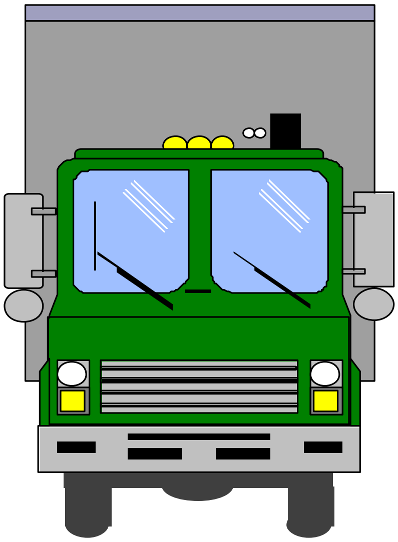
CHAPTER V

Pavement



Introduction

The States spend billions of dollars each year to maintain their highway systems. The *1997 Status of the Nation's Surface Transportation System: Conditions and Performance Report to Congress* indicates that $470 billion will be required over the next 20 years just to maintain the condition of the system. Changes in truck size and weight (TS&W) policy, especially if they include new axle weight limits, could have a major impact on pavement quality and performance characteristics and, therefore, future investment requirements.

The condition and performance of a highway pavement depend on many factors including:

- Pavement structure, materials, and layer depth;
- Construction quality (including uniformity of pavement layers) and maintenance practices;
- Weather—amount of precipitation and freeze-thaw cycles;
- Subbase characteristics that underlie the pavement;
- Magnitude, spacing, and frequency of axle loads; and
- Dynamic interaction between pavement conditions and vehicle speed, number of tires per axle, tire pressures, and suspension characteristics.

The factors most relevant to a national level TS&W study are the magnitude, spacing and frequency of axle loads. These factors along with information on surface roughness, base strength, pavement materials and structure, and weather conditions have been considered in this study. Tire, wheel, and suspension parameters important to estimating pavement damage were not considered in this study. This analysis is concerned with the incremental change in pavement costs caused by the scenario vehicles relative to the damage caused by the current fleet. Since there is no reason to expect these wheel, tire pressure, and suspension parameters to differ between the various existing and proposed configurations, these factors are not critical in estimating pavement impacts of TS&W scenarios.

The elements of dynamic truck-pavement interaction have been the focus of considerable research in recent years (such as the Organization for Economic Cooperation and Development's "Dynamic Interaction Vehicle-Infrastructure Experiment"). However, current information on these dynamic interactions is inconclusive with respect to TS&W policy and their effects appear to be of secondary importance relative to static axle loads.

Axle load and frequency information have been estimated based on vehicle-miles-of-travel (VMT) information for various classes of highway vehicles, which includes the number of axles, from the *1997 Highway Cost Allocation (HCA) Study*. The *HCA Study* VMT estimates by vehicle class and weight group were modified for the alternative TS&W policies through the freight diversion analytical process (see Chapter IV).

Pavement and subbase data by highway section were taken from the Federal Highway Administration (FHWA) Highway Performance Monitoring System (HPMS) database to which was added State specific weather, soil, and base thickness data. The HPMS data base, the most comprehensive national database currently available, includes detailed characteristics on about 100,000 sections of U.S. highways.

Basic Principles

Truck-Pavement Interaction

In terms of vehicle-specific characteristics, pavement wear 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. However, the analysis conducted for this study does not quantify these secondary, vehicle-specific characteristics because they are less important to pavement deterioration than pavement type and axle weight. Further, there is no reason to assume that these characteristics are different, in general, for one truck configuration versus another.

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 and axle groups 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 of both rigid and flexible pavements and permanent deformation or rutting in flexible pavements. Eventually, if the pavement is not routinely maintained, the axle loads, in combi-nation with environmental effects, such as pavement moisture, accelerate cracking and deformation. Figure V-1 explains pavement fatigue in more detail.

Pavement Life Consumption

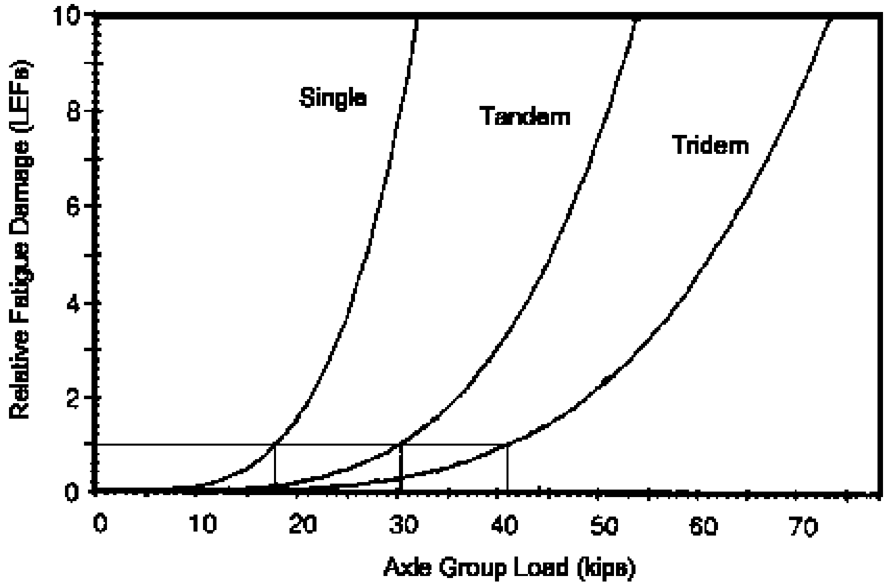
Proper pavement design relative to loading is a significant factor, which varies by highway system. The incremental effect on pavement deterioration increases sharply as the axle load increases. A fourth power relationship between axle load and pavement deterioration has been the rule of thumb since the American Association of State Highway Officials' road test conducted during the late 1950s (see Figure V-2). Such a relationship means that if axle loads are doubled from say 10,000 pounds to 20,000 pounds, the impact on the pavement will increase by

Figure V-1. Pavement Fatigue

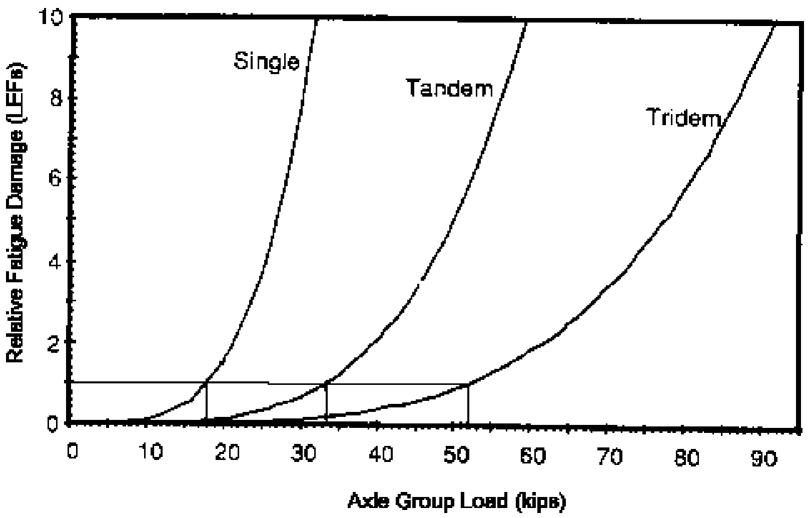
The break-up of pavements is usually caused by fatigue. Fatigue or fatigue cracking is caused by many repeated loadings and the heavier the loads the fewer the number of repetitions required to reach the same condition of cracking. It is possible, especially for a thin pavement, for one very heavy load to break up the pavement in the two wheel paths. To account for the effect of different axle weights, the relative amount of fatigue for an axle at a given weight is compared to that of a standard weight axle. Historically this standard axle has been a single-axle with dual tires and an 18,000-pound load.

FigureV-2. Impact of Axle Load on Fatigue in Flexible and Rigid Pavements

FLEXIBLE PAVEMENT



RIGID PAVEMENT



Source: Gillespie, et. al. "Effects of Heavy-Vehicle Characteristics on Pavement Response and Performance," NCHRP Report 353, Transportation Research Board, Washington, DC, 1993.

a factor of approximately 16. More recent research has shown that the influence of load on pavement deterioration varies depending on the nature of the pavement distress. For instance the influence of axle load on pavement rutting is somewhat different from the relationship to cracking. In general, however, the relationship between axle load and pavement deterioration may be closer to a third power than a fourth power relationship. Thus doubling axle load may increase pavement deterioration by a factor of eight rather than 16, but still a very significant difference.

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. These axle groups reduce pavement consumption by spreading the load along more of the pavement. This effect is more significant for flexible than for rigid pavements (see Figure V-4), although Figure V-3 shows the difference is not large.

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. Spreading axles within a group increases the fatigue damage in flexible pavements. Rigid pavements are affected differently by axle spread. Over short distances, rigid pavements act like bridges, and consequently, pavement damage is reduced by spreading axles.

Tables V-1 through V-3 compare the relative pavement consumption of various axle groups and truck configurations evaluated in the study at the maximum allowable weights that would be allowed in the various scenarios. These

Figure V-3. The AASHO Road Test

In the late 1950's the then American Association of State Highway Officials (now the American Association of State Highway and Transportation Officials) conducted pavement deterioration tests at Ottawa, Illinois. The measure of pavement deterioration used was the Present Serviceability Rating (PSR). The tests found that, with increasing axle load, pavements deteriorated at a rate that was roughly equivalent to the relative weight increase raised to the fourth power. It is important to note that the analysis methods used in the AASHO road test were purely empirical and were not based on physical properties of the pavement structures. Furthermore all tests were conducted at a single site with a limited number of pavement designs, soil characteristics, environmental conditions, etc. More recent research drawing upon physical properties of construction materials and pavement emphasizes that pavements deteriorate in different ways and that the relationship of axle load to various types of pavement deterioration are not uniform. For most pavement distresses the relationship between axle load and pavement deterioration is less than a fourth power, and the overall relationship between axle load and pavement deterioration may be closer to a third power rather than a fourth power relationship. Recent reviews of the original AASHO road test data also have concluded that the data show approximately a third power relationship.

Figure V-4. Flexible Versus Rigid Pavements

High-type pavements include a weather-resistant surface and are classified as either flexible or rigid. Flexible pavements are surfaced with bituminous (or asphalt) materials. The total pavement structure “bends” or “deflects” in response to a load. Also, a flexible pavement structure is usually composed of several layers that absorb most of the deflection. Rigid pavements are made from portland cement concrete (PCC) and are substantially “stiffer” than flexible pavements. Some, PCC pavements have reinforcing steel to help resist cracking due to temperature changes and repeated loading.

Only 11 percent of all hard surfaced highways have rigid or composite pavements (rigid pavements with flexible overlays). The remaining have flexible pavements. About 50 percent of the Interstate System mileage has rigid or composite pavement. Flexible pavements are expected to serve from 10 years to 15 years. In contrast, rigid pavements may serve 30 years or more. However, when a flexible pavement requires major rehabilitation, the work is generally less expensive and quicker to perform than for rigid pavements.

comparisons are based on the effects of the axle groups and their loads relative to a 18,000-pound single axle load. These relative effects are expressed in load equivalency factors (LEFs) that may be defined as the number of repetitions of a reference load and axle combination (such as the 18,000-pound single axle) that is equivalent in pavement life consumption to one application of the load and axle configuration in question. LEFs are useful in distilling the effects of different vehicle types into a single measure for comparison purposes. However, actual LEFs vary by pavement type, thickness, and distress type.

Table V-1 shows LEFs for three of the more significant pavement distress types by axle group and weight derived from theoretical pavement damage models. Rigid and flexible pavement LEFs for fatigue were interpolated from Figure V-2. These theoretical values show relative relationships among axle load, axle type, pavement type, and pavement distress, but they do not show the influence of environmental factors and thus should not be used in specific applications. As discussed later in this chapter, the pavement analysis in this study did not use the theoretical LEFs shown in Table V-1, but rather used distress models that take into account differences in pavement type and thickness and environmental factors. The theoretical LEFs, however, are useful in demonstrating fundamental relationships of interest to TS&W considerations.

To estimate pavement impacts of different vehicle configurations at different weights, LEFs can be estimated for each group of axles and then summed to derive a total LEF for the vehicle. LEFs for each vehicle would be different for their travel on flexible pavement than for travel on rigid pavement, and they also differ depending on the type of pavement distress. Table V-2 shows total LEFs for various scenario vehicles at their maximum allowable weights under the illustrative scenarios.

Table V-1. Theoretical Load Equivalency Factors for Various Axle Groups and Loads for Major Types of Rigid and Flexible Pavement Distress

Axle Group	Load (pounds)	Load Equivalency Factors *		
		Rigid Pavement Fatigue (10-inch thickness)	Flexible Pavement (5-inch wearing surface)	
			Fatigue	Rutting
Steering Axle Single tires	12,000	0.6	1.4	1.3
	20,000	3.1	4.0	2.2
Single Axle Dual tires	17,000 (STAA double)	0.9	0.9	0.9
	20,000	1.6	1.5	1.1
Tandem Axle	34,000	1.1	1.6	1.9
Spread Tandem-Axle (10-foot Spread)	40,000	1.4	3.0	2.2
Tridem-Axle (9-foot spread)	44,000	0.6	1.4	2.4
	51,000	1.0	2.5	2.8

* Based on 18,000 pound single axle with dual tires

Source: Gillespie, et. al. “Effects of Heavy-Vehicle Characteristics on Pavement Response and Performance,”

Table V-2 clearly shows the benefits of adding axles to vehicles. The LEFs for the four-axle SUT at 64,000 pounds are lower than those for the three-axle SUT at 54,000 pounds. Likewise, differences in axle configuration also are clearly illustrated in Table V-2 when one compares LEFs for the conventional five-axle tractor-semitrailer, the five-axle tractor-semitrailer with spread axles on the rear, and the five-axle STAA double.

The conventional tractor-semitrailer with tandem axles on the rear of the semitrailer has lower LEFs than a similar vehicle with the rear axles spread by 10 feet so they act like two single axles rather than like a tandem axle group. The STAA double with five single axles has greater LEFs than the two tractor-semitrailer combinations except for flexible pavement rutting where all three vehicles have similar impacts.

Two sets of LEFs are shown in Table V-2 for the seven-axle triple combination, one typical of less-than-truckload (LTL) operations and one at the maximum allowable weight assumed for triples in the study scenarios. The lower weight assumes 17,000-pound single axles and the second, 20,000-pound axles. This 3,000-pound difference in axle weights increases rigid pavement fatigue by 70 percent, flexible pavement fatigue by 53 percent, and flexible pavement rutting by 18 percent.

Table V-3 presents impacts of different vehicle configurations from a different perspective. It shows the total LEFs that would be accumulated by different vehicle configurations in hauling 100,000 pounds of freight. Total LEFs, and thus total pavement impacts, vary considerably by configuration and weight. The eight-axle B-train combination with a gross weight of 124,000 pounds and the six-axle tractor-semitrailer at 90,000 pounds would cause the least pavement impact to carry 100,000 pounds of freight, while the two SUTs and the triple at 132,000 pounds would have the greatest impact.

To realistically compare how pavement impacts change with changes in weight limits, it cannot be assumed that it is always cheaper to use the larger configurations, or that they always operate at their maximum allowable weights.

Analytical Approach

Alternative weights for current truck configurations were analyzed in terms of their interaction with highway infrastructure features. The configurations included were single-unit or straight trucks and single- and multitrailer truck combinations. Pavement types analyzed include flexible (asphaltic concrete) and rigid (portland cement concrete).

The methods used to assess the potential pavement impact of alternative TS&W policy scenarios on pavement life consumption involved two phases. The first phase included new research on tridem-axle impacts. Of particular interest was the relationship between axle loads, axle spacings and pavement deterioration. The goal was to develop optimum axle load and spacing criteria that also took into account potential bridge impacts.

The second phase included the development of pavement impact cost estimates based on the pavement cost model used for the *HCA Study* analysis. A number of revisions were made to that model to make it more sensitive to TS&W policy options.

Tridem-axle Impact Research

In the United States, the allowable load on a group of three axles connected through a common suspension system (a tridem-axle) is determined by the Federal Bridge Formula (FBF) rather than a limit set by law (or regulation). In Europe, Canada, Mexico, and other jurisdictions, tridem axles are given a unique load limit in the same way the United States specifies unique single- and tandem-axle limits without the use of a bridge formula. This is not to say that these unique tridem limits are not bridge-related. In Canada, for example, the tridem limits vary as a function of spacing, based on bridge loading limitations—not pavement limitations.

Tridem axles could be considered as a way to increase truck load capacity while reducing pavement damage (see Figure V-5).

Table V-2. Theoretical Load Equivalency Factors for Scenario Vehicles

Configuration	Gross Vehicle Weight (pounds)	Number of Axles in Each Group (S=Steering Axle)	Load Equivalency Factors ***		
			Rigid Pavement Fatigue (10-inch thickness)	Flexible Pavement (5-inch wearing surface)	
				Fatigue	Rutting
Three-Axle Single Unit Truck	54,000	S,2	4.2	5.6	4.1
Four-Axle Single Unit Truck	64,000	S,3	3.6	5.4	4.6
	71,000	S,3	4.1	6.5	5.0
Five-Axle Semitrailer	80,000	S,2,2	2.8	4.6	5.1
Five-Axle Semitrailer (10-foot Spread)	80,000	S,2,2 (spread)	3.1	6.0	5.4
Six-Axle Semitrailer	90,000	S,2,3	2.2	4.4	5.6
	97,000	S,2,3	2.7	5.5	6.0
STAA Double (five-axle)	80,000	S,1,1,1,1	4.2	5.0	4.9
B-Train Double (eight-axle)	124,000	S,2,3,2	3.3	6.0	6.5
	131,000	S,2,3,2	3.8	7.1	6.9
Rocky Mt.Double (seven-axle)	120,000	S,2,2,1,1	6.0	7.6	7.3
Turnpike Double (nine-axle)	148,000	S,2,2,2,2	5.0	7.8	7.3
Triple (seven-axle)	114,000 (LTL operation)*	S,1,1,1,1,1,1	6.0	6.8	6.7
	132,000 (TL operation)**	S,1,1,1,1,1,1	10.2	10.4	7.9

*LTL= Less-than-truckload

**TL=Truckload

*** Based on 18,000-pound single axle with dual tires

There already has been a switch from three-axle to four-axle SUTs by many heavy bulk freight haulers, and as noted above, significant pavement cost savings may be possible. The 80,000-pound GVW limit poses a constraint on adding axles to five-axle combinations because, under the GVW limit, the extra axle would reduce the payload.

An evaluation of a specific

Table V-3. Theoretical Load Equivalency Factors Per 100,000 Pounds of Payload

Configuration	Gross Vehicle Weight (pounds)	Empty Weight (pounds)	Payload Weight (pounds)	No. Of Vehicles per 100,000 pounds of payload	Load Equivalency Factors		
					Rigid Pavement Fatigue (10-inch thickness)	Flexible Pavement (5-inch wearing surface)	
						Fatigue	Rutting
Three-Axle Single Unit Truck	54,000	22,600	31,400	3.18	13.4	17.8	13.0
Four-Axle Single Unit Truck	64,000	26,400	37,600	2.66	9.6	14.4	12.2
	71,000	26,400	44,600	2.24	9.2	14.6	11.2
Five-Axle Semitrailer	80,000	30,500	49,500	2.02	5.7	9.3	10.3
Five-Axle Semitrailer (10-foot Spread)	80,000	30,500	49,500	2.02	6.3	12.2	10.9
Six-Axle Semitrailer	90,000	31,500	58,500	1.71	3.8	7.5	9.6
	97,000	31,500	65,500	1.53	4.1	8.4	9.2
STAA Double (five-axle)	80,000	29,300	50,700	1.97	8.3	9.9	9.7
B-Train Double (eight-axle)	124,000	38,700	85,300	1.17	3.9	7.0	7.6
	131,000	38,700	92,300	1.08	4.1	7.7	7.5
Rocky Mt.Double (seven-axle)	120,000	43,000	77,000	1.30	7.8	9.9	9.5
Turnpike Double (nine-axle)	148,000	46,700	101,300	0.99	5.0	7.7	7.2
Triple (seven-axle)	114,000 (LTL operation)*	44,500	69,500	1.44	8.6	9.8	9.6
	132,000 (TL operation)**	44,500	87,500	1.14	11.6	11.8	9.0

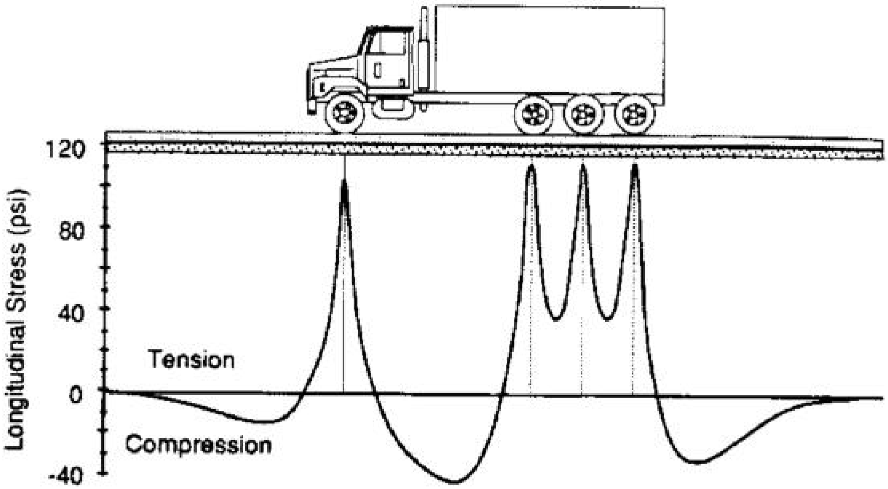
*LTL= Less-than-truckload
**TL= Truckload

limit for tridem groups was undertaken as the FBF is conservative for closely spaced axles. In contrast, it is liberal in the weight it allows for long multitrailer combinations. During the development of the truck configuration building blocks early in the study, a 97,000-pound six-axle semitrailer combination was selected for evaluation, because at that weight a 40-foot container loaded to the ISO

FigureV-5. Use of Spread-Tandem Versus Tridem Axles

There is increasing use of wide-spread (up to 10 feet) “spread-tandem” axle groups, particularly in flatbed heavy haul operations. These axles are allowed to be loaded at single axle limits–20,000 pounds on each of the two axles as opposed to 34,000 pounds on a closed tandem. They offer two key benefits relative to five-axle tractor semitrailers combinations: (1) flexibility in load distribution, and (2) full achievement of the 80,000-pound gross vehicle weight cap, which is limited by the ability to distribute up to 12,000 pounds on the steering axle of a combination. But they do so with significant pavement costs. Their expanding use could be counteracted with a higher tridem-axle load to the benefit of pavements.

The diagram below shows why tridem-axles are more pavement friendly than split-tandem axles. As loads are moved from farther to closer distances, the stresses they apply to the pavement structure begin to overlap; they stop acting as separate loads. While maximum deflection of the pavement surface increases as axle spacing is reduced, maximum tensile stress at the underside of the surface layer will decrease. Tensile stress is a primary cause of fatigue cracking and can decrease as axle spacing is reduced. However, the net effect of changes in axle spacing is very complex and dependent on the nature--flexible versus rigid--of the pavement structure.



(International Standards Organization) maximum limit could be moved without requiring a permit on Interstate highways. Implicit in this is a 51,000-pound limit for the tridem-axle group. (See Chapter III, North American Trade Scenario discussion.)

weight from both a pavement and a bridge perspective, found that the optimum limit was 44,000 pounds for a tridem axle with nine feet between the first and last axles in the group. If the axles were to be spread more than this, pavement fatigue would increase, while bridge stress would decrease. And conversely, if the nine feet were shortened, bridge stresses would increase, while pavement fatigue would decrease. As a result of the research, both the 44,000-pound and the 51,000-pound limits were evaluated. (See Figure V-6.)

The National Pavement Cost Model

The National Pavement Cost Model (NAPCOM) is used to estimate potential pavement impacts resulting from changes in the Nation's TS&W limits. NAPCOM is a complex simulation model initially developed in 1992 and subsequently improved for use in the 1997 *HCA Study*. The key output of NAPCOM for cost allocation is the relative responsibility for pavement damage attributable to different vehicle classes operating at different weights and highway systems. For TS&W analysis NAPCOM is used to estimate how overall pavement improvement needs would vary under alternative TS&W scenarios and to attribute changes in pavement rehabilitation costs to specific groups of vehicles. The model is sensitive to different weight policies, depending on truck configuration, including the number of axles.

Overview

To estimate the impact of the various scenarios on pavement requirements, NAPCOM was applied to generate: (1) lane-miles of failed pavement in the base case, and (2) lane-miles of failed pavement under the test scenario conditions. In each case, lane-miles of failed pavement were translated into pavement costs. NAPCOM implements a 20-year analysis to generate the number of failed lane miles by functional class of highway and highway type. The improvement needs relate to a 20-year stream of traffic (from 2000 to 2020).

Input Data

NAPCOM uses information about specific, representative highway sections supplied by the States through the FHWA's HPMS process. The HPMS includes approximately 100,000 records of pavement sections each of which includes detailed information on design characteristics, current condition of the pavement, and the traffic that uses that particular segment (current and 20-year projection).

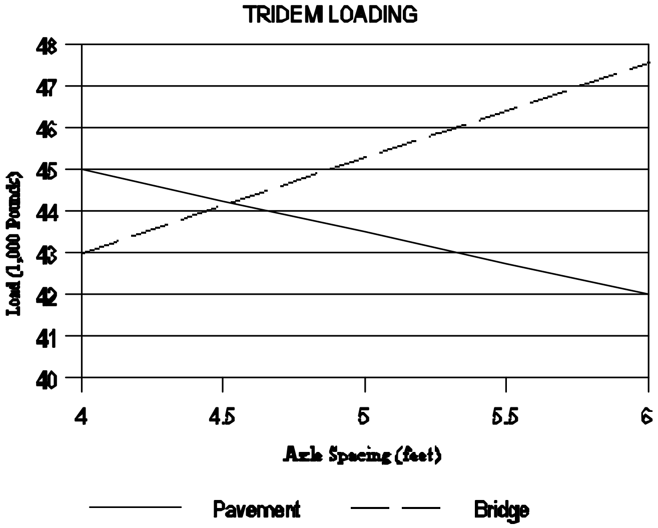
NAPCOM uses the following information from HPMS: number of lanes, type of pavement, pavement thickness, current pavement condition, average daily traffic, percentage of trucks in the traffic stream, predicted 20-year traffic levels, climatic zone, and some rudimentary information about the pavement base. The HPMS data is supplemented with additional State-characteristic information, to include: freeze-thaw cycles, freezing index, average rainfall and thickness of base.

NAPCOM uses the following fleet data developed for the *HCA Study*: (1) annual VMT by vehicle class, highway functional class, and State; (2) operating weight distribution for each vehicle class on groups of highway types in groups of States; and (3) axle weights for the midpoint of each weight group for each vehicle class.

Figure V-6. Tridem Axle Infrastructure Impacts

The complexity of the interactions of truck weights and dimensions on pavements and bridges is illustrated in the graph below. This graph shows that spreading the individual axles in the tridem-axle group increases pavement wear primarily through fatigue, but it decreases the maximum stresses in a simple bridge span by reducing the maximum stress at the midpoint of the span. It also shows that the optimal weight limit considering both pavement and bridge impacts for a tridem axle is 44,000 pounds when there is 4.5 feet between two adjacent axles. To spread the axles further would increase pavement wear beyond that of the present 34,000 pounds allowed on a tandem axle. To move the axles closer together would increase stresses in certain bridges beyond that allowed under the current bridge stress criteria.

Relative Pavement and Bridge Impacts
Tridem Axle



A different traffic loading was estimated for each TS&W policy scenario. This was done by starting with the VMT file created by the *HCA Study* and modifying it based on the new distribution of freight between truck and rail, from one truck configuration to another, and from one weight group to another for a given truck configuration (see Chapter IV). This produces a VMT file for each scenario stratified by truck configuration, weight group (5,000-pound increments), functional class of highway, and State.

Pavement Deterioration Models

NAPCOM relies on 11 pavement distress models to estimate when pavement restoration will be required. These models determine the expected pavement condition at the end of each year of analysis. They evaluate the following distresses on flexible pavements: (1) traffic-related Pavement Serviceability Rating (PSR) loss; (2) expansive-clay-related PSR loss; (3) fatigue cracking; (4) thermal cracking; (5) rutting; and (6) loss of skid resistance. Distresses considered for rigid pavements include: (1) traffic-related PSR loss; (2) faulting; (3) loss of skid resistance; (4) fatigue cracking; (5) spalling; and (6) soil-induced swelling and depression. Additionally, NAPCOM estimates the damage attributable to environmental factors.

To improve NAPCOM, the FHWA undertook new research using the mechanistic cause and effect relationships between wheel load and frequency-induced stress and pavement distress. Results were calibrated using recent empirical data to determine the impact of wheel loads and frequency on pavement deterioration. Weighted averages of the distresses were used to develop a single scale which determines the overall pavement condition and which is used to determine the need for rehabilitation.

NAPCOM distress models do not use AASHTO's Fourth Power Law for pavement load and deterioration. Rather, load relationships and exponential relationships for each of the types of distress have been estimated. For most of them, the exponent would be slightly less than four. The effect of load is not as great as the simple AASHTO road test relationship for loss of serviceability would indicate.

Cost Calculations

Of interest for this study, the model provides the number of failed lane miles by highway type (flexible or rigid) and functional class of highway. The estimate of total failed lane miles by functional class of highway is combined with pavement rehabilitation unit cost figures by functional class of highway to create an estimate of the impact on pavement rehabilitation costs, all expressed in 1994 dollars.

Assessment of Scenario Impacts

To properly measure the pavement impacts, each scenario result must be compared with those pavement costs that would be incurred without a change in truck weight policy, the base case (see Table V-4). The estimated cost to maintain the current pavement conditions for the year 2000 with no TS&W policy changes is $196 billion in pavement restoration costs over 20 years. A comparison of the relative pavement impacts of the scenarios reveals that the Triples Nationwide Scenario had the largest increase in pavement restoration costs. It had an impact of $58 million in costs over 20 years (0.03 percent of the base case).

The fact that these pavement impacts are very small should not be surprising as axle weight limits were not increased in any of the scenarios, except for the 44,000-pound and the 51,000-pound limits for the tridem-axle on the four-axle SUT, six-axle semitrailer, and eight-axle B-train configurations in the North American Trade Scenario.

Table V-4. Scenario Pavement Impacts

Analytical Case		VMT (million)		Impacts ($million)	
		All Highway Vehicles	Heavy Trucks (3 or more axles)	20-Year Pavement Costs	Change from Base Case
1994		2,359,984	109,979	194,285	- 2,254
2000 Base Case		2,693,845	128,288	196,539	0
Scenarios					
Uniformity		2,697,908	132,351	195,873	- 666
North American Trade	44,000-pound tridem axle	2,680,228	114,671	193,475	- 3,064
	51,000-pound tridem axle	2,680,189	114,632	194,092	- 2,447
LCVs Nationwide		2,664,119	98,562	196,141	- 398
H.R. 551		2,693,868	128,311	196,541	2

Further, this scenario, with the 44,000-pound tridem-axle weight limit, resulted in a net savings of $3.1 billion in pavement restoration costs (a 1.56 percent decrease) over 20 years. The North American Trade Scenario with the 51,000-pound tridem-axle weight limit would result in a savings over 20 years of $2.4 billion (a 1.25 percent decrease).

Uniformity Scenario

Although this scenario had a 3.2 percent increase in heavy truck VMT, pavement restoration costs were 0.3 percent lower than the base case pavement improvement costs. This results from the significant shift of VMT to lower weight groups for all configurations, but especially for combination vehicles.

At the most pavement-sensitive axle weights, this shift was as much as 5,000 pounds downward in GVW for semitrailer combinations and more for those truck configurations that typically operate above the 80,000-pound Federal maximum GVW limit. This decrease in weight resulted in reduced axle loads that resulted in even greater decreases in pavement wear. The positive effect of decreased axle loads more than offset the increased in VMT.

North American Trade Scenarios

These two scenarios, one based on a 51,000-pound tridem-axle weight limit and the other on a 44,000-pound weight limit, were estimated to result in the largest savings in pavement restoration costs. While heavy truck VMT in both scenarios was approximately 10 percent lower than the base case, pavement cost savings for the 44,000 pound tridem axle scenario were estimated to be greater than savings for the 51,000 pound tridem scenario (3.0 billion over 20 years versus $2.4 billion). The reductions in pavement costs result from reduced VMT and lower LEFs for the tridem-axle configurations per unit of payload.

VMT for five-axle semitrailer combinations was approximately 70 percent less than base case VMT for both scenarios while VMT for the eight-axle B-train increased from less that 700 million miles annually under the base case to almost 50 billion annual miles under the North American Trade Scenarios.

Also significant are the differences in LEFs for the scenario vehicles. Table V-4 shows that in terms of payload carried, the six-axle semitrailer and eight-axle B-train double have much lower LEFs than the five-axle semitrailer combination.

Longer Combination Vehicles Nationwide Scenario

Despite the fact that much heavier vehicles are assumed to operate under this scenario than under the base case, pavement restoration costs are estimated to fall by $398 million over 20 years, a 0.2 percent decrease. The primary reason for the slight decrease in pavement costs is the fact that total truck VMT is estimated to decrease by 23 percent compared to the base case. The configurations of greatest significance in this scenario in terms of changes in VMT are the five-axle semitrailer which loses freight to the TPD and the five-axle STAA double which loses freight to the triple. VMT by five-axle semitrailer combinations is predicted to decrease by 76.6 percent under this scenario while TPD VMT is predicted to increase from just 76 million in the base case to over 32 billion under this scenario. VMT for the STAA double-trailer combination drops by 82 percent, while triples VMT increases from 126 million to almost 6 billion.

Another significant factor in reduced pavement costs is the fact that TPDs cause less pavement wear per unit of cargo than the five-axle tractor-semitrailers they would replace. Triples and doubles cause about the same pavement damage to carry the same amount of cargo.

H.R. 551 Scenario

This scenario had no change in weight limits and virtually no impact on heavy truck VMT (an increase of 23 million—0.02 percent) and consequently, virtually no impact on pavement restoration costs.

Triples Nationwide Scenario

Pavement restoration costs under this scenario are estimated to be virtually unchanged (an increase of less than 0.1 percent). Total truck VMT is estimated to decrease by about 20 percent, but triples VMT in 2000 is estimated to increase from 126 million to almost 40 billion. Since triples cause more pavement wear per unit of cargo carried than the five-axle tractor-semitrailers they would replace, the large increase in pavement wear caused by increased triples traffic would offset reductions in pavement wear caused by decreases in traffic by other vehicle configurations, primarily the five-axle tractor-semitrailer.