0	0	0	0	0
9	34	2984	100120	15790	19090	21520	21270	22450	0	0	0	0	4	5	2984	869	209	1706	200	0	0	0	0	0
9	68	7162	100210	15370	24440	23090	18770	18540	0	0	0	0	4	5	6396	1788	433	3769	406	0	0	0	0	0
9	33	2571	100220	15800	19500	21120	22640	21160	0	0	0	0	4	5	2571	633	213	1525	200	0	0	0	0	0
9	63	7165	100240	18910	20190	14520	23450	23170	0	0	0	0	4	5	6402	1719	419	3763	501	0	0	0	0	0
9	68	6679	100280	16180	19210	19510	20910	24470	0	0	0	0	4	5	5979	1971	426	3182	400	0	0	0	0	0
9	65	6876	100280	18850	19020	19700	20540	21770	0	0	0	0	4	5	5900	1735	429	3336	400	0	0	0	0	0
9	71	6847	100310	19020	20730	12880	24040	23640	0	0	0	0	4	5	6376	1952	449	2965	1010	0	0	0	0	0
9	74	6515	102290	17500	21940	22430	19250	21170	0	0	0	0	4	5	5824	1833	419	3172	400	0	0	0	0	0
9	65	6135	102320	13320	23790	23550	20370	21290	0	0	0	0	4	5	5798	1348	413	3631	406	0	0	0	0	0
9	31	2915	102350	49350	15000	16020	13080	8900	0	0	0	0	4	5	2915	754	187	1522	452	0	0	0	0	0
9	54	6686	102390	16240	22020	21470	19520	23140	0	0	0	0	4	5	5794	1715	419	3257	403	0	0	0	0	0
9	64	6952	102390	20190	17590	17460	23140	24010	0	0	0	0	4	5	5694	1574	433	3284	403	0	0	0	0	0
9	62	6948	102540	18260	20030	20560	20420	23270	0	0	0	0	4	5	6598	1948	426	3818	406	0	0	0	0	0
9	70	6837	102540	17420	23750	23720	18290	19360	0	0	0	0	4	5	5280	1486	429	2962	403	0	0	0	0	0
9	67	6151	102670	15520	21490	22400	22970	20290	0	0	0	0	4	5	5940	1719	429	3382	410	0	0	0	0	0
9	67	7030	102720	16340	21110	19980	21730	23560	0	0	0	0	4	5	6041	1817	436	2762	1026	0	0	0	0	0
9	74	6561	102720	20480	18760	20380	23400	19700	0	0	0	0	4	5	5845	1676	423	3343	403	0	0	0	0	0
9	64	6820	102720	17950	20150	17210	23060	24350	0	0	0	0	4	5	5723	1532	426	3362	403	0	0	0	0	0
9	65	6781	102760	16420	20280	20050	21990	21220	0	0	0	0	4	5	5982	1706	429	3441	406	0	0	0	0	0
9	63	6945	102760	16420	20500	20190	23700	21950	0	0	0	0	4	5	3941	1295	419	1827	400	0	0	0	0	0
9	68	4419	102780	13540	15470	14290	28320	31160	0	0	0	0	4	5	5093	1358	426	2883	426	0	0	0	0	0
9	62	5446	102820	15390	16870	21530	24450	24580	0	0	0	0	4	5	5792	1784	423	3175	410	0	0	0	0	0
9	71	6407	102870	19750	22790	19300	19640	21390	0	0	0	0	4	5	2846	790	213	1650	193	0	0	0	0	0
9	33	2965	102880	24220	20790	20380	19310	18180	0	0	0	0	4	5	5880	1738	429	3313	400	0	0	0	0	0
9	62	6558	102920	17130	21760	24160	18280	21590	0	0	0	0	4	5	6261	1807	472	3566	416	0	0	0	0	0
9	73	6729	102930	16840	19490	15450	22110	29040	0	0	0	0	4	5	5684	1916	426	2946	406	0	0	0	0	0
9	66	6161	108370	17370	21130	20400	24500	24970	0	0	0	0	4	5	5654	1499	429	3323	403	0	0	0	0	0
9	69	6643	108400	20730	19800	20800	23420	23650	0	0	0	0	4	5										

Vehicle Class (Scheme "F") Code	Speed of Vehicle (in mi/hr)	Length of Vehicle From Bumper to Bumper	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Numb ber of Axles	Wheel base distance from first axle to last axle (in ft)	Axle 1 Space 1- 2 (format mm mm)	Axle 2 Space 2- 3 (format mm mm)	Axle 3 Space 3- 4 (format mm mm)	Axle 4 Space 4- 5 (format mm mm)	Axle 5 Space 5- 6 (format mm mm)	Axle 6 Space 6- 7 (format mm mm)	Axle 7 Space 7- 8 (format mm mm)	Axle 8 Space 8- 9 (format mm mm)
9 75	6643	137150	53610	18740	23300	20160	21340	0	0	0	0	0	4	5	6061	1797	433	2801	1030	0	0	0
9 79	6778	138540	15060	31440	27880	30000	34160	0	0	0	0	0	4	5	6497	1768	488	3799	442	0	0	0
9 79	5738	147810	11610	43940	32860	28620	30780	0	0	0	0	0	4	5	5532	1338	488	3287	419	0	0	0
9 74	7365	149870	28160	57150	21880	20520	22160	0	0	0	0	0	4	5	6901	2191	462	3169	1079	0	0	0
9 76	7221	153100	16400	38020	37680	27660	33340	0	0	0	0	0	4	5	6490	1873	465	3723	429	0	0	0
9 79	6463	153790	15210	33160	36400	35860	33160	0	0	0	0	0	4	5	6002	1784	446	3349	423	0	0	0
9 70	7165	155480	60420	23320	25140	22800	23800	0	0	0	0	0	4	5	6678	1870	446	3300	1062	0	0	0
9 68	6827	156040	25600	66560	18620	22420	22840	0	0	0	0	0	4	5	6503	1817	452	3359	875	0	0	0
9 76	6998	157510	43500	56890	21960	17200	18020	0	0	0	0	0	4	5	6387	1850	456	2992	1089	0	0	0
9 72	6512	171140	79220	21280	22660	24160	23820	0	0	0	0	0	4	5	6005	1692	423	2900	990	0	0	0
9 74	7004	172920	60320	28480	28200	27400	28520	0	0	0	0	0	4	5	6504	2001	439	3041	1023	0	0	0
9 82	7493	196140	34790	65650	28300	33740	33660	0	0	0	0	0	4	5	7042	2185	465	3313	1079	0	0	0
10 60	6463	30180	11570	7250	3070	3600	2630	2060	0	0	0	0	5	6	5557	1610	393	2906	393	255	0	0
10 64	7276	32240	14950	5270	5740	2920	1910	1450	0	0	0	0	5	6	5914	1755	423	3179	282	275	0	0
10 75	7398	34280	14470	7730	7030	1920	1360	1770	0	0	0	0	5	6	5857	1906	449	2847	334	321	0	0
10 65	6017	36210	12050	10090	3370	3090	2760	4850	0	0	0	0	5	6	5929	1433	433	3257	403	403	0	0
10 65	6269	38640	12770	9080	2620	8530	3090	2550	0	0	0	0	5	6	5644	1640	426	2673	449	456	0	0
10 62	5583	40230	13620	9690	3090	2300	4150	7380	0	0	0	0	5	6	5539	1171	439	3136	403	390	0	0
10 71	6768	41180	12260	9150	2550	5490	5490	6240	0	0	0	0	5	6	6313	1627	436	3280	488	482	0	0
10 62	6181	41230	14390	8270	3400	4980	6450	3740	0	0	0	0	5	6	6060	1318	436	3408	449	449	0	0
10 34	3123	42650	11700	9970	8320	3110	5210	4340	0	0	0	0	5	6	2793	777	206	1502	154	154	0	0
10 38	3052	44990	12710	10490	10190	3690	3450	4460	0	0	0	0	5	6	3052	770	216	1620	223	223	0	0
10 73	6167	45420	11420	11670	10110	4120	2830	5270	0	0	0	0	5	6	5424	1719	459	2522	377	347	0	0
10 67	6457	45510	10200	8660	7820	5930	7320	5580	0	0	0	0	5	6	6457	1525	433	3503	495	501	0	0
10 39	3541	46650	12250	9470	12040	4660	4190	4040	0	0	0	0	5	6	3541	994	206	1916	206	219	0	0
10 36	3211	48890	13760	10270	10280	5820	5180	3600	0	0	0	0	5	6	2891	849	213	1532	147	150	0	0
10 36	3374	50270	11870	5860	7340	8620	8330	8250	0	0	0	0	5	6	3374	974	213	1692	249	246	0	0
10 62	5853	53020	16310	12120	5620	2900	6220	9850	0	0	0	0	5	6	5618	1187	433	3192	410	396	0	0
10 74	5633	53450	14260	12230	13550	5080	3940	4390	0	0	0	0	5	6	5463	1181	439	2998	426	419	0	0
10 37	3253	53740	14660	10910	10040	7090	5910	5130	0	0	0	0	5	6	3253	925	216	1666	223	223	0	0
10 65	6650	54930	12880	10090	11240	6130	7130	7460	0	0	0	0	5	6	6385	1571	433	3477	452	452	0	0
10 39	3413	55570	14790	8220	7900	10260	8380	6020	0	0	0	0	5	6	3413	994	216	1699	252	252	0	0
10 35	3619	56920	11630	9790	10410	9340	8470	6280	0	0	0	0	5	6	3619	866	206	987	4651	95	0	0
10 71	6571	57050	14740	11740	13200	4300	5790	7280	0	0	0	0	5	6	6274	1607	442	3405	410	410	0	0
10 60	7083	59520	16440	10470	12570	7660	6060	6320	0	0	0	0	5	6	6756	1837	429	3494	498	498	0	0
10 66	6781	62350	14580	11530	11970	7010	9110	8150	0	0	0	0	5	6	6499	1541	429	3526	498	505	0	0
10 70	6975	63890	10320	9780	12660	12570	11050	7510	0	0	0	0	5	6	5654	1145	419	3277	400	413	0	0
10 33	3453	68780	14220	12650	13180	8420	9870	440	0	0	0	0	5	6	3453	908	213	1840	246	246	0	0
10 35	3331	69980	17830	13520	11750	6920	10040	9920	0	0	0	0	5	6	3331	892	213	1820	206	200	0	0
10 62	7191	71240	12390	14420	13850	8590	10240	1750	0	0	0	0	5	6	5511	1548	419	3015	318	311	0	0
10 33	3252	74460	15220	13560	13760	10230	10880	800	0	0	0	0	5	6	6907	1948	426	3740	403	390	0	0
10 35	3420	74740	16330	14570	14710	9170	9600	360	0	0	0	0	5	6	3252	872	209	1771	200	200	0	0
10 58	6906	75820	19230	14150	15190	5430	11570	250	0	0	0	0	5	6	6582	1817	429	3448	442	446	0	0
10 34	2881	76030	10720	14770	15460	13400	9300	2380	0	0	0	0	5	6	2881	849	216	1374	223	219	0	0
10 37	3196	77040	12130	10270	10940	16030	10300	4030	0	0	0	0	5	6	3609	859	206	990	4591	95	0	0
10 33	3659	77770	14960	8930	11320	15060	13840	3660	0	0	0	0	5	6	3659	866	209	990	5051	89	0	0
10 71	8431	79100	22150	15740	16140	4080	11030	9960	0	0	0	0	5	6	8232	2211	488	4530	495	508	0	0
10 34	3386	79400	8850	17030	3700	17000	15860	6960	0	0	0	0	5	6	3386	629	226	964	4981	69	0	0
10 31	1743	79560	12830	11350	11690	13620	16250	3820	0	0	0	0	5	6	1743	718	213	406	203	203	0	0
10 34	81330	17190	13700	13110	12740	12080	2510	0	0	0	0	0	5	6	2744	882	216	1240	206	206	0	0
10 35	3287	81430	11880	15810	15690	12810	12730	2510	0	0	0	0	5	6	3072	990	216	1414	226	226	0	0
10 33	3567	81760	12800	12010	12360	14550	15230	4710	0	0	0	0	5	6	3567	813	213	994	4621	85	0	0
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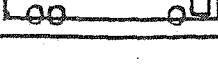
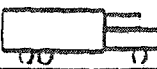
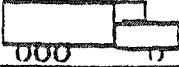
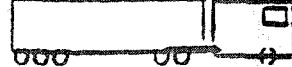
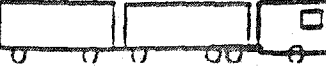
Vehicle Class (Scheme "g") Code	Speed of Vehicle (in m.p.h.)	Length of Vehicle From Bumper to Bumper	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Total Axle 9 Weight (in lbs)	Num ber of Axles	Wheel base - distance from first axle to last	Axle 1 (format mm mm)	Axle 2 (format mm mm)	Axle 3 (format mm mm)	Axle 4 (format mm mm)	Axle 5 (format mm mm)	Axle 6 (format mm mm)	Axle 7 (format mm mm)	Axle 8 (format mm mm)	Axle 9 (format mm mm)
10	35	3174	84060	15920	16550	15690	11540	12310	2050	0	0	0	5	6	3174	302	223	1607	219	223	0	0	0
10	34	3622	84160	14760	13880	13060	11570	16450	4440	0	0	0	5	6	3622	885	206	990	4561	85	0	0	0
10	31	2575	84590	14840	17200	16250	13240	11990	1070	0	0	0	5	6	2488	820	213	1059	193	203	0	0	0
10	36	2085	84680	9070	12030	12090	11630	198201	40	0	0	0	5	6	2085	866	213	803	203	200	0	0	0
10	35	3623	84700	18640	15710	8580	15900	198201	2370	0	0	0	5	6	3623	869	216	977	4721	89	0	0	0
10	67	7345	86950	19450	15730	15370	14610	11090	700	0	0	0	5	6	6503	1738	433	3500	413	419	0	0	0
10	35	3602	87210	12450	11640	13730	16710	15760	6920	0	0	0	5	6	3602	862	206	977	4651	92	0	0	0
10	61	7106	88840	21240	12710	12780	10830	20350	930	0	0	0	5	6	5840	1722	429	2778	436	475	0	0	0
10	36	2215	90000	14040	13960	13920	3750	212301	3100	0	0	0	5	6	2215	846	209	770	190	200	0	0	0
10	34	3389	91360	13930	16240	15100	15040	14110	6940	0	0	0	5	6	3135	1010	213	1509	203	200	0	0	0
10	37	2025	91560	10420	14340	14620	7810	198901	4480	0	0	0	5	6	2025	738	213	682	196	196	0	0	0
10	35	2429	91630	19960	12900	12890	15290	15000	5590	0	0	0	5	6	2429	843	213	948	216	209	0	0	0
10	35	2140	92360	11150	14400	14870	10330	220201	9590	0	0	0	5	6	2140	718	216	807	203	196	0	0	0
10	35	2185	94120	10420	16510	14860	14830	185301	8970	0	0	0	5	6	2185	780	216	784	209	196	0	0	0
10	35	2130	94850	10960	15120	15790	10420	224301	130	0	0	0	5	6	2130	715	209	810	200	196	0	0	0
10	76	6883	95030	16090	37520	20500	14670	16590	4260	0	0	0	5	6	5831	2339	387	2316	298	291	0	0	0
10	35	3085	95300	14660	17900	17220	14670	16590	4260	0	0	0	5	6	3085	725	216	1732	203	209	0	0	0
10	63	4484	97530	17350	14120	12610	12950	192001	1300	0	0	0	5	6	4059	1200	426	1538	492	403	0	0	0
10	36	2402	97970	10260	15660	14520	15380	207301	1420	0	0	0	5	6	2402	823	226	823	321	209	0	0	0
10	35	1942	98220	12490	15180	15140	11540	215401	2330	0	0	0	5	6	1942	636	209	682	209	206	0	0	0
10	36	3348	99420	18320	19560	18520	14700	13980	4340	0	0	0	5	6	3348	905	213	1735	249	246	0	0	0
10	33	2143	101170	10930	17390	15350	10260	227901	4450	0	0	0	5	6	2143	715	216	810	206	196	0	0	0
10	63	4471	101630	14440	13530	13010	14160	230701	3320	0	0	0	5	6	3522	974	213	1883	226	226	0	0	0
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10	34	2149	106540	13990	18210	15860	14490	217101	4280	0	0	0	5	6	2149	734	213	767	239	196	0	0	0
10	65	7017	106910	15710	26630	25160	11870	12530	5010	0	0	0	5	6	6671	1955	423	3487	400	406	0	0	0
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10	31	2741	107850	20690	15890	15540	23380	18190	4160	0	0	0	5	6	2741	784	213	1302	219	223	0	0	0
10	70	7352	108970	14980	23460	20810	21450	21790	6480	0	0	0	5	6	7098	1955	433	3789	446	465	0	0	0
10	63	7148	109350	19280	17280	16510	18720	17790	9770	0	0	0	5	6	5910	1748	433	2798	462	469	0	0	0
10	35	3319	110700	19110	21270	20220	17730	16470	5900	0	0	0	5	6	3319	889	213	1811	206	200	0	0	0
10	64	5925	112040	14880	20810	20030	23430	17510	5380	0	0	0	5	6	5523	1692	423	2490	459	459	0	0	0
10	66	4780	112300	14840	13760	14100	12880	292801	7440	0	0	0	5	6	4348	1486	433	1541	488	400	0	0	0
10	32	3573	114250	13240	16910	16110	26610	205501	830	0	0	0	5	6	3573	764	209	1036	4721	92	0	0	0
10	66	4799	118680	15300	15020	16230	13510	306101	8010	0	0	0	5	6	4357	1492	429	1541	492	403	0	0	0
10	59	7368	120020	24740	21620	22520	14210	176801	9250	0	0	0	5	6	6884	1794	426	3654	410	400	0	0	0
10	36	3529	124180	16150	27090	26770	17690	18320	8160	0	0	0	5	6	3529	1053	223	1801	226	226	0	0	0
10	65	6505	126090	15220	20520	22350	21740	223101	3950	0	0	0	5	6	6166	1204	426	3631	446	459	0	0	0
10	58	5623	137060	17920	26380	24860	20330	242901	1280	0	0	0	5	6	5521	1673	429	2303	403	413	0	0	0
10	35	3584	147440	38770	34130	18500	19960	17380	8700	0	0	0	5	6	3584	1187	226	1696	239	236	0	0	0
10	57	6095	149860	13900	32730	30170	25180	24320	3560	0	0	0	5	6	5647	1469	436	2926	403	413	0	0	0
11	70	7522	51410	13820	14430	9020	6740	7400	0	0	0	0	4	5	6971	1391	2339	889	2352	0	0	0	0
11	60	6893	52040	11320	12650	11420	10370	6280	0	0	0	0	4	5	6540	1249	2165	941	2185	0	0	0	0
11	62	6656	52120	11730	10920	11020	9800	8650	0	0	0	0	4	5	6432	1253	2063	941	2175	0	0	0	0
11	75	6824	52310	11530	14330	8730	10140	7580	0	0	0	0	4	5	6435	1223	2139	928	2145	0	0	0	0
11	68	6824	52310	10770	14360	8380	10690	8110	0	0	0	0	4	5	6616	1220	2175	958	2263	0	0	0	0
11	65	7519	52320	17480	11950	4440	10170	8280	0	0	0	0	4	5	7032	1719	2175	885	2253	0	0	0	0
11	67	6952	53120	15000	13890	8990	8430	6810	0	0	0	0	4	5	6450	1236	2089	921	2204	0	0	0	0
11	65	7089	53210	17500	11110	8140	10340	6120	0	0	0	0	4	5	6517	1279	2073	948	2217	0	0	0	0
11	68	7004	53420	12830	13620	12910	5730	8330	0	0	0	0	4	5	6534	1181	2227	879	2247	0	0	0	0
11	65	7089	53800	14240	11180	10810	7680	9890	0	0	0	0	4	5	6537	1272	2116	948	2201	0	0	0	0
11	65	7050	54050	13370	14450	13940	6210	6080	0	0	0	0	4	5	6547	1272	2116	958	2201	0	0	0	0
11	65	7004	54320	14840	13420	7790	11260	7010	0	0	0	0	4	5	6458	1240	2089	925	2204	0	0	0	0
11	62	6541	54680	13380	15100	13840	6330	6030	0	0	0	0	4	5	6264	1181	2063	908	2112	0	0	0	0
11	64	7257	54790	12580	12040	10230	7450	12490	0	0	0	0	4	5	6688	1295	2106	1066	2221	0	0	0	0

Vehicle Class (Scheme "F") Code	Speed of Vehicle (in km/h)	Length of Vehicle From Bumper to Bumper	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Num ber of Axles	Wheel base distance from first axle	Axle 2 Space 1 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872 873 874 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889 890 891 892 893 894 895 896 897 898 899 900 901 902 903 904 905 906 907 908 909 910 911 912 913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930 931 932 933 934 935 936 937 938 939 940 941 942 943 944 945 946 947 948 949 950 951 952 953 954 955 956 957 958 959 960 961 962 963 964 965 966 967 968 969 970 971 972 973 974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992 993 994 995 996 997 998 999 1000 1001 1002 1003 1004 1005 1006 1007 1008 1009 1010 1011 1012 1013 1014 1015 1016 1017 1018 1019 1020 1021 1022 1023 1024 1025 1026 1027 1028 1029 1030 1031 1032 1033 1034 1035 1036 1037 1038 1039 1040 1041 1042 1043 1044 1045 1046 1047 1048 1049 1050 1051 1052 1053 1054 1055 1056 1057 1058 1059 1060 1061 1062 1063 1064 1065 1066 1067 1068 1069 1070 1071 1072 1073 1074 1075 1076 1077 1078 1079 1080 1081 1082 1083 1084 1085 1086 1087 1088 1089 1090 1091 1092 1093 1094 1095 1096 1097 1098 1099 1100 1101 1102 1103 1104 1105 1106 1107 1108 1109 1110 1111 1112 1113 1114 1115 1116 1117 1118 1119 1120 1121 1122 1123 1124 1125 1126 1127 1128 1129 1130 1131 1132 1133 1134 1135 1136 1137 1138 1139 1140 1141 1142 1143 1144 1145 1146 1147 1148 1149 1150 1151 1152 1153 1154 1155 1156 1157 1158 1159 1160 1161 1162 1163 1164 1165 1166 1167 1168 1169 1170 1171 1172 1173 1174 1175 1176 1177 1178 1179 1180 1181 1182 1183 1184 1185 1186 1187 1188 1189 1190 1191 1192 1193 1194 1195 1196 1197 1198 1199 1200 1201 1202 1203 1204 1205 1206 1207 1208 1209 1210 1211 1212 1213 1214 1215 1216 1217 1218 1219 1220 1221 1222 1223 1224 1225 1226 1227 1228 1229 1230 1231 1232 1233 1234 1235 1236 1237 1238 1239 1240 1241 1242 1243 1244 1245 1246 1247 1248 1249 1250 1251 1252 1253 1254 1255 1256 1257 1258 1259 1260 1261 1262 1263 1264 1265 1266 1267 1268 1269 1270 1271 1272 1273 1274 1275 1276 1277 1278 1279 1280 1281 1282 1283 1284 1285 1286 1287 1288 1289 1290 1291 1292 1293 1294 1295 1296 1297 1298 1299 1300 1301 1302 1303 1304 1305 1306 1307 1308 1309 1310 1311 1312 1313 1314 1315 1316 1317 1318 1319 1320 1321 1322 1323 1324 1325 1326 1327 1328 1329 1330 1331 1332 1333 1334 1335 1336 1337 1338 1339 1340 1341 1342 1343 1344 1345 1346 1347 1348 1349 1350 1351 1352 1353 1354 1355 1356 1357 1358 1359 1360 1361 1362 1363 1364 1365 1366 1367 1368 1369 1370 1371 1372 1373 1374 1375 1376 1377 1378 1379 1380 1381 1382 1383 1384 1385 1386 1387 1388 1389 1390 1391 1392 1393 1394 1395 1396 1397 1398 1399 1400 1401 1402 1403 1404 1405 1406 1407 1408 1409 1410 1411 1412 1413 1414 1415 1416 1417 1418 1419 1420 1421 1422 1423 1424 1425 1426 1427 1428 1429 1430 1431 1432 1433 1434 1435 1436 1437 1438 1439 1440 1441 1442 1443 1444 1445 1446 1447 1448 1449 1450 1451 1452 1453 1454 1455 1456 1457 1458 1459 1460 1461 1462 1463 1464 1465 1466 1467 1468 1469 1470 1471 1472 1473 1474 1475 1476 1477 1478 1479 1480 1481 1482 1483 1484 1485 1486 1487 1488 1489 1490 1491 1492 1493 1494 1495 1496 1497 1498 1499 1500 1501 1502 1503 1504 1505 1506 1507 1508 1509 1510 1511 1512 1513 1514 1515 1516 1517 1518 1519 1520 1521 1522 1523 1524 1525 1526 1527 1528 1529 1530 1531 1532 1533 1534 1535 1536 1537 1538 1539 1540 1541 1542 1543 1544 1545 1546 1547 1548 1549 1550 1551 1552 1553 1554 1555 1556 1557 1558 1559 1560 1561 1562 1563 1564 1565 1566 1567 1568 1569 1570 1571 1572 1573 1574 1575 1576 1577 1578 1579 1580 1581 1582 1583 1584 1585 1586 1587 1588 1589 1590 1591 1592 1593 1594 1595 1596 1597 1598 1599 1600 1601 1602 1603 1604 1605 1606 1607 1608 1609 1610 1611 1612 1613 1614 1615 1616 1617 1618 1619 1620 1621 1622 1623 1624 1625 1626 1627 1628 1629 1630 1631 1632 1633 1634 1635 1636 1637 1638 1639 1640 1641 1642 1643 1644 1645 1646 1647 1648 1649 1650 1651 1652 1653 1654 1655 1656 1657 1658 1659 1660 1661 1662 1663 1664 1665 1666 1667 1668 1669 1670 1671 1672 1673 1674 1675 1676 1677 1678 1679 1680 1681 1682 1683 1684 1685 1686 1687 1688 1689 1690 1691 1692 1693 1694 1695 1696 1697 1698 1699 1700 1701 1702 1703 1704 1705 1706 1707 1708 1709 1710 1711 1712 1713 1714 1715 1716 1717 1718 1719 1720 1721 1722 1723 1724 1725 1726 1727 1728 1729 1730 1731 1732 1733 1734 1735 1736 1737 1738 1739 1740 1741 1742 1743 1744 1745 1746 1747 1748 1749 1750 1751 1752 1753 1754 1755 1756 1757 1758 1759 1760 1761 1762 1763 1764 1765 1766 1767 1768 1769 1770 1771 1772 1773 1774 1775 1776 1777 1778 1779 1780 1781 1782 1783 1784 1785 1786 1787 1788 1789 1790 1791 1792 1793 1794 1795 1796 1797 1798 1799 1800 1801 1802 1803 1804 1805 1806 1807 1808 1809 1810 1811 1812 1813 1814 1815 1816 1817 1818 1819 1820 1821 1822 1823 1824 1825 1826 1827 1828 1829 1830 1831 1832 1833 1834 1835 1836 1837 1838 1839 1840 1841 1842 1843 1844 1845 1846 1847 1848 1849 1850 1851 1852 1853 1854 1855 1856 1857 1858 1859 1860 1861 1862 1863 1864 1865 1866 1867 1868 1869 1870 1871 1872 1873 1874 1875 1876 1877 1878 1879 1880 1881 1882 1883 1884 1885 1886 1887 1888 1889 1890 1891 1892 1893 1894 1895 1896 1897 1898 1899 1900 1901 1902 1903 1904 1905 1906 1907 1908 1909 1910 1911 1912 1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 1940 1941 1942 1943 1944 1945 1946 1947 1948 1949 1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057 2058 2059 2060 2061 2062 2063 2064 2065 2066 2067 2068 2069 2070 2071 2072 2073 2074 2075 2076 2077 2078 2079 2080 2081 2082 2083 2084 2085 2086 2087 2088 2089 2090 2091 2092 2093 2094 2095 2096 2097 2098 2099 2100 2101 2102 2103 2104 2105 2106 2107 2108 2109 2110 2111 2112 2113 2114 2115 2116 2117 2118 2119 2120 2121 2122 2123 2124 2125 2126 2127 2128 2129 2130 2131 2132 2133 2134 2135 2136 2137 2138 2139 2140 2141 2142 2143 2144 2145 2146 2147 2148 2149 2150 2151 2152 2153 2154 2155 2156 2157 2158 2159 2160 2161 2162 2163 2164 2165 2166 2167 2168 2169 2170 2171 2172 2173 2174 2175 2176 2177 2178 2179 2180 2181 2182 2183 2184 2185 2186 2187 2188 2189 2190 2191 2192 2193 2194 2195 2196 2197 2198 2199 2200 2201 22
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Vehicle Class (Scheme "P") Code	Speed (in km/h)	Length of Vehicle From Bumper (in)	Gross Weight of Vehicle (in lbs)	Total Axle 1 Weight (in lbs)	Total Axle 2 Weight (in lbs)	Total Axle 3 Weight (in lbs)	Total Axle 4 Weight (in lbs)	Total Axle 5 Weight (in lbs)	Total Axle 6 Weight (in lbs)	Total Axle 7 Weight (in lbs)	Total Axle 8 Weight (in lbs)	Axle 1 Weight (in lbs)	Axle 2 Weight (in lbs)	Axle 3 Weight (in lbs)	Axle 4 Weight (in lbs)	Axle 5 Weight (in lbs)	Axle 6 Weight (in lbs)	Axle 7 Weight (in lbs)	Axle 8 Weight (in lbs)	Axle 9 Weight (in lbs)	Space 7 (format from max)	Space 8 (format from max)	Space 9 (format from max)	
12	68	7188	68650	12210	15350	11120	10850	11390	7730	0	0	0	6480	1000	426	2037	8722	145	0	0	0	0	0	0
12	67	7700	68990	14850	12430	11930	15480	8120	6380	0	0	0	5	6	7202	1679	429	1975	9382	181	0	0	0	0
12	65	7903	69870	21610	8910	8440	10750	8070	2090	0	0	0	5	6	67369	1702	436	2089	8892	253	0	0	0	0
12	55	7253	69910	10580	12160	10080	13610	13090	390	0	0	0	5	6	67566	1154	426	1994	9582	224	0	0	0	0
12	68	7142	71040	12000	11600	11060	11850	13830	700	0	0	0	5	6	6783	1128	423	2070	8822	280	0	0	0	0
12	53	5567	71740	39100	7960	8100	6700	5440	4440	0	0	0	5	6	5247	1266	305	1423	6951	558	0	0	0	0
12	71	7339	73340	16420	10000	9490	14960	13190	9280	0	0	0	5	6	6691	1138	439	1965	9642	185	0	0	0	0
12	55	7001	73390	13230	11330	9120	15720	12090	1900	0	0	0	5	6	6644	1135	426	1961	9312	191	0	0	0	0
12	70	7916	73570	15620	9930	10750	15050	11720	500	0	0	0	5	6	7274	1653	429	2060	8622	270	0	0	0	0
12	78	8415	74700	26770	8250	7480	12520	9960	9720	0	0	0	5	6	7727	1837	475	2043	10302	342	0	0	0	0
12	68	7821	76110	15250	11620	11360	11470	14260	2150	0	0	0	5	6	7448	1738	423	2109	8822	296	0	0	0	0
12	64	7585	79840	18170	11970	12140	18480	12120	6960	0	0	0	5	6	7067	1571	419	1948	9382	191	0	0	0	0
12	71	7729	80290	15340	10250	10420	13910	15580	4790	0	0	0	5	6	7169	1479	429	2089	8822	290	0	0	0	0
12	67	7854	80960	17040	12990	13140	16120	10740	930	0	0	0	5	6	7206	1509	426	2093	9842	194	0	0	0	0
12	71	8028	82230	15590	14410	11410	13600	12990	4230	0	0	0	5	6	7307	1643	429	2014	10202	201	0	0	0	0
12	70	7857	82230	18600	11280	11560	13750	12990	9830	0	0	0	5	6	7438	1745	426	2112	8792	276	0	0	0	0
12	69	7975	82270	14570	13790	13320	13280	13020	4290	0	0	0	5	6	7298	1778	433	1968	9442	175	0	0	0	0
12	69	7877	83890	16460	14070	15300	10140	15420	2500	0	0	0	5	6	8029	2066	449	2185	9252	404	0	0	0	0
12	73	8556	85400	14160	12080	11780	15180	17290	4910	0	0	0	5	6	7452	1804	423	2116	8692	240	0	0	0	0
12	65	7890	86200	20390	11680	13040	16460	12800	1830	0	0	0	5	6	7169	1532	419	2083	9312	204	0	0	0	0
12	65	7634	86470	14640	15760	15720	16600	13430	320	0	0	0	5	6	7205	1541	416	2089	9512	208	0	0	0	0
12	64	7749	87980	12650	14270	15190	18540	15870	1460	0	0	0	5	6	7941	1873	456	2270	9412	401	0	0	0	0
12	72	8490	89940	15480	14690	14010	14760	15420	5580	0	0	0	5	6	7184	1601	423	2001	9512	208	0	0	0	0
12	65	7933	92600	16910	13540	14140	18550	15040	4420	0	0	0	5	6	7541	1958	433	2011	8822	257	0	0	0	0
12	63	7959	93020	15980	13830	13550	19940	17830	1890	0	0	0	5	6	7468	1968	419	1929	9442	208	0	0	0	0
12	71	8080	94390	17700	14450	16830	15050	13930	6430	0	0	0	5	6	4446	757	288	1292	6431	466	0	0	0	0
12	48	4652	97390	38430	8480	8540	12820	17480	1640	0	0	0	5	6	7626	1998	423	2066	9482	191	0	0	0	0
12	74	8264	100000	17930	14550	17000	20450	15820	4250	0	0	0	5	6	7252	1729	416	1958	8892	260	0	0	0	0
12	70	7844	100180	19060	15380	17360	17110	15900	5370	0	0	0	5	6	6714	1066	439	2014	9872	208	0	0	0	0
12	65	7270	100560	15900	14640	14470	19080	17510	8960	0	0	0	5	6	6880	1049	429	2001	9872	214	0	0	0	0
12	66	7362	100650	12240	15180	12740	24170	20320	6000	0	0	0	5	6	7150	1535	436	1965	9412	273	0	0	0	0
12	68	7604	101950	15240	14380	15750	21720	166101	8250	0	0	0	5	6	7384	1801	423	1952	9942	214	0	0	0	0
12	70	7844	105040	18060	17150	17340	23220	15120	4150	0	0	0	5	6	7510	1797	436	2037	9642	276	0	0	0	0
12	73	8244	108040	51300	9700	9720	12380	13660	1280	0	0	0	5	6	7696	1656	449	2230	10032	358	0	0	0	0
12	72	8251	118050	22750	32660	12980	15500	20120	4040	0	0	0	5	6	7472	1778	439	2034	9122	309	0	0	0	0
12	70	8011	120750	48150	11560	11140	16820	17940	5140	0	0	0	5	6	7222	1719	416	1942	9412	204	0	0	0	0
12	70	7680	121280	18300	17050	18280	20400	24850	2400	0	0	0	5	6	7037	1213	462	2004	10262	332	0	0	0	0
12	76	7601	127440	28220	43740	14560	14940	14100	1880	0	0	0	5	6	5995	1397	351	1656	7151	876	0	0	0	0
12	56	6427	130680	58680	13420	11260	17320	16040	3960	0	0	0	5	6	7858	1863	452	2132	10822	329	0	0	0	0
12	70	8474	135620	45910	40650	14080	11980	11020	1980	0	0	0	5	6	8330	1994	488	2253	10892	506	0	0	0	0
12	79	9229	147390	64670	14420	16220	20480	15900	5700	0	0	0	5	6	7245	1233	452	2142	10922	326	0	0	0	0
12	75	8106	151300	61860	15920	14100	20260	19880	9280	0	0	0	5	6	8590	2250	495	2257	10822	506	0	0	0	0
12	80	9370	159510	90670	15220	14100	13820	14020	1680	0	0	0	5	6	7750	1833	452	2109	9942	362	0	0	0	0
12	75	8353	165050	23290	41680	18340	26520	315601	3560	0	0	0	5	6	7476	1761	433	2057	9582	267	0	0	0	0
12	69	7900	168050	55730	19280	16200	25100	299601	1780	0	0	0	5	6	7688	1712	449	2093	11122	322	0	0	0	0
12	72	8185	168180	83480	17060	14320	19740	19020	4560	0	0	0	5	6	8007	1935	456	2247	9122	457	0	0	0	0
12	75	8536	182480	45660	56660	20520	20400	20880	8360	0	0	0	5	6	0	0	0	0	0	0	0	0	0	0
12	87	306	655350	0	0	0	0	0	0	0	0	0	8	9	0	0	0	0	0	0	0	0	0	0
13	32	3324	32420	4330	9220	5140	5870	4140	2140	1580	0	0	6	7	3324	692	994	134	141	921	442	0	0	0
13	36	6008	41330	12820	7880	7710	2470	4200	3840	2410	0	0	6	7	6008	820	203	1742	1932	503	547	0	0	0
13	37	5355	42480	11130	8450	8220	6920	3360	2110	2290	0	0	6	7	5355	633	209	1479	2002	401	433	0	0	0
13	38	44151	44390	10680	15840	5600	2470	5570	3970	260	0	0	6	7	4151	728	2516	236	246	255	170	0	0	0
13	25	11155	51470	8650	19880	10880	3840	1060	660	0	0	0	6	7	1115	1781	334	1902	35433	264	331	0	0	0
13	62	11448	52340	16190	11450	10240	6930	5060	1580	890	0	0	6	7	1060	1597	433	3077	4034	209	882	0	0	0
13	30	3452	55320	5860	9790	10360	8810	8040	6720	0	0	0	6	7	3452	885	282	905	1000	177	203	0	0	0
13	76	15725	57650	6310	4710	13030	10780	11020	5800	6000	0	0	6	7	8524	1069	820	1866	4593	2511	59	0	0	0

	Record Code	7=weight 4=class	Rec. code
	State Code FL = 12	12	State code
	Highway Functional Class	02	Func class
	Station I.D. Number	029 5	Station ID#
	Direction 1= North, 3=East, 5=South, 7=West	5	Direction
	YEAR / MONTH / DAY	6/1/92	Date (M-D-Y)
	Hour of Day	6	Time
	Vehicle Classification Number	332000	Ven.type code
	Open	999	Open
	Open	999	Open
	Open	0009 5	Open
	(x 1000 lb) Gross Vehicle Weight(read --)	0009 5	Lane of travel
	Open	999999	Open
	Total-axle weight (hundreds of pounds)	665	Tot.wgt x100 lbs
	A-axle weight (hundreds of pounds)	247	A-ax wgt x100 lbs
	B-axle weight (hundreds of pounds)	707	B-ax wgt x100 lbs
	C-axle weight (hundreds of pounds)	161	C-ax wgt x100 lbs
	D-axle weight (hundreds of pounds)	148	D-ax wgt x100 lbs
	E-axle weight (hundreds of pounds)	120	E-ax wgt x100 lbs
	A-B axle spacing (divide by 10 --)	123	A-B ax spac ft/10
	B-C axle spacing (divide by 10 --)	41	B-C ax spac ft/10
	C-D axle spacing (divide by 10 --)	25	C-D ax spac ft/10
	D-E axle spacing (divide by 10 --)	41	D-E ax spac ft/10
	Total Wheel Base(axle spacing)	480	Tot W-base ft/10
	Recreational Serial Number	003	Rec. serial #
	Continuation Code (for more than 5 axes)	0	Continue Ind.

FHWA CLASSIFICATION

CLASS GROUP	CLASS NO. & TYPE	DESCRIPTION	NO. OF AXLES
1	NOT INCLUDED	MOTORCYCLES	
2	NOT INCLUDED	ALL CARS	
3	NOT INCLUDED	PICK-UPS & VANS	
190200		BUSES	2
190300		BUSES	3
220000		2 AXLE, SINGLE UNIT	2
230000		3 AXLE, SINGLE UNIT	3
240000		4 AXLE, SINGLE UNIT	4
321000		2 AXLE TRACTOR 1 AXLE TRAILER	3
322000		2 AXLE TRACTOR 2 AXLE TRAILER	4
322000		3 AXLE TRACTOR 1 AXLE TRAILER	4
332000		3 AXLE TRACTOR 2 AXLE TRAILER	5
332000		3 AXLE TRUCK 2 AXLE TRAILER	5
333000		3 AXLE TRACTOR 3 AXLE TRAILER	6
521200		5 AXLE MULTI-TRAILER	5
531200		6 AXLE MULTI-TRAILER	6

APPENDIX –C

KENLAYER OUT PUT FILES

Input Parameters for KENLAYER

For ease of references, input parameters are listed in alphabetical order. Either English or SI unit can be used depending on whether the input parameter NUNIT is 0 or 1. In U. S. customary unit, length is in inches (in.); pressure, stress, or modulus is in pounds per square inch (psi); and unit weight is in pounds per cubic feet (pcf). In SI unit, length is in centimeters (cm), pressure is in kilonewtons per square meter (kN/m² or kPa), and unit weight is in kilonewtons per cubic meter (kN/m³). The actual unit to be used for each input parameter is shown on the input screen to avoid confusion.

The conversion of nonlinear coefficient K1 of granular material from English to SI units needs clarification. According to Eq. 3.8, p. 100, $E = K1(\theta)^{K2}$, where θ is the first stress invariant or the sum of the three principal stresses. If English unit is used to plot E vs θ , then E, K1 and θ are in psi. If SI unit is used for the plot, they are all in kPa. To convert K1 from psi to kPa, the effect of θ on K1 should also be considered. Since $E = K1 \times 6.895 \times (\theta / 6.895)^{K2}$, $K1 \text{ in Pa} = (K1 \text{ in psi}) \times (6.895)^{(1 - K2)}$. For example, if $K1 = 10,000 \text{ psi}$ and $K2 = 0.4$, then $K1 = 10,000 \times (6.895)^{(1 - 0.4)} = 31,860 \text{ kPa}$.

The input parameters are listed below with the maximum dimension of each array shown. The parameter which determines the actual dimension is indicated in parentheses after the definition.

BETA(12) - temperature shift coefficient, or the slope of time-temperature shift factor versus temperature on a semilog plot (NVL), as shown in Figure 2.38, p. 85. For hot mix asphalt, use 0.113.

CP(12) - contact pressure on circular loaded area (NLG).

CR(12) - contact radius of circular loaded area (NLG).

CREEP(12,15) - creep compliance at reference temperature (NVL, NTYME).

DEL - tolerance for integration involving Bessel functions, 0.001 suggested.

DELNOL - tolerance for nonlinear analysis, 0.01 suggested.

DUR - duration of moving loads, assign 0 for stationary loads, 0.1 sec for 40 mph and increasing proportionately with decreasing speed.

E(19,12) - elastic modulus of each layer (NL,NPY). Use as assumed modulus when the layer is nonlinear. Assign 0 or any value for viscoelastic layer.

EMAX(12,12) - maximum elastic modulus of clayed layer (NOLAY,NPY). If EMAX is assigned a very large value, there is no horizontal cutoff line and the sloping K3 line will be extended until it hits the vertical axis (see Figure 3.6, p. 102).

EMIN(12,12) - minimum elastic modulus of clayey layer (NOLAY,NPY). If EMIN is assigned 0, there is no horizontal cutoff line and the sloping K4 or K3 line will be extended until it hits the horizontal axis (see Figure 3.6, p. 102).

FT(5,19) - damage coefficients (5, NL). Subscripts 1, 2 and 3 are the fatigue coefficients for bottom tension as shown by Eq. 3.6, p. 98, and subscripts 4 and 5 are the permanent deformation coefficients for top compression, as shown by Eq. 3.7, p. 98. Values suggested by the Asphalt Institute are 0.0796 (0.414 for SI unit), 3.291, 0.854, 1.365E-9, and 4.477.

GAM(19) - unit weight of each layer (NL). Suggested values are 145 pcf (22.8 kN/m³) for HMA, 135 pcf (21.2 kN/m³) for granular materials, and 125 pcf (19.6 kN/m³) for soil.

ICL - maximum number of integration cycles involving Bessel functions,

80 suggested.

INT(18) - condition at each interface (NL - 1). Assign 1 for bonded interface and 0 for frictionless interface.

ITENOL - maximum number of iterations for nonlinear analysis, 15 suggested.

KO(12) - coefficient of earth pressure at rest (NOLAY). Suggested values are 0.6 for granular materials and 0.8 for fine grained soils.

K1(12,12) - nonlinear coefficient of granular layer or break point modulus for clayey layer (NOLAY, NPY).

K2(12) - nonlinear exponent for granular layer or deviator stress at break point for clayey layer (NOLAY).

K3(12) - slope of straight line relationship between resilient modulus and deviator stress for clayey layer when the deviator stress is smaller than K2 (NOLAY).

K4(12) - slope of straight line relationship between resilient modulus and deviator stress for clayey layer when the deviator stress is greater than K2 (NOLAY).

LAYNO(12) - nonlinear layer number at which elastic modulus is stress dependent (NOLAY).

LNBT(19) - layer number for damage analysis of bottom tension (NL).

LNTC(19) - layer number for damage analysis of top compression (NL).

LVN(12) - layer number which is viscoelastic (NVL).

LOAD(12) - type of loadings, 0 for single axle with single tire, 1 for single axle with dual tires, 2 for tandem axles, and 3 for tridem axles (NLG).

MATL - material property, 1 for linear elastic, 2 for nonlinear elastic, 3 for linear viscoelastic, and 4 for combination of nonlinear elastic and linear viscoelastic.

NCLAY(12) - type of nonlinear layer (NOLAY). Assign 1 for clayey layer and 0, or any value other than 1, for granular layer.

NDAMA - index for damage analysis, 0 for no damage analysis, 1 for damage analysis with summary printout, and 2 for damage analysis with detailed printout.

NBOND - type of interface between two layers, 1 when all layers are bounded and 0 when some interfaces are unbonded or frictionless.

NL - total number of layer, maximum 19.

NLBT - number of layers for bottom tension, maximum 19.

NLG - number of load groups, maximum 12.

NLTC - number of layers for top compression, maximum 19.

NOLAY - number of nonlinear layer, maximum 12.

NPROB - number of problems to be solved, maximum 5.

NPT(12) - number of points in x and y coordinates to be analyzed under multiple wheels, maximum 25 (NLG).

NPY - number of periods per year, maximum 12.

NR(12) - number of radial coordinates to be analyzed under a single wheel, maximum 25 (NLG).

NSTD - computing code, 1 for vertical displacements only, 5 for vertical displacements and four stresses, and 9 for vertical displacements, four stresses, and four strains.

NTYME - number of times at which creep compliances are to be inputted, maximum 15, suggested 11.

NUNIT - system of unit, 0 for English unit and 1 for SI unit.

NVL - number of viscoelastic layers, maximum 12.

NZ - number of vertical distances to be analyzed, maximum 19. Assign 0 when NDAMA = 1 or 2

PHI(12,12) - angle of internal friction of granular layer (NOLAY, NPY).

Three methods can be used for nonlinear analysis. In method 1, PHI is assigned 0 so no tension is allowed. In method 2 PHI is assigned a large value representing the minimum modulus of the granular material, so no stress adjustment is needed. In method 3. PHI is assigned a realistic friction angle between 30 to 60.

PR (19) - Poisson 's ratio of each layer (NL). Suggested values are 0.3 for HMA and granular materials and 0.45 for fine grained soils.

RC(25, 12) - radial distance, or r coordinate, of each point to be analyzed (NR(NLG),NLG).

RCNOL - radial coordinate on pavement surface for computing elastic modulus of nonlinear layer under single wheel. Assign 0 or any value if there is no single wheel. The same RCNOL is used for all load groups with a single wheel.

RELAX(12) - relaxation factor for nonlinear analysis, 0.5 suggested(NPY). The use of relaxation factor is to insure the convergence of elastic modulus. If the results diverge, smaller relaxation factors should be used.

SLD - slope of load distribution for computing the elastic modulus of nonlinear layer.

TEMP(12,12) - pavement temperature for each viscoelastic layer during each period (NPY, NVL).

TEMREF(12) - reference temperature of each viscoelastic layer at which creep compliances are determined (NVL).

TH(18) - thickness of each layer (NL-1). The last layer is infinite in thickness and need not be inputted.

TITLE - any title or comments, if possible, not more than 68 characters including spaces.

TNLR(12,12) - total predicted number of load repetitions for each load group in each period (NPY,NLG).

TYME(15) - times at which creep compliances are to be inputted (NTYME). Suggested values with NTYME of 11 are 0.001, 0.003, 0.01, 0.03, 0.1, 0.3, 1, 3, 10, 30, 100 sec.

XPT(25) - x coordinates of points to be analyzed (NPT).

XPTNOL - x coordinate of point on pavement surface for computing elastic modulus of nonlinear layer under multiple wheels. Assign 0 or any value if there are no multiple wheels. The same XPTNOL is used for all load groups with multiple wheels.

XW(12) - center to center spacing between two axles along x axis (NLG). Assign 0 if only one axle exists.

YPT(25) - y coordinates of points to be analyzed (NPT).

YPTNOL - y coordinate of point on pavement surface for computing elastic modulus of nonlinear layer under multiple wheels. Assign 0 or any value if there are no multiple wheels. The same YPTNOL is used for all load groups with multiple wheels.

YW(12) - center to center spacing between two dual wheels along y axis (NLG). Assign 0 if there is only one wheel.

ZC(19) - vertical distance, or z coordinate, of each point (NZ). When the point is located exactly at the interface between two layers, the results are at the bottom of upper layer. If the results at the top of lower layer are desired, a slightly larger z coordinate, say 0.0001 or larger, should be used.

ZCNOL(12) - z coordinate of points for computing elastic modulus of nonlinear layer (NOLAY). If the base or subbase is subdivided into several layers, as suggested for method 1, the points are located at the midheight of each layer with PHI =0. If they are not subdivided, the upper third or quarter point will be used with PHI = K1, as suggested for method 2, and a

page 4: Input Parameters for KENLAYER

point at the midheight with $\text{PHI} = 40$ for a weak subgrade and $\text{PHI} = 50$ for a strong subgrade will be used, as suggested for method 3.

Output Parameters for KENLAYER

Every input parameter, after being read in, will be printed out for inspection. In most cases, the definition of the parameter, in addition to the variable name, is printed for easy understanding. The text is stored in a file with an extension .TXT.

SINGLE WHEEL VERSUS MULTIPLE WHEELS

The soil mechanics sign convention is used with compression as positive and tension as negative. The form of output depends on whether single or multiple loads are specified.

For a single load, the point at which responses are sought is identified by both radial and vertical coordinates (RC,ZC) and a maximum of nine responses can be obtained: vertical displacement, vertical stress, vertical strain, radial stress, radial strain, tangential stress, tangential strain, shear stress, and shear strain. Only the vertical compressive strain on the surface of subgrade and the radial (or tangential) tensile strain at the bottom of asphalt layer are used for damage analysis.

For multiple loads, the response points are identified by point number defined by x and y coordinates (XPT,YPT), together with the vertical coordinate ZC, and a maximum of ten responses can be obtained: vertical displacement, horizontal principal strain, vertical stress, vertical strain, major principal stress, major principal strain, minor principal stress, minor principal strain, intermediate principal stress, and intermediate principal strain. Only the vertical compressive strain on the surface of subgrade and the horizontal principal strain in tension at the bottom of asphalt layer are used for damage analysis. Note that the horizontal principal strain is a two-dimensional strain computed by Eq. 3.4, p. 97, and may be slightly different from the three-dimensional minor principal strain. In addition to the above ten required items, the following message will appear when NPY = 1, NLG = 1, and NDAMA = 0: 'Do you want to print all the components of stresses and strains in addition to the vertical stresses and strains and the three principal stresses and strains?' If the 'Yes' button is clicked, all components of normal and shear stresses and strains in x, y and z directions will be printed.

The number of responses is controlled by the input parameter NSTD. If NSTD = 1, only vertical displacements will be computed; if NSTD = 5, only one displacement and four stresses will be computed at each point; and if NSTD = 9, all nine items (plus the horizontal principal strain for multiple loads) will be computed. For damage analysis, NSTD must be specified as 9.

During the execution of KENLAYER, some information will be printed on the screen to show that the program is running. Everytime when the procedure LAYERS is executed, the actual number of cycles, IC, for numerical integration is printed on the screen. This number should be smaller than the maximum ICL of 80, otherwise the results have not converged. If the problem is nonlinear, the previous and the new elastic moduli of each nonlinear layer will be printed on the screen during each iteration. The maximum number of iterations (ITENOL) is 15 by default. When a run is completed but the moduli have not converged to the desired accuracy, a rerun should be made using a large ITENOL until the results converge. Printouts for nonlinear elastic systems are the same as linear elastic systems except that the vertical geostatic stress at each stress point, the elastic moduli of all nonlinear layers during each iteration, and the three normal stresses to compute the final modulus of each granular layer are printed.

In the case of viscoelastic systems under moving loads, the output is the same as that in the case of elastic systems. However, if the load is stationary, the solution at each time duration will be printed.

For damage analysis with summary printout (NDAMA = 1), the critical strain in each specified layer together with the allowable number of repetitions and damage ratio is printed for each load group in each period. The damage ratios at the end of a year, the maximum damage ratio, and the design life in years are also printed. For damage analysis with detailed printout (NDAMA = 2), in addition to the above summary information, tables of complete responses will be printed for each load group during each period.

Data File for KENLAYER

To facilitate entering and editing data, a program named LAYERINP can be used. The program uses menus and data entry forms to create and edit the data file.

The arrangement of data file is listed below. The file can be set up automatically by LAYERINP or entered manually according to the arrangement listed below. By using LAYERINP, it is really not necessary to know the data arrangement. This listing is useful only to experienced users who may like to edit the data more expediently by an editor rather than by LAYERINP. When the data file is set up by LAYERINP, each line is identified at the end by a number in parentheses, which indicates the line number, followed by one or more input parameters. If an error occurs in the data file, KENLAYER will use the line number to pinpoint the location of the error. The listing can also be used to check the correctness of the data file using EDITOR, instead of LAYERINP. Any format can be used to edit the data. The only requirements are that each input value must be separated by one or more spaces and that each line must be ended with the correct line number in parentheses with or without the input list. A line can be arbitrarily broken into several lines with the identifier at the end of the last line. If an asterisk appears before the step number, the step may be skipped under the condition specified.

Because of its conciseness, the FORTRAN method is used to describe repetitions. For example, $(X(I), Y(I), I=1, N)$ means that the data be read in the following order: $X(1), Y(1), X(2), Y(2), \dots, X(N), Y(N)$.

- (1) 1 line NPROB
- (2) 1 line TITLE
Title should not be more than 68 characters including spaces. This is the only line where identifier (2) TITLE is not needed
- (3) 1 line MATL, NDAMA, NPY, NLG
- (4) 1 line DEL
- (5) 1 line NL, NZ, ICL, NSTD, NUNIT
- (6) 1 line $(TH(I), I=1, NL - 1)$
- (7) 1 line $(PR(I), I=1, NL)$
- * (8) 1 line $(ZC(I), I=1, NZ)$
Skip if NDAMA = 1 or 2.
- (9) 1 line NBOND
- * (10) 1 line $(INT(I), I=1, NL - 1)$
Skip if NBOND = 1.
- (11) NPY lines $(E(I, J), I=1, NL)$
Each period, as indicated by the subscript J from 1 to NPY, should begin with a new line. $E = 0$ or any value if layer is viscoelastic.
- (12) There is a do loop for load from steps 13 to 21. The load number is indicated by the subscript J which starts from 1 to NLG.
- (13) 1 line LOAD(J)
- (14) 1 line CR(J), CP(J)
- (15) If $LOAD(J) > 0$, go to (19)
- (16) 1 line NR(J)
- (17) 1 line $(RC(I, J), I=NR)$
- (18) go to (21)
- (19) 1 line NPT(J)
- (20) 1 line $XW(J), YW(J), (XPT(I), YPT(I), I=1, NPT)$
- (21) Go to (13) NLG times, one for each load
- (22) If MATL = 1, go to (45)

```

(23)  If MATL = 2 or 4, go to (25)
(24)  If MATL = 3, go to (36)
(25)  1 line NOLAY,ITENOL
(26)  1 line (LAYNO(I),NCLAY(I),I=1,NOLAY)
(27)  1 line (ZCNOL(I),I=1,NOLAY)
(28)  1 line RCNOL,XCNOL,YNOL,SLD,DELNOL
(29)  1 line (RELAX(I),I=1,NPY)
(30)  1 line (GAM(I),I=1,NL)
(31)  NOLAY lines. For each nonlinear layer, check whether it is clayey
      or granular material. Each nonlinear layer, as indicated by the
      subscript I from 1 to NOLAY, should begin with a new line.
      If NCLAY(I) <> 1, i.e. the layer is granular, then
      1 line K2(I),K0(I)
      If NCLAY(I) = 1, or the layer is clay, then
      1 line K2(I),K3(I),K4(I),K0(I)
(32)  There is a do loop for period from steps 33 to 34. The period
      number is indicated by the subscript J from 1 to NPY
(33)  NOLAY lines. For each nonlinear layer, check whether it is clayey
      or granular material. Each nonlinear layer, as indicated by the
      subscript I from 1 to NOLAY, should begin with a new line.
      If NCLAY(I) <> 1, i.e. the layer is granular, then
      1 line PHI(I,J),K1(I,J)
      If NCLAY(I) = 1, or the layer is clay
      1 line EMIN(I,J),EMAX(I,J),K1(I,J)
(34)  Go to (33) NPY times, one for each period
(35)  If MATL = 2, go to (45)
(36)  1 line DUR
      DUR = 0 for stationary load.
(37)  1 line NVL,(LNV(I),I=1,NVL)
(38)  1 line NTYPE
(39)  1 line (TYME(J),J=1,NTYPE)
(40)  There is a do loop for viscoelastic layer from steps 41 to 43. The
      viscoelastic layer number is indicated by subscript I from 1 to NVL
(41)  1 line BETA(I),TEMPREF(I)
(42)  1 line (CREEP(I,J),J=1,NTYPE)
(43)  Go to (41) NVL times, one for each viscolastic layer
(44)  NPY lines (TEMP(I),I=1,NVL)
(45)  If NDAMA = 0, go to (52)
(46)  1 line NLBT,NLTC
*(47)  1 line (LNBT(I),I=1,NLBT)
      Skip if NLBT = 0.
*(48)  1 line (LNTC(I),I=1,NLTC)
      Skip if NLTC = 0.
(49)  NPY lines (TNLR(I,J),J=1,NLG)
      Each period, as indicated by the subscript I from 1 to NPY , should
      begin with a new line.
*(50)  NLBT lines FT(1,I),FT(2,I),FT(3,I)
      Each layer, as indicated by the subscript I from 1 to NLBT, should
      begin with a new line.
      Skip if NLBT = 0.
*(51)  NLTC lines FT(4,I),FT(5,I)
      Each layer, as indicated by the subscript I from 1 to NLTC, should
      begin with a new line
      Skip if NLTC = 0.
(52)  Go to (2) NPROB times

```

ESAL Test.TXT

INPUT FILE NAME -C:\KENPAVE\Examples\ESAL Test.DAT

NUMBER OF PROBLEMS TO BE SOLVED = 1

TITLE -EX. 4: VISCOELASTIC THREE LAYER SYSTEM - 1 18k LOAD G.

MATL = 3 FOR VISCOELASTIC LAYERED SYSTEM
 NDAMA=2, SO DAMAGE ANALYSIS WITH DETAILED PRINTOUT WILL BE PERFORMED
 NUMBER OF PERIODS PER YEAR (NPY) = 1
 NUMBER OF LOAD GROUPS (NLG) = 1
 TOLERANCE FOR INTEGRATION (DEL) -- = 0.001
 NUMBER OF LAYERS (NL)----- = 3
 NUMBER OF Z COORDINATES (NZ)----- = 0
 LIMIT OF INTEGRATION CYCLES (ICL)- = 80
 COMPUTING CODE (NSTD)----- = 9
 SYSTEM OF UNITS (NUNIT)----- = 0

Length and displacement in in., stress and modulus in psi
 unit weight in pcf, and temperature in F

THICKNESSES OF LAYERS (TH) ARE : 6 8
 POISSON'S RATIOS OF LAYERS (PR) ARE : 0.5 0.5 0.5
 ALL INTERFACES ARE FULLY BONDED

FOR PERIOD NO. 1 LAYER NO. AND MODULUS ARE : 1 0.000E+00 2 3.000E+04
 3 1.500E+04

LOAD GROUP NO. 1 HAS 2 CONTACT AREAS
 CONTACT RADIUS (CR)----- = 4.23
 CONTACT PRESSURE (CP)----- = 80
 NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
 WHEEL SPACING ALONG X-AXIS (XW)----- = 0
 WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
 3 0.000 6.750

DURATION OF MOVING LOAD (DUR) = 0.1
 NUMBER OF VISCOELASTIC LAYER (NVL) = 1
 LAYER NUMBERS WHICH ARE VISCOELASTIC (LNV) = 1
 CREEP TIMES (TYME) ARE: 0.001 0.003 0.01 0.03 0.1 0.3 1 3 10 30 100

FOR LAYER 1 TIME TEMPERATURE SHIFT FACTOR (BETA) = 0.113
 REFERENCE TEMPERATURE (TEMREF) = 70

CREEP COMPLIANCES (CREEP) AT REFERENCE TEMP. (TEMREF) OF 70 ARE:
 3.700E-07 5.200E-07 8.600E-07 1.450E-06 2.500E-06 4.000E-06 6.200E-06
 8.600E-06 1.200E-05 1.600E-05 1.900E-05

LAYER NO. 1 DIRICHLET SERIES AT REFERENCE TEMPERATURE (TEMREF) OF 70 ARE:
 -6.594E-07 3.123E-07 -2.196E-06 -4.217E-06 -4.040E-06 -8.178E-06 1.927E-05

COMPUTED COMPLIANCES (CREEP) AT REFERENCE TEMP.(TEMREF) OF 70 ARE:
 3.704E-07 5.120E-07 8.772E-07 1.434E-06 2.506E-06 4.019E-06 6.152E-06
 8.667E-06 1.192E-05 1.606E-05 1.898E-05

FOR PERIOD NO. 1 LAYER NO. AND TEMPERATURE ARE: 1 65.2

CREEP COMPLIANCES (CREEP) OF LAYER 1 AT TEMPERATURE (TEMP) OF 65.2 ARE:
 3.146E-07 3.598E-07 5.033E-07 8.168E-07 1.407E-06 2.329E-06 3.953E-06
 5.832E-06 8.565E-06 1.142E-05 1.590E-05

ESAL Test.TXT
NUMBER OF LAYERS FOR BOTTOM TENSION (NLBT)---- = 1
NUMBER OF LAYERS FOR TOP COMPRESSION (NLTC)--- = 1
LAYER NO. FOR BOTTOM TENSION (LNBT) ARE: 1
LAYER NO. FOR TOP COMPRESSION (LNTC) ARE: 3

LOAD REPETITIONS (TNLR) IN PERIOD 1 FOR EACH LOAD GROUP ARE : 846621

DAMAGE COEF.'S (FT) FOR BOTTOM TENSION OF LAYER 1 ARE: 0.0796 3.291 0.854

DAMAGE COEFFICIENTS (FT) FOR TOP COMPRESSION OF LAYER 3 ARE: 1.365E-09 4.477

DAMAGE ANALYSIS OF PERIOD NO. 1 LOAD GROUP NO. 1

POINT NO.	VERTICAL COORDINATE	VERTICAL DISPL. (HORIZONTAL P. STRAIN)	VERTICAL STRESS (STRAIN)	MAJOR PRINCIPAL STRESS (STRAIN)	MINOR PRINCIPAL STRESS (STRAIN)	INTERMEDIATE PRINCIPAL STRESS (STRAIN)
1	6.00000	0.00988	6.501	6.505	-197.269	-174.938
	(STRAIN)	-8.122E-05	1.383E-04	1.383E-04	-8.122E-05	-3.325E-04
1	14.00010	0.00873	3.640	3.717	1.021	1.162
	(STRAIN)	-9.454E-05	1.673E-04	1.750E-04	-9.454E-05	-2.189E-04
2	6.00000	0.01012	6.414	6.415	-191.271	-157.984
	(STRAIN)	-8.294E-05	1.297E-04	1.297E-04	-8.294E-05	-1.339E-04
2	14.00010	0.00894	3.821	3.840	1.057	1.232
	(STRAIN)	-9.859E-05	1.779E-04	1.797E-04	-9.859E-05	-2.041E-04
3	6.00000	0.01018	6.072	6.072	-176.734	-132.824
	(STRAIN)	-8.136E-05	1.149E-04	1.149E-04	-8.136E-05	8.218E-05
3	14.00010	0.00900	3.876	3.876	1.068	1.258
	(STRAIN)	-9.991E-05	1.808E-04	1.808E-04	-9.991E-05	-1.938E-04

AT BOTTOM OF LAYER 1 TENSILE STRAIN = -8.294E-05 E. MODULUS = 1.392E+06
ALLOWABLE LOAD REPETITIONS = 1.218E+07 DAMAGE RATIO = 6.953E-02

AT TOP OF LAYER 3 COMPRESSIVE STRAIN = 1.808E-04
ALLOWABLE LOAD REPETITIONS = 7.787E+07 DAMAGE RATIO = 1.087E-02

* SUMMARY OF DAMAGE ANALYSIS *

AT BOTTOM OF LAYER 1 SUM OF DAMAGE RATIO = 6.953E-02
AT TOP OF LAYER 3 SUM OF DAMAGE RATIO = 1.087E-02

MAXIMUM DAMAGE RATIO = 6.953E-02 DESIGN LIFE IN YEARS = 14.38

All Load Groups.TXT

INPUT FILE NAME -C:\KENPAVE\Examples\All Load Groups.DAT

NUMBER OF PROBLEMS TO BE SOLVED = 1

TITLE -EX. 4: VISCOELASTIC THREE LAYER SYSTEM - 1 18k LOAD G.

MATL = 3 FOR VISCOELASTIC LAYERED SYSTEM
 NDAMA=2, SO DAMAGE ANALYSIS WITH DETAILED PRINTOUT WILL BE PERFORMED
 NUMBER OF PERIODS PER YEAR (NPY) = 1
 NUMBER OF LOAD GROUPS (NLG) = 12
 TOLERANCE FOR INTEGRATION (DEL) -- = 0.001
 NUMBER OF LAYERS (NL)----- = 3
 NUMBER OF Z COORDINATES (NZ)----- = 0
 LIMIT OF INTEGRATION CYCLES (ICL)- = 80
 COMPUTING CODE (NSTD)----- = 9
 SYSTEM OF UNITS (NUNIT)----- = 0

Length and displacement in in., stress and modulus in psi
 unit weight in pcf, and temperature in F

THICKNESSES OF LAYERS (TH) ARE : 6 8
 POISSON'S RATIOS OF LAYERS (PR) ARE : 0.5 0.5 0.5
 ALL INTERFACES ARE FULLY BONDED

FOR PERIOD NO. 1 LAYER NO. AND MODULUS ARE : 1 0.000E+00 2 3.000E+04
 3 1.500E+04

LOAD GROUP NO. 1 HAS 2 CONTACT AREAS
 CONTACT RADIUS (CR)----- = 4.23
 CONTACT PRESSURE (CP)----- = 80
 NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
 WHEEL SPACING ALONG X-AXIS (XW)----- = 0
 WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
 3 0.000 6.750

LOAD GROUP NO. 2 HAS 2 CONTACT AREAS
 CONTACT RADIUS (CR)----- = 3.15
 CONTACT PRESSURE (CP)----- = 80
 NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
 WHEEL SPACING ALONG X-AXIS (XW)----- = 0
 WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
 3 0.000 6.750

LOAD GROUP NO. 3 HAS 2 CONTACT AREAS
 CONTACT RADIUS (CR)----- = 3.73
 CONTACT PRESSURE (CP)----- = 80
 NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
 WHEEL SPACING ALONG X-AXIS (XW)----- = 0
 WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
 3 0.000 6.750

LOAD GROUP NO. 4 HAS 2 CONTACT AREAS
 CONTACT RADIUS (CR)----- = 4.78
 CONTACT PRESSURE (CP)----- = 80
 NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
 WHEEL SPACING ALONG X-AXIS (XW)----- = 0

All Load Groups.TXT

WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
3 0.000 6.750

LOAD GROUP NO. 5 HAS 4 CONTACT AREAS
CONTACT RADIUS (CR)----- = 2.12
CONTACT PRESSURE (CP)----- = 80
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
WHEEL SPACING ALONG X-AXIS (XW)----- = 48
WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
3 0.000 6.750

LOAD GROUP NO. 6 HAS 4 CONTACT AREAS
CONTACT RADIUS (CR)----- = 2.73
CONTACT PRESSURE (CP)----- = 80
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
WHEEL SPACING ALONG X-AXIS (XW)----- = 48
WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
3 0.000 6.750

LOAD GROUP NO. 7 HAS 4 CONTACT AREAS
CONTACT RADIUS (CR)----- = 3.23
CONTACT PRESSURE (CP)----- = 80
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
WHEEL SPACING ALONG X-AXIS (XW)----- = 48
WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
3 0.000 6.750

LOAD GROUP NO. 8 HAS 4 CONTACT AREAS
CONTACT RADIUS (CR)----- = 3.66
CONTACT PRESSURE (CP)----- = 80
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
WHEEL SPACING ALONG X-AXIS (XW)----- = 48
WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
3 0.000 6.750

LOAD GROUP NO. 9 HAS 4 CONTACT AREAS
CONTACT RADIUS (CR)----- = 3.93
CONTACT PRESSURE (CP)----- = 80
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
WHEEL SPACING ALONG X-AXIS (XW)----- = 48
WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
3 0.000 6.750

LOAD GROUP NO. 10 HAS 4 CONTACT AREAS
CONTACT RADIUS (CR)----- = 4.01
CONTACT PRESSURE (CP)----- = 80
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
WHEEL SPACING ALONG X-AXIS (XW)----- = 48
WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375

Page 2

All Load Groups.TXT

3 0.000 6.750

LOAD GROUP NO. 11 HAS 4 CONTACT AREAS
 CONTACT RADIUS (CR)----- = 4.07
 CONTACT PRESSURE (CP)----- = 80
 NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
 WHEEL SPACING ALONG X-AXIS (XW)----- = 48
 WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
 3 0.000 6.750

LOAD GROUP NO. 12 HAS 4 CONTACT AREAS
 CONTACT RADIUS (CR)----- = 4.17
 CONTACT PRESSURE (CP)----- = 80
 NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
 WHEEL SPACING ALONG X-AXIS (XW)----- = 48
 WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
 3 0.000 6.750

DURATION OF MOVING LOAD (DUR) = 0.1
 NUMBER OF VISCOELASTIC LAYER (NVL) = 1
 LAYER NUMBERS WHICH ARE VISCOELASTIC (LNV) = 1
 CREEP TIMES (TYME) ARE: 0.001 0.003 0.01 0.03 0.1 0.3 1 3 10 30 100

FOR LAYER 1 TIME TEMPERATURE SHIFT FACTOR (BETA) = 0.113
 REFERENCE TEMPERATURE (TEMREF) = 70

CREEP COMPLIANCES (CREEP) AT REFERENCE TEMP. (TEMREF) OF 70 ARE:
 3.700E-07 5.200E-07 8.600E-07 1.450E-06 2.500E-06 4.000E-06 6.200E-06
 8.600E-06 1.200E-05 1.600E-05 1.900E-05

LAYER NO. 1 DIRICHLET SERIES AT REFERENCE TEMPERATURE (TEMREF) OF 70 ARE:
 -6.594E-07 3.123E-07 -2.196E-06 -4.217E-06 -4.040E-06 -8.178E-06 1.927E-05

COMPUTED COMPLIANCES (CREEP) AT REFERENCE TEMP.(TEMREF) OF 70 ARE:
 3.704E-07 5.120E-07 8.772E-07 1.434E-06 2.506E-06 4.019E-06 6.152E-06
 8.667E-06 1.192E-05 1.606E-05 1.898E-05

FOR PERIOD NO. 1 LAYER NO. AND TEMPERATURE ARE: 1 65.2

CREEP COMPLIANCES (CREEP) OF LAYER 1 AT TEMPERATURE (TEMP) OF 65.2 ARE:
 3.146E-07 3.598E-07 5.033E-07 8.168E-07 1.407E-06 2.329E-06 3.953E-06
 5.832E-06 8.565E-06 1.142E-05 1.590E-05

NUMBER OF LAYERS FOR BOTTOM TENSION (NLBT)---- = 1
 NUMBER OF LAYERS FOR TOP COMPRESSION (NLTC)--- = 1
 LAYER NO. FOR BOTTOM TENSION (LNBT) ARE: 1
 LAYER NO. FOR TOP COMPRESSION (LNTC) ARE: 3

LOAD REPETITIONS (TNLR) IN PERIOD 1 FOR EACH LOAD GROUP ARE : 6610 158632
 17626 1102 15423 23134 48471 46268 48471 23134 111263 47369

DAMAGE COEF.'S (FT) FOR BOTTOM TENSION OF LAYER 1 ARE: 0.0796 3.291 0.854

DAMAGE COEFICIENTS (FT) FOR TOP COMPRESSION OF LAYER 3 ARE: 1.365E-09 4.477

DAMAGE ANALYSIS OF PERIOD NO. 1 LOAD GROUP NO. 1

POINT	VERTICAL	VERTICAL	VERTICAL	MAJOR	MINOR	INTERMEDIATE
	DISPL.	DISPL.	DISPL.	PRINCIPAL	PRINCIPAL	PRINCIPAL

All Load Groups.TXT
AT BOTTOM OF LAYER 1 SUM OF DAMAGE RATIO = 1.812E-02
AT TOP OF LAYER 3 SUM OF DAMAGE RATIO = 2.565E-03
MAXIMUM DAMAGE RATO = 1.812E-02 DESIGN LIFE IN YEARS = 55.18

Class 8 Loading.TXT

INPUT FILE NAME -C:\KENPAVE\Examples\Class 8 Loading.DAT

NUMBER OF PROBLEMS TO BE SOLVED = 1

TITLE -Class 8 - Loading

MATL = 1 FOR LINEAR ELASTIC LAYERED SYSTEM
NDAMA=1, SO DAMAGE ANALYSIS WITH SUMMARY PRINTOUT WILL BE PERFORMED
NUMBER OF PERIODS PER YEAR (NPY) = 1
NUMBER OF LOAD GROUPS (NLG) = 3
TOLERANCE FOR INTEGRATION (DEL) -- = 0.001
NUMBER OF LAYERS (NL)----- = 3
NUMBER OF Z COORDINATES (NZ)----- = 0
LIMIT OF INTEGRATION CYCLES (ICL)- = 80
COMPUTING CODE (NSTD)----- = 9
SYSTEM OF UNITS (NUNIT)----- = 0

Length and displacement in in., stress and modulus in psi
unit weight in pcf, and temperature in F

THICKNESSES OF LAYERS (TH) ARE : 6 8
POISSON'S RATIOS OF LAYERS (PR) ARE : 0.4 0.35 0.45
ALL INTERFACES ARE FULLY BONDED

FOR PERIOD NO. 1 LAYER NO. AND MODULUS ARE : 1 7.400E+05 2 2.300E+04
3 1.100E+04

LOAD GROUP NO. 1 HAS 1 CONTACT AREA
CONTACT RADIUS (CR)----- = 6.31
CONTACT PRESSURE (CP)----- = 80
RADIAL COORDINATES OF 3 POINT(S) (RC) ARE : 0 3.375 6.75

LOAD GROUP NO. 2 HAS 2 CONTACT AREAS
CONTACT RADIUS (CR)----- = 6.31
CONTACT PRESSURE (CP)----- = 80
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
WHEEL SPACING ALONG X-AXIS (XW)----- = 0
WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
3 0.000 6.750

LOAD GROUP NO. 3 HAS 4 CONTACT AREAS
CONTACT RADIUS (CR)----- = 4.46
CONTACT PRESSURE (CP)----- = 80
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
WHEEL SPACING ALONG X-AXIS (XW)----- = 48
WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
3 0.000 6.750

NUMBER OF LAYERS FOR BOTTOM TENSION (NLBT)---- = 1
NUMBER OF LAYERS FOR TOP COMPRESSION (NLTC)--- = 1
LAYER NO. FOR BOTTOM TENSION (LNBT) ARE: 1
LAYER NO. FOR TOP COMPRESSION (LNTC) ARE: 3

LOAD REPETITIONS (TNLR) IN PERIOD 1 FOR EACH LOAD GROUP ARE : 1 1
1

DAMAGE COEF.'S (FT) FOR BOTTOM TENSION OF LAYER 1 ARE: 0.0796 3.291 0.854

Class 8 Loading.TXT

DAMAGE COEFFICIENTS (FT) FOR TOP COMPRESSION OF LAYER 3 ARE: 1.365E-09 4.477

DAMAGE ANALYSIS OF PERIOD NO. 1 LOAD GROUP NO. 1

AT BOTTOM OF LAYER 1 TENSILE STRAIN = -1.812E-04 E. MODULUS = 7.400E+05
ALLOWABLE LOAD REPETITIONS = 1.596E+06 DAMAGE RATIO = 6.265E-07

AT TOP OF LAYER 3 COMPRESSIVE STRAIN = 4.404E-04
ALLOWABLE LOAD REPETITIONS = 1.447E+06 DAMAGE RATIO = 6.910E-07

DAMAGE ANALYSIS OF PERIOD NO. 1 LOAD GROUP NO. 2

AT BOTTOM OF LAYER 1 TENSILE STRAIN = -2.865E-04 E. MODULUS = 7.400E+05
ALLOWABLE LOAD REPETITIONS = 3.535E+05 DAMAGE RATIO = 2.829E-06

AT TOP OF LAYER 3 COMPRESSIVE STRAIN = 7.340E-04
ALLOWABLE LOAD REPETITIONS = 1.470E+05 DAMAGE RATIO = 6.802E-06

DAMAGE ANALYSIS OF PERIOD NO. 1 LOAD GROUP NO. 3

AT BOTTOM OF LAYER 1 TENSILE STRAIN = -1.469E-04 E. MODULUS = 7.400E+05
ALLOWABLE LOAD REPETITIONS = 3.183E+06 DAMAGE RATIO = 3.141E-07

AT TOP OF LAYER 3 COMPRESSIVE STRAIN = 3.742E-04
ALLOWABLE LOAD REPETITIONS = 3.003E+06 DAMAGE RATIO = 3.330E-07

DAMAGE ANALYSIS OF PERIOD NO. 1 LOAD GROUP NO. 3
MULTIPLE AXLES WITH RESPONSE POINT HALFWAY BETWEEN TWO AXLES

AT BOTTOM OF LAYER 1 DIFFERENTIAL TENSILE STRAIN = -9.061E-05
ALLOWABLE LOAD REPETITIONS = 1.561E+07 DAMAGE RATIO = 6.405E-08

AT TOP OF LAYER 3 DIFFERENTIAL COMPRESSIVE STRAIN = 2.126E-04
ALLOWABLE LOAD REPETITIONS = 3.774E+07 DAMAGE RATIO = 2.649E-08

* SUMMARY OF DAMAGE ANALYSIS *

AT BOTTOM OF LAYER 1 SUM OF DAMAGE RATIO = 3.833E-06
AT TOP OF LAYER 3 SUM OF DAMAGE RATIO = 7.852E-06

MAXIMUM DAMAGE RATIO = 7.852E-06 DESIGN LIFE IN YEARS = 127351.2

Class 9 actual simulation.TXT

INPUT FILE NAME -C:\KENPAVE\Examples\Class 9 actual simulation.DAT

NUMBER OF PROBLEMS TO BE SOLVED = 1

TITLE -Class 9 - Actual Simulation

MATL = 1 FOR LINEAR ELASTIC LAYERED SYSTEM
NDAMA=1, SO DAMAGE ANALYSIS WITH SUMMARY PRINTOUT WILL BE PERFORMED
NUMBER OF PERIODS PER YEAR (NPY) = 1
NUMBER OF LOAD GROUPS (NLG) = 3
TOLERANCE FOR INTEGRATION (DEL) -- = 0.001
NUMBER OF LAYERS (NL)----- = 3
NUMBER OF Z COORDINATES (NZ)----- = 3
LIMIT OF INTEGRATION CYCLES (ICL)- = 80
COMPUTING CODE (NSTD)----- = 9
SYSTEM OF UNITS (NUNIT)----- = 0

Length and displacement in in., stress and modulus in psi
unit weight in pcf, and temperature in F

THICKNESSES OF LAYERS (TH) ARE : 6 8
POISSON'S RATIOS OF LAYERS (PR) ARE : 0.4 0.35 0.45
ALL INTERFACES ARE FULLY BONDED

FOR PERIOD NO. 1 LAYER NO. AND MODULUS ARE : 1 7.400E+05 2 2.300E+04
3 1.100E+04

LOAD GROUP NO. 1 HAS 1 CONTACT AREA
CONTACT RADIUS (CR)----- = 4.23
CONTACT PRESSURE (CP)----- = 80
RADIAL COORDINATES OF 3 POINT(S) (RC) ARE : 0 3.375 6.75

LOAD GROUP NO. 2 HAS 4 CONTACT AREAS
CONTACT RADIUS (CR)----- = 4.52
CONTACT PRESSURE (CP)----- = 80
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
WHEEL SPACING ALONG X-AXIS (XW)----- = 57.6
WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
3 0.000 6.750

LOAD GROUP NO. 3 HAS 4 CONTACT AREAS
CONTACT RADIUS (CR)----- = 4.37
CONTACT PRESSURE (CP)----- = 80
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
WHEEL SPACING ALONG X-AXIS (XW)----- = 55.2
WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
3 0.000 6.750

NUMBER OF LAYERS FOR BOTTOM TENSION (NLBT)---- = 1
NUMBER OF LAYERS FOR TOP COMPRESSION (NLTC)--- = 1
LAYER NO. FOR BOTTOM TENSION (LNBT) ARE: 1
LAYER NO. FOR TOP COMPRESSION (LNTC) ARE: 3

LOAD REPETITIONS (TNLR) IN PERIOD 1 FOR EACH LOAD GROUP ARE : 1 1
1

DAMAGE COEF.'S (FT) FOR BOTTOM TENSION OF LAYER 1 ARE: 0.0796 3.291 0.854

Class 9 actual simulation.TXT

DAMAGE COEFFICIENTS (FT) FOR TOP COMPRESSION OF LAYER 3 ARE: 1.365E-09 4.477

DAMAGE ANALYSIS OF PERIOD NO. 1 LOAD GROUP NO. 1

AT BOTTOM OF LAYER 1 TENSILE STRAIN = -1.058E-04 E. MODULUS = 7.400E+05
ALLOWABLE LOAD REPETITIONS = 9.376E+06 DAMAGE RATIO = 1.067E-07

AT TOP OF LAYER 3 COMPRESSIVE STRAIN = 2.091E-04
ALLOWABLE LOAD REPETITIONS = 4.063E+07 DAMAGE RATIO = 2.461E-08

DAMAGE ANALYSIS OF PERIOD NO. 1 LOAD GROUP NO. 2

AT BOTTOM OF LAYER 1 TENSILE STRAIN = -1.546E-04 E. MODULUS = 7.400E+05
ALLOWABLE LOAD REPETITIONS = 2.692E+06 DAMAGE RATIO = 3.715E-07

AT TOP OF LAYER 3 COMPRESSIVE STRAIN = 3.797E-04
ALLOWABLE LOAD REPETITIONS = 2.812E+06 DAMAGE RATIO = 3.557E-07

DAMAGE ANALYSIS OF PERIOD NO. 1 LOAD GROUP NO. 2
MULTIPLE AXLES WITH RESPONSE POINT HALFWAY BETWEEN TWO AXLES

AT BOTTOM OF LAYER 1 DIFFERENTIAL TENSILE STRAIN = -1.120E-04
ALLOWABLE LOAD REPETITIONS = 7.779E+06 DAMAGE RATIO = 1.286E-07

AT TOP OF LAYER 3 DIFFERENTIAL COMPRESSIVE STRAIN = 2.812E-04
ALLOWABLE LOAD REPETITIONS = 1.079E+07 DAMAGE RATIO = 9.266E-08

DAMAGE ANALYSIS OF PERIOD NO. 1 LOAD GROUP NO. 3

AT BOTTOM OF LAYER 1 TENSILE STRAIN = -1.451E-04 E. MODULUS = 7.400E+05
ALLOWABLE LOAD REPETITIONS = 3.312E+06 DAMAGE RATIO = 3.019E-07

AT TOP OF LAYER 3 COMPRESSIVE STRAIN = 3.561E-04
ALLOWABLE LOAD REPETITIONS = 3.749E+06 DAMAGE RATIO = 2.667E-07

DAMAGE ANALYSIS OF PERIOD NO. 1 LOAD GROUP NO. 3
MULTIPLE AXLES WITH RESPONSE POINT HALFWAY BETWEEN TWO AXLES

AT BOTTOM OF LAYER 1 DIFFERENTIAL TENSILE STRAIN = -1.021E-04
ALLOWABLE LOAD REPETITIONS = 1.053E+07 DAMAGE RATIO = 9.500E-08

AT TOP OF LAYER 3 DIFFERENTIAL COMPRESSIVE STRAIN = 2.505E-04
ALLOWABLE LOAD REPETITIONS = 1.811E+07 DAMAGE RATIO = 5.522E-08

* SUMMARY OF DAMAGE ANALYSIS *

AT BOTTOM OF LAYER 1 SUM OF DAMAGE RATIO = 1.004E-06
AT TOP OF LAYER 3 SUM OF DAMAGE RATIO = 7.949E-07

MAXIMUM DAMAGE RATIO = 1.004E-06 DESIGN LIFE IN YEARS = 996394.9

FDOT Constant Speed.TXT

INPUT FILE NAME -C:\KENPAVE\Examples\FDOT Constant Speed.DAT

NUMBER OF PROBLEMS TO BE SOLVED = 1

TITLE -EX. 4: VISCOELASTIC THREE LAYER SYSTEM - 1 18k LOAD and const 58mph

MATL = 3 FOR VISCOELASTIC LAYERED SYSTEM
 NDAMA=2, SO DAMAGE ANALYSIS WITH DETAILED PRINTOUT WILL BE PERFORMED
 NUMBER OF PERIODS PER YEAR (NPY) = 1
 NUMBER OF LOAD GROUPS (NLG) = 1
 TOLERANCE FOR INTEGRATION (DEL) -- = 0.001
 NUMBER OF LAYERS (NL)----- = 3
 NUMBER OF Z COORDINATES (NZ)----- = 0
 LIMIT OF INTEGRATION CYCLES (ICL)- = 80
 COMPUTING CODE (NSTD)----- = 9
 SYSTEM OF UNITS (NUNIT)----- = 0

Length and displacement in in., stress and modulus in psi
 unit weight in pcf, and temperature in F

THICKNESSES OF LAYERS (TH) ARE : 8 10
 POISSON'S RATIOS OF LAYERS (PR) ARE : 0.5 0.5 0.5
 ALL INTERFACES ARE FULLY BONDED

FOR PERIOD NO. 1 LAYER NO. AND MODULUS ARE : 1 0.000E+00 2 3.000E+04
 3 1.500E+04

LOAD GROUP NO. 1 HAS 2 CONTACT AREAS
 CONTACT RADIUS (CR)----- = 4.23
 CONTACT PRESSURE (CP)----- = 80
 NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
 WHEEL SPACING ALONG X-AXIS (XW)----- = 0
 WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
 3 0.000 6.750

DURATION OF MOVING LOAD (DUR) = 0.05
 NUMBER OF VISCOELASTIC LAYER (NVL) = 1
 LAYER NUMBERS WHICH ARE VISCOELASTIC (LNV) = 1
 CREEP TIMES (TYME) ARE: 0.001 0.003 0.01 0.03 0.1 0.3 1 3 10 30 100

FOR LAYER 1 TIME TEMPERATURE SHIFT FACTOR (BETA) = 0.113
 REFERENCE TEMPERATURE (TEMREF) = 70

CREEP COMPLIANCES (CREEP) AT REFERENCE TEMP. (TEMREF) OF 70 ARE:
 3.700E-07 5.200E-07 8.600E-07 1.450E-06 2.500E-06 4.000E-06 6.200E-06
 8.600E-06 1.200E-05 1.600E-05 1.900E-05

LAYER NO. 1 DIRICHLET SERIES AT REFERENCE TEMPERATURE (TEMREF) OF 70 ARE:
 -6.594E-07 3.123E-07 -2.196E-06 -4.217E-06 -4.040E-06 -8.178E-06 1.927E-05

COMPUTED COMPLIANCES (CREEP) AT REFERENCE TEMP.(TEMREF) OF 70 ARE:
 3.704E-07 5.120E-07 8.772E-07 1.434E-06 2.506E-06 4.019E-06 6.152E-06
 8.667E-06 1.192E-05 1.606E-05 1.898E-05

FOR PERIOD NO. 1 LAYER NO. AND TEMPERATURE ARE: 1 65.2

CREEP COMPLIANCES (CREEP) OF LAYER 1 AT TEMPERATURE (TEMP) OF 65.2 ARE:
 3.146E-07 3.598E-07 5.033E-07 8.168E-07 1.407E-06 2.329E-06 3.953E-06
 5.832E-06 8.565E-06 1.142E-05 1.590E-05

FDOT Constant Speed.TXT
NUMBER OF LAYERS FOR BOTTOM TENSION (NLBT)---- = 1
NUMBER OF LAYERS FOR TOP COMPRESSION (NLTC)---- = 1
LAYER NO. FOR BOTTOM TENSION (LNBT) ARE: 1
LAYER NO. FOR TOP COMPRESSION (LNTC) ARE: 3

LOAD REPETITIONS (TNLR) IN PERIOD 1 FOR EACH LOAD GROUP ARE : 2409897

DAMAGE COEF.'S (FT) FOR BOTTOM TENSION OF LAYER 1 ARE: 0.0796 3.291 0.854

DAMAGE COEFICIENTS (FT) FOR TOP COMPRESSION OF LAYER 3 ARE: 1.365E-09 4.477

DAMAGE ANALYSIS OF PERIOD NO. 1 LOAD GROUP NO. 1

POINT NO.	VERTICAL COORDINATE	VERTICAL DISPL. (HORIZONTAL P. STRAIN)	VERTICAL STRESS (STRAIN)	MAJOR PRINCIPAL STRESS (STRAIN)	MINOR PRINCIPAL STRESS (STRAIN)	INTERMEDIATE PRINCIPAL STRESS (STRAIN)
1	8.00000	0.00721	3.499	3.501	-143.552	-129.055
	(STRAIN)	-4.398E-05	7.604E-05	7.604E-05	-4.398E-05	-2.295E-04
1	18.00010	0.00642	2.003	2.034	0.602	0.652
	(STRAIN)	-4.940E-05	9.075E-05	9.380E-05	-4.940E-05	-1.603E-04
2	8.00000	0.00733	3.523	3.523	-143.258	-123.689
	(STRAIN)	-4.530E-05	7.453E-05	7.453E-05	-4.530E-05	-1.288E-04
2	18.00010	0.00652	2.077	2.085	0.614	0.671
	(STRAIN)	-5.093E-05	9.537E-05	9.614E-05	-5.093E-05	-1.604E-04
3	8.00000	0.00736	3.434	3.434	-137.822	-113.427
	(STRAIN)	-4.512E-05	7.021E-05	7.021E-05	-4.512E-05	-3.206E-05
3	18.00010	0.00655	2.099	2.099	0.617	0.677
	(STRAIN)	-5.142E-05	9.681E-05	9.681E-05	-5.142E-05	-1.594E-04

AT BOTTOM OF LAYER 1 TENSILE STRAIN = -4.530E-05 E. MODULUS = 1.836E+06
ALLOWABLE LOAD REPETITIONS = 7.035E+07 DAMAGE RATIO = 3.425E-02

AT TOP OF LAYER 3 COMPRESSIVE STRAIN = 9.681E-05
ALLOWABLE LOAD REPETITIONS = 1.277E+09 DAMAGE RATIO = 1.888E-03

* SUMMARY OF DAMAGE ANALYSIS *

AT BOTTOM OF LAYER 1 SUM OF DAMAGE RATIO = 3.425E-02
AT TOP OF LAYER 3 SUM OF DAMAGE RATIO = 1.888E-03

MAXIMUM DAMAGE RATIO = 3.425E-02 DESIGN LIFE IN YEARS = 29.19

FDOT axle addition-before.TXT

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NUMBER OF PROBLEMS TO BE SOLVED = 1

TITLE -EX. 4: VISCOELASTIC THREE LAYER SYSTEM - Axle addition -Before

MATL = 3 FOR VISCOELASTIC LAYERED SYSTEM

NDAMA=2, SO DAMAGE ANALYSIS WITH DETAILED PRINTOUT WILL BE PERFORMED

NUMBER OF PERIODS PER YEAR (NPY) = 1

NUMBER OF LOAD GROUPS (NLG) = 9

TOLERANCE FOR INTEGRATION (DEL) -- = 0.001

NUMBER OF LAYERS (NL)----- = 3

NUMBER OF Z COORDINATES (NZ)----- = 0

LIMIT OF INTEGRATION CYCLES (ICL)- = 80

COMPUTING CODE (NSTD)----- = 9

SYSTEM OF UNITS (NUNIT)----- = 0

Length and displacement in in., stress and modulus in psi
unit weight in pcf, and temperature in F

THICKNESSES OF LAYERS (TH) ARE : 8 10

POISSON'S RATIOS OF LAYERS (PR) ARE : 0.5 0.5 0.5

ALL INTERFACES ARE FULLY BONDED

FOR PERIOD NO. 1 LAYER NO. AND MODULUS ARE : 1 0.000E+00 2 3.000E+04
3 1.500E+04

LOAD GROUP NO. 1 HAS 1 CONTACT AREA

CONTACT RADIUS (CR)----- = 5.06

CONTACT PRESSURE (CP)----- = 80

RADIAL COORDINATES OF 3 POINT(S) (RC) ARE : 0 0 0

LOAD GROUP NO. 2 HAS 2 CONTACT AREAS

CONTACT RADIUS (CR)----- = 3.97

CONTACT PRESSURE (CP)----- = 80

NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3

WHEEL SPACING ALONG X-AXIS (XW)----- = 0

WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
3 0.000 6.750

LOAD GROUP NO. 3 HAS 2 CONTACT AREAS

CONTACT RADIUS (CR)----- = 3.52

CONTACT PRESSURE (CP)----- = 80

NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3

WHEEL SPACING ALONG X-AXIS (XW)----- = 0

WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
3 0.000 6.750

LOAD GROUP NO. 4 HAS 1 CONTACT AREA

CONTACT RADIUS (CR)----- = 7.43

CONTACT PRESSURE (CP)----- = 80

RADIAL COORDINATES OF 3 POINT(S) (RC) ARE : 0 0 0

LOAD GROUP NO. 5 HAS 2 CONTACT AREAS

CONTACT RADIUS (CR)----- = 4.86

CONTACT PRESSURE (CP)----- = 80

NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3

WHEEL SPACING ALONG X-AXIS (XW)----- = 0

WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

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FDOT axle addition-before.TXT

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
3 0.000 6.750

LOAD GROUP NO. 6 HAS 4 CONTACT AREAS
CONTACT RADIUS (CR)----- = 3.29
CONTACT PRESSURE (CP)----- = 80
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
WHEEL SPACING ALONG X-AXIS (XW)----- = 4.5
WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
3 0.000 6.750

LOAD GROUP NO. 7 HAS 1 CONTACT AREA
CONTACT RADIUS (CR)----- = 5.54
CONTACT PRESSURE (CP)----- = 80
RADIAL COORDINATES OF 3 POINT(S) (RC) ARE : 0 0 0

LOAD GROUP NO. 8 HAS 4 CONTACT AREAS
CONTACT RADIUS (CR)----- = 3.7
CONTACT PRESSURE (CP)----- = 80
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
WHEEL SPACING ALONG X-AXIS (XW)----- = 3.3
WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
3 0.000 6.750

LOAD GROUP NO. 9 HAS 4 CONTACT AREAS
CONTACT RADIUS (CR)----- = 3.59
CONTACT PRESSURE (CP)----- = 80
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
WHEEL SPACING ALONG X-AXIS (XW)----- = 3.8
WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
3 0.000 6.750

DURATION OF MOVING LOAD (DUR) = 0.05
NUMBER OF VISCOELASTIC LAYER (NVL) = 1
LAYER NUMBERS WHICH ARE VISCOELASTIC (LNV) = 1
CREEP TIMES (TYME) ARE: 0.001 0.003 0.01 0.03 0.1 0.3 1 3 10 30 100

FOR LAYER 1 TIME TEMPERATURE SHIFT FACTOR (BETA) = 0.113
REFERENCE TEMPERATURE (TEMREF) = 70

CREEP COMPLIANCES (CREEP) AT REFERENCE TEMP. (TEMREF) OF 70 ARE:
3.700E-07 5.200E-07 8.600E-07 1.450E-06 2.500E-06 4.000E-06 6.200E-06
8.600E-06 1.200E-05 1.600E-05 1.900E-05

LAYER NO. 1 DIRICHLET SERIES AT REFERENCE TEMPERATURE (TEMREF) OF 70 ARE:
-6.594E-07 3.123E-07 -2.196E-06 -4.217E-06 -4.040E-06 -8.178E-06 1.927E-05

COMPUTED COMPLIANCES (CREEP) AT REFERENCE TEMP. (TEMREF) OF 70 ARE:
3.704E-07 5.120E-07 8.772E-07 1.434E-06 2.506E-06 4.019E-06 6.152E-06
8.667E-06 1.192E-05 1.606E-05 1.898E-05

FOR PERIOD NO. 1 LAYER NO. AND TEMPERATURE ARE: 1 65.2

CREEP COMPLIANCES (CREEP) OF LAYER 1 AT TEMPERATURE (TEMP) OF 65.2 ARE:
3.146E-07 3.598E-07 5.033E-07 8.168E-07 1.407E-06 2.329E-06 3.953E-06
5.832E-06 8.565E-06 1.142E-05 1.590E-05

FDOT axle addition-before.TXT

NUMBER OF LAYERS FOR BOTTOM TENSION (NLBT)----- = 1
 NUMBER OF LAYERS FOR TOP COMPRESSION (NLTC)---- = 1
 LAYER NO. FOR BOTTOM TENSION (LNBT) ARE: 1
 LAYER NO. FOR TOP COMPRESSION (LNTC) ARE: 3

LOAD REPETITIONS (TNLR) IN PERIOD 1 FOR EACH LOAD GROUP ARE : 28891 28891
 28891 169096 169096 169096 893141 893141 893141

DAMAGE COEF.'S (FT) FOR BOTTOM TENSION OF LAYER 1 ARE: 0.0796 3.291 0.854

DAMAGE COEFFICIENTS (FT) FOR TOP COMPRESSION OF LAYER 3 ARE: 1.365E-09 4.477

DAMAGE ANALYSIS OF PERIOD NO. 1 LOAD GROUP NO. 1

RADIAL COORDINATE	VERTICAL COORDINATE	VERTICAL DISPLACEMENT	VERTICAL STRESS (STRAIN)	RADIAL STRESS (STRAIN)	TANGENTIAL STRESS (STRAIN)	SHEAR STRESS (STRAIN)
0.00000	8.00000	0.00552	3.296	-141.590	-141.590	0.000
(STRAIN)			7.898E-05	-3.949E-05	-3.949E-05	.000E+00
0.00000	18.00010	0.00479	1.618	0.458	0.458	0.000
(STRAIN)			7.737E-05	-3.868E-05	-3.868E-05	.000E+00
0.00000	8.00000	0.00552	3.296	-141.590	-141.590	0.000
(STRAIN)			7.898E-05	-3.949E-05	-3.949E-05	.000E+00
0.00000	18.00010	0.00479	1.618	0.458	0.458	0.000
(STRAIN)			7.737E-05	-3.868E-05	-3.868E-05	.000E+00
0.00000	8.00000	0.00552	3.296	-141.590	-141.590	0.000
(STRAIN)			7.898E-05	-3.949E-05	-3.949E-05	.000E+00
0.00000	18.00010	0.00479	1.618	0.458	0.458	0.000
(STRAIN)			7.737E-05	-3.868E-05	-3.868E-05	.000E+00

AT BOTTOM OF LAYER 1 TENSILE STRAIN = -3.949E-05 E. MODULUS = 1.834E+06
 ALLOWABLE LOAD REPETITIONS = 1.106E+08 DAMAGE RATIO = 2.612E-04

AT TOP OF LAYER 3 COMPRESSIVE STRAIN = 7.737E-05
 ALLOWABLE LOAD REPETITIONS = 3.484E+09 DAMAGE RATIO = 8.292E-06

DAMAGE ANALYSIS OF PERIOD NO. 1 LOAD GROUP NO. 2

POINT NO.	VERTICAL COORDINATE	VERTICAL DISPL. (HORIZONTAL P. STRAIN)	VERTICAL STRESS (STRAIN)	MAJOR PRINCIPAL STRESS (STRAIN)	MINOR PRINCIPAL STRESS (STRAIN)	INTERMEDIATE PRINCIPAL STRESS (STRAIN)
1	8.00000	0.00636	3.111	3.112	-128.355	-115.499
	(STRAIN)		6.801E-05	6.801E-05	-3.929E-05	-2.106E-04
1	18.00010	0.00566	1.768	1.795	0.530	0.574
	(STRAIN)		8.016E-05	8.285E-05	-4.364E-05	-1.419E-04
2	8.00000	0.00646	3.117	3.117	-127.269	-109.553
	(STRAIN)		6.612E-05	6.612E-05	-4.033E-05	-1.135E-04
2	18.00010	0.00574	1.833	1.840	0.541	0.592
	(STRAIN)		8.423E-05	8.490E-05	-4.500E-05	-1.417E-04
3	8.00000	0.00649	3.027	3.027	-121.753	-99.512
	(STRAIN)		6.184E-05	6.184E-05	-4.004E-05	-2.123E-05
3	18.00010	0.00577	1.852	1.852	0.543	0.597
	(STRAIN)		8.546E-05	8.546E-05	-4.541E-05	-1.407E-04

AT BOTTOM OF LAYER 1 TENSILE STRAIN = -4.033E-05 E. MODULUS = 1.836E+06
 ALLOWABLE LOAD REPETITIONS = 1.031E+08 DAMAGE RATIO = 2.802E-04

AT TOP OF LAYER 3 COMPRESSIVE STRAIN = 8.546E-05
 ALLOWABLE LOAD REPETITIONS = 2.232E+09 DAMAGE RATIO = 1.294E-05

FDOT axle addition-before.TXT						
NO.	COORDINATE	(HORIZONTAL P. STRAIN)	STRESS (STRAIN)	STRESS (STRAIN)	STRESS (STRAIN)	STRESS (STRAIN)
1	8.00000	0.01037	5.006	5.008	-203.000	-185.642
	(STRAIN)	-6.134E-05	1.084E-04	1.084E-04	-6.134E-05	-3.468E-04
1	18.00010	0.00924	2.882	2.926	0.870	0.936
	(STRAIN)	-7.073E-05	1.305E-04	1.348E-04	-7.073E-05	-2.313E-04
2	8.00000	0.01055	5.005	5.005	-200.611	-174.934
	(STRAIN)	-6.298E-05	1.049E-04	1.049E-04	-6.298E-05	-1.816E-04
2	18.00010	0.00938	2.986	2.997	0.888	0.965
	(STRAIN)	-7.283E-05	1.369E-04	1.380E-04	-7.283E-05	-2.307E-04
3	8.00000	0.01059	4.856	4.856	-191.705	-158.380
	(STRAIN)	-6.260E-05	9.786E-05	9.786E-05	-6.260E-05	-2.896E-05
3	18.00010	0.00942	3.016	3.016	0.893	0.973
	(STRAIN)	-7.348E-05	1.389E-04	1.389E-04	-7.348E-05	-2.289E-04

AT BOTTOM OF LAYER 1 DIFFERENTIAL TENSILE STRAIN = 2.982E-06
ALLOWABLE LOAD REPETITIONS = 5.440E+11 DAMAGE RATIO = 1.642E-06

AT TOP OF LAYER 3 DIFFERENTIAL COMPRESSIVE STRAIN = -1.220E-06
ALLOWABLE LOAD REPETITIONS = 4.074E+17 DAMAGE RATIO = 2.192E-12

* SUMMARY OF DAMAGE ANALYSIS *

AT BOTTOM OF LAYER 1 SUM OF DAMAGE RATIO = 1.063E-01
AT TOP OF LAYER 3 SUM OF DAMAGE RATIO = 1.046E-02

MAXIMUM DAMAGE RATIO = 1.063E-01 DESIGN LIFE IN YEARS = 9.41

class 9-100000 pricing.TXT

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NUMBER OF PROBLEMS TO BE SOLVED = 1

TITLE -EX. 4: VISCOELASTIC THREE LAYER SYSTEM - Individual Vehicle Pricing

MATL = 3 FOR VISCOELASTIC LAYERED SYSTEM
 NDAMA=2, SO DAMAGE ANALYSIS WITH DETAILED PRINTOUT WILL BE PERFORMED
 NUMBER OF PERIODS PER YEAR (NPY) = 1
 NUMBER OF LOAD GROUPS (NLG) = 3
 TOLERANCE FOR INTEGRATION (DEL) -- = 0.001
 NUMBER OF LAYERS (NL)----- = 3
 NUMBER OF Z COORDINATES (NZ)----- = 0
 LIMIT OF INTEGRATION CYCLES (ICL)- = 80
 COMPUTING CODE (NSTD)----- = 9
 SYSTEM OF UNITS (NUNIT)----- = 0

Length and displacement in in., stress and modulus in psi
 unit weight in pcf, and temperature in F

THICKNESSES OF LAYERS (TH) ARE : 8 10
 POISSON'S RATIOS OF LAYERS (PR) ARE : 0.5 0.5 0.5
 ALL INTERFACES ARE FULLY BONDED

FOR PERIOD NO. 1 LAYER NO. AND MODULUS ARE : 1 0.000E+00 2 3.000E+04
 3 1.500E+04

LOAD GROUP NO. 1 HAS 1 CONTACT AREA
 CONTACT RADIUS (CR)----- = 6.31
 CONTACT PRESSURE (CP)----- = 80
 RADIAL COORDINATES OF 3 POINT(S) (RC) ARE : 0 0 0

LOAD GROUP NO. 2 HAS 4 CONTACT AREAS
 CONTACT RADIUS (CR)----- = 4.46
 CONTACT PRESSURE (CP)----- = 80
 NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
 WHEEL SPACING ALONG X-AXIS (XW)----- = 3.3
 WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
 3 0.000 6.750

LOAD GROUP NO. 3 HAS 4 CONTACT AREAS
 CONTACT RADIUS (CR)----- = 4.46
 CONTACT PRESSURE (CP)----- = 80
 NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
 WHEEL SPACING ALONG X-AXIS (XW)----- = 3.8
 WHEEL SPACING ALONG Y-AXIS (YW)----- = 13.5

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 3.375
 3 0.000 6.750

DURATION OF MOVING LOAD (DUR) = 0.05
 NUMBER OF VISCOELASTIC LAYER (NVL) = 1
 LAYER NUMBERS WHICH ARE VISCOELASTIC (LNV) = 1
 CREEP TIMES (TYME) ARE: 0.001 0.003 0.01 0.03 0.1 0.3 1 3 10 30 100

FOR LAYER 1 TIME TEMPERATURE SHIFT FACTOR (BETA) = 0.113
 REFERENCE TEMPERATURE (TEMREF) = 70

CREEP COMPLIANCES (CREEP) AT REFERENCE TEMP. (TEMREF) OF 70 ARE:
 3.700E-07 5.200E-07 8.600E-07 1.450E-06 2.500E-06 4.000E-06 6.200E-06

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class 9-100000 pricing.TXT
 3 (STRAIN) -9.070E-05 1.474E-04 1.474E-04 -9.068E-05 -1.026E-04
 18.00010 0.01449 4.607 4.616 1.377 1.495
 (STRAIN) -1.110E-04 2.111E-04 2.120E-04 -1.119E-04 -3.484E-04

AT BOTTOM OF LAYER 1 TENSILE STRAIN = -9.070E-05 E. MODULUS = 1.837E+06
 ALLOWABLE LOAD REPETITIONS = 7.159E+06 DAMAGE RATIO = 1.397E-07

AT TOP OF LAYER 3 COMPRESSIVE STRAIN = 2.111E-04
 ALLOWABLE LOAD REPETITIONS = 3.893E+07 DAMAGE RATIO = 2.568E-08

DAMAGE ANALYSIS OF PERIOD NO. 1 LOAD GROUP NO. 3
 MULTIPLE AXLES WITH RESPONSE POINT HALFWAY BETWEEN TWO AXLES

POINT NO.	VERTICAL COORDINATE	VERTICAL DISPL. (HORIZONTAL P. STRAIN)	VERTICAL STRESS (STRAIN)	MAJOR PRINCIPAL STRESS (STRAIN)	MINOR PRINCIPAL STRESS (STRAIN)	INTERMEDIATE PRINCIPAL STRESS (STRAIN)
1	8.00000	0.01596	7.533	7.536	-301.086	-273.893
	(STRAIN)	-9.140E-05	1.604E-04	1.604E-04	-9.140E-05	-4.726E-04
1	18.00010	0.01425	4.422	4.489	1.345	1.444
	(STRAIN)	-1.081E-04	1.996E-04	2.063E-04	-1.081E-04	-3.518E-04
2	8.00000	0.01623	7.629	7.629	-302.959	-266.184
	(STRAIN)	-9.457E-05	1.589E-04	1.589E-04	-9.457E-05	-2.804E-04
2	18.00010	0.01446	4.583	4.600	1.372	1.487
	(STRAIN)	-1.114E-04	2.097E-04	2.114E-04	-1.114E-04	-3.529E-04
3	8.00000	0.01630	7.482	7.482	-293.903	-247.625
	(STRAIN)	-9.466E-05	1.514E-04	1.514E-04	-9.466E-05	-9.597E-05
3	18.00010	0.01452	4.634	4.634	1.380	1.500
	(STRAIN)	-1.125E-04	2.129E-04	2.129E-04	-1.125E-04	-3.511E-04

AT BOTTOM OF LAYER 1 DIFFERENTIAL TENSILE STRAIN = 3.964E-06
 ALLOWABLE LOAD REPETITIONS = 2.133E+11 DAMAGE RATIO = 4.688E-12

AT TOP OF LAYER 3 DIFFERENTIAL COMPRESSIVE STRAIN = -1.828E-06
 ALLOWABLE LOAD REPETITIONS = 6.670E+16 DAMAGE RATIO = 1.499E-17

 * SUMMARY OF DAMAGE ANALYSIS *

AT BOTTOM OF LAYER 1 SUM OF DAMAGE RATIO = 3.172E-07
 AT TOP OF LAYER 3 SUM OF DAMAGE RATIO = 5.375E-08

MAXIMUM DAMAGE RATIO = 3.172E-07 DESIGN LIFE IN YEARS = 3153072.

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