Truck Size and Weight

*www.mnltap.umn.edu/about/programs/**truck**weight/**videos**/*

The U.S. Department of Transportation's Comprehensive Truck Size and Weight Study

&

Minnesota Truck Size and Weight Project

The second issue of *Public Roads* magazine published in 1918 focused on the problems State highway departments were encountering as the result of truck traffic. The lead article, "*The Highways of the Country and the Burden They Must Carry*," summarized the issues of that era, many of which are still familiar today:

> Apparently the point has been reached where the demands of traffic have exceeded the strength of the average road to meet them. Highways designed to withstand the pounding of ordinary loads, that have stood up under imposts they were intended to sustain, no longer appear to be adequate to meet the present-day conditions. Widespread failure is demonstrative of the fact the roads can not carry unlimited loadings. Their capacity is limited.

There are two aspects of truck weight that are interdependent and that interact with the highway infrastructure -- axle weight (loading) and GVW. As shown in Table VI-1, the effect of axle weight is more significant to pavements and short-span bridges, whereas GVW is of more significance to long-span bridges.

North Dakota Department of Transportation

Table VI-1
Highway Infrastructure Elements Affected by TS&W Limits

Highway Infrastructure Element		Axle Weight	GVW	Axle Spacing	Truck Length	Truck Width	Truck Height
Pavement	Flexible	E		E			
	Rigid	E		e			
Bridge Features	Short-Span	E		E	E		
	Long-Span		E	e	E		
	Clearance					e	E
Roadway Geometric Features	Interchange Ramps		e		E	e	
	Intersections				E	e	
	Climbing Lanes		E				
	Horizontal Curvature		e		e		
	Vertical Curve Length		E				
	Intersection Clearance Time		E		E		
	Passing Sight Distance				e		

Key: E = Significant Effect
e = Some Effect

Industry Challenges and Considerations
TS&W limits affect freight transportation costs because they control the amount of payload that can be carried in a truck. Increases in truck weight limits increase the allowable weight per trip, so fewer trips are required to carry the same amount of goods. Freight transportation cost savings due to increases in TS&W limits accrue to shippers, carriers, and consumers.

Truck-Pavement Interaction

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.

Axle groups, such as tandems or tridems, distribute the load along the pavement, allowing greater weights to be carried and resulting in the same or less pavement distress than that occasioned by a single axle at a lower weight. While spreading the axles in an axle group is beneficial to short-span bridges, it is detrimental to pavement. It is not GVW but the distribution of the GVW over axles that impacts pavements.

Over time, the accumulated strains (the pavement deformation from all the axle loads) deteriorate pavement condition, ……. If the pavement is not routinely maintained, the axle loads, in combination with environmental effects, will accelerate the cracking and deformation. Proper pavement design relative to loading is a significant factor in pavement life, and varies by highway system and the number of trucks in the traffic stream.

Pavement Considerations

Engineers design roads to accommodate projected vehicle loads, in particular, heavy vehicle axle loads. The life of a pavement is related to the magnitude and frequency of these heavy axle loads. Pavement engineers use the concept of an equivalent single-axle load (ESAL) to measure the effects of heavy vehicles on pavements. Any truck axle configuration and weight can be converted to this common unit of measure. Adding axles to a truck can greatly reduce the impact on pavement.

The effect of ESALs on pavements is not constant throughout the calendar year. During the winter when the ground is frozen, a given traffic loading does much less damage to pavements than at other times of the year. During the spring, pavement layers are generally in a saturated, weakened state due to partial thaw conditions and trapped water. A given traffic loading during spring thaw results in five to eight times more damage to pavements than that same loading at other times of the year.

A conventional five-axle tractor-semitrailer operating at 80,000 pounds gross vehicle weight (GVW) is equivalent to about 2.4 ESALs. If the weight of this vehicle were increased to 90,000 pounds (a 12.5 percent increase), its ESAL value goes up to 4.1 (a 70.8 percent increase), because pavement damage increases at a geometric rate with weight increases.

However, a six-axle tractor-semitrailer at 90,000 pounds has an ESAL value of only 2.0, because its weight is distributed over six axles instead of five. An added pavement benefit of the 90,000-pound six-axle truck is that fewer trips are required to carry the same amount of payload, resulting in almost 30 percent fewer ESAL miles per payload ton-mile.

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 comparisons are based on the effects of the axle groups and their loads relative to an 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.

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. Theoretical Load Equivalency Factors for Scenario Vehicles

Configuration	Gross Vehicle Weight (pounds)	Number of Axles in Each Group (S=Steering Axle)	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

**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	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

Bridge Considerations

However, GVW *is* a factor for the life of long-span bridges -- that is, bridge spans longer than the wheelbase of the truck. Bridge bending stress is more sensitive to the spread of axles than to the number of axles. The FBF takes into account both the number of axles and axle spreads in determining allowable GVW.
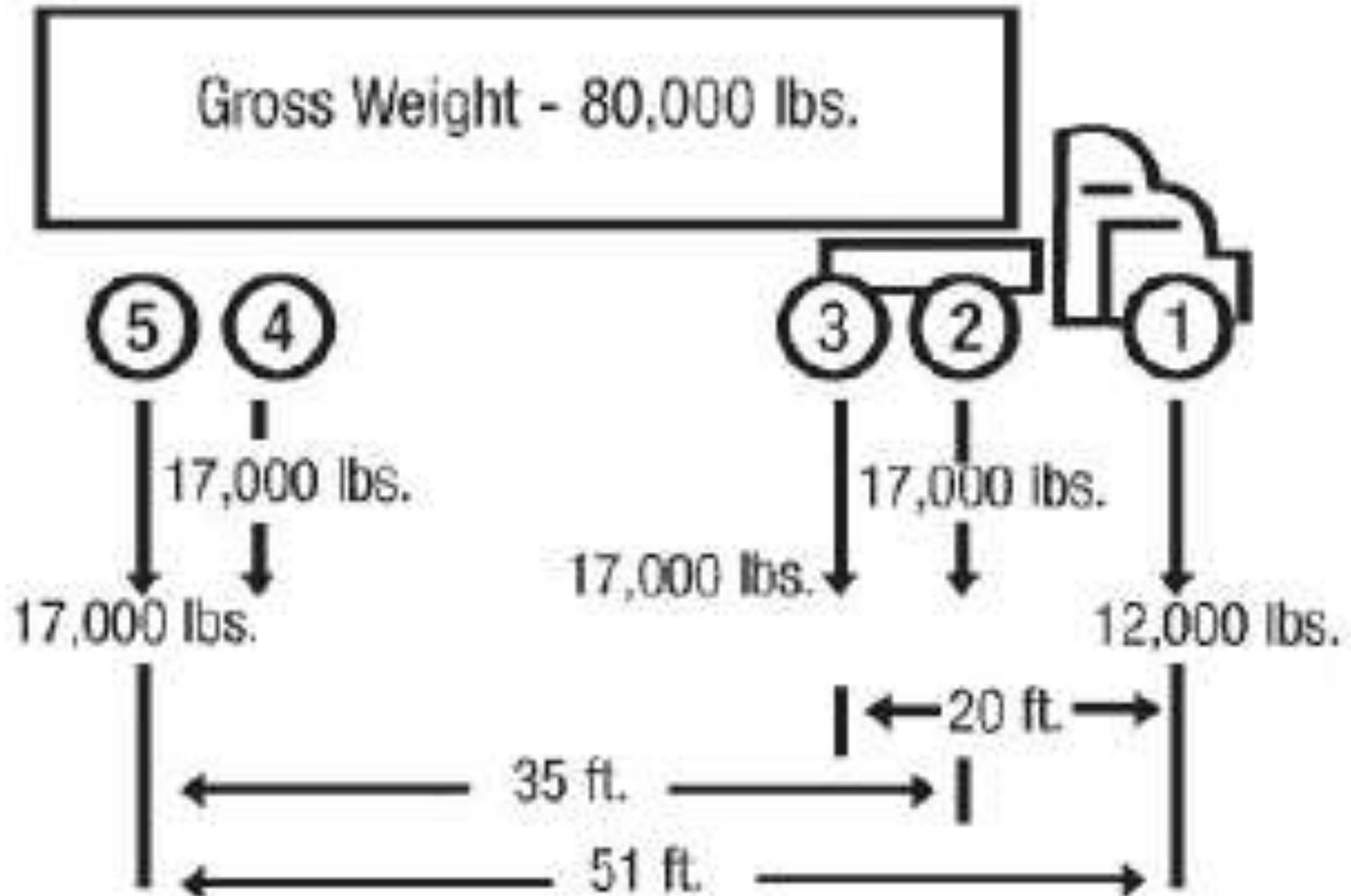
Long 80,000 lb. Truck

(A)

Short 80,000 lb. Truck

(B)
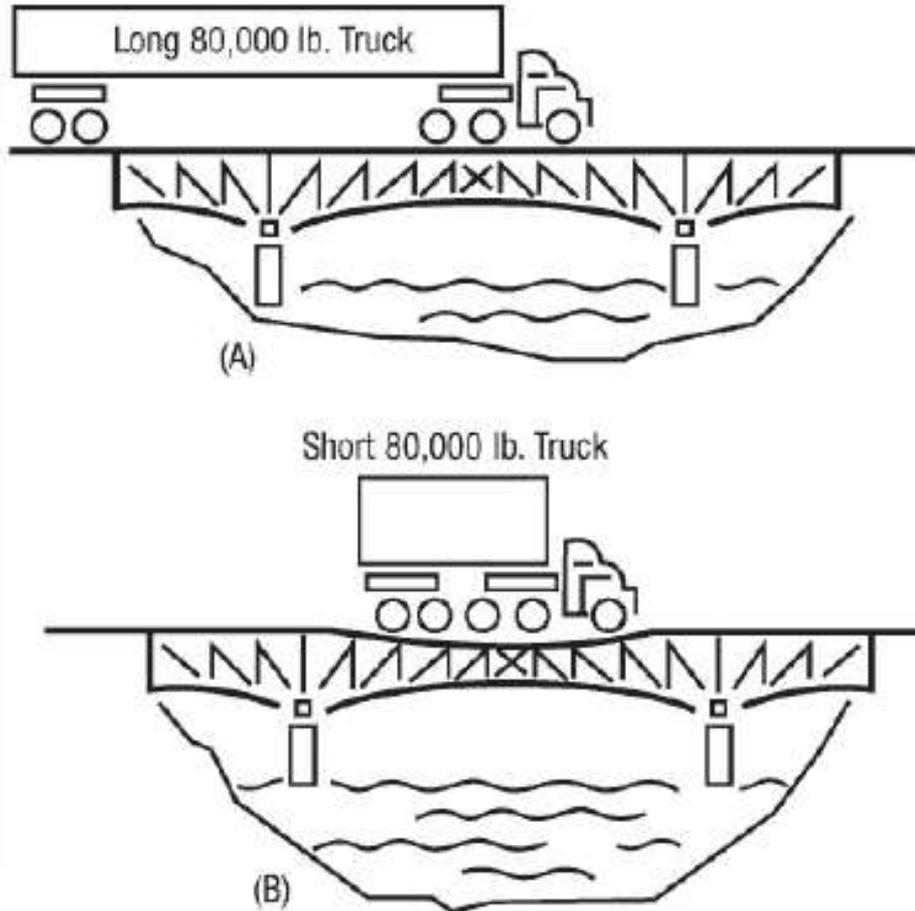
Is the Formula Necessary?

Bridges on the Interstate System highways are designed to support a wide variety of vehicles and their expected loads. As trucks grew heavier in the 1950s and 1960, something had to be done to protect bridges. The solution was to link allowable weights to the number and spacing of axles. Axle spacing is as important as axle weight in designing bridges. In Figure A, the stress on bridge members as a longer truck rolls across is much less than that caused by a short vehicle as shown in Figure B, even though both trucks have the same total weight and individual axle weights. The weight of the longer vehicle is spread out, while the shorter vehicle is concentrated on a smaller area.

Increases in truck weight limits can affect bridges in several ways. Should the legally allowable limits change, and the limits exceed the design criteria for a bridge, the bridge must be posted (signed for restricted use) to prevent those heavy vehicles from using it. Changing allowable limits may increase agency costs for inspecting and rating bridges and for posting signs. The number, spacing, and weight of individual axles, as well as the GVW carried on a truck, are important considerations for bridges.

The formula is: W = 500 [L N / (N − 1) + 12 N + 36] where W is the maximum weight of the axle group, L is the distance from the first to last axle in feet, and N is the number of axles. The Federal Highway Administration's brochure Bridge Formula Weights is available at:

http://www.ops.fhwa.dot.gov/freight/publications/bridge_frm_wts/index.htm

Gross Weight - 80,000 lbs.

5   4

3   2   1

17,000 lbs.

17,000 lbs.

17,000 lbs.

17,000 lbs.

12,000 lbs.

←20 ft.→

←— 35 ft. —→

←— 51 ft. —→

Based on weight formula $W = 500 \left[\dfrac{LN}{N-1} + 12N + 36 \right]$

Distance in feet (L) between the extremes of any group of 2 or more consecutive axles

Maximum load in pounds carried on any group of 2 or more consecutive axles[1]

L	2 AXLES	3 AXLES	4 AXLES	5 AXLES	6 AXLES	7 AXLES	8 AXLES	9 AXLES
4	34,000							
5	34,000							
6	34,000							
7	34,000							
8	34,000	34,000						
More than 8 less than 9	38,000	42,000						
9	39,000	42,500						
10	40,000	43,500						
11		44,000						
12		45,000	50,000					
13		45,500	50,500					
14		46,500	51,500					
15		47,000	52,000					
16		48,000*	52,500	58,000				
17		48,500	53,500	58,500				
18		49,500	54,000	59,000				
19		50,000	54,500	60,000				
20		51,000	55,500	60,500	66,000			
21		51,500	56,000	61,000	66,500			
22		52,500	56,500	61,500	67,000			
23		53,000	57,500	62,500	68,000			
24		54,000	58,000	63,000	68,500	74,000		
25		54,500	58,500	63,500	69,000	74,500		
26		55,500	59,500	64,000	69,500	75,000		
27		56,000	60,000	65,000	70,000	75,500		
28		57,000	60,500	65,500	71,000	76,500	82,000	
29		57,500	61,500	66,000	71,500	77,000	82,500	
30		58,500	62,000	66,500	72,000	77,500	83,000	
31		59,000	62,500	67,500	72,500	78,000	83,500	
32		60,000	63,500	68,000	73,000	78,500	84,500	90,000
33			64,000	68,500	74,000	79,000	85,000	90,500
34			64,500	69,000	74,500	80,000	85,500	91,000
35			65,500	70,000	75,000	80,500	86,000	91,500
36		66,000 (Exception, see page 8)	70,500	75,500	81,000	86,500	92,000
37		66,500 (Exception, see page 8)	71,000	76,000	81,500	87,000	93,000
38		67,500 (Exception, see page 8)	71,500	77,000	82,000	87,500	93,500
39			68,000	72,000	77,500	82,500	88,500	94,000
40			68,500	73,000	78,000	83,500	89,000	94,500
41			69,500	73,500	78,500	84,000	89,500	95,000
42			70,000	74,000	79,000	84,500	90,000	95,500
43			70,500	75,000	80,000	85,000	90,500	96,000
44			71,500	75,500	80,500	85,500	91,000	96,500
45			72,000	76,000	81,000	86,000	91,500	97,500
46			72,500	76,500	81,500	87,000	92,500	98,000
47			73,500	77,500	82,000	87,500	93,000	98,500
48			74,000	78,000	83,000	88,000	93,500	99,000
49			74,500	78,500	83,500	88,500	94,000	99,500
50			75,500	79,000	84,000	89,000	94,500	100,000
51			76,000	80,000	84,500	89,500	95,000	100,500
52			76,500	80,500	85,000	90,500	95,500	101,000
53			77,500	81,000	86,000	91,000	96,500	101,500
54			78,000	81,500	86,500	91,500	97,000	102,000
55			78,500	82,500	87,000	92,000	97,500	102,500
56		79,500	83,000	87,500	92,500	98,000	103,000
57	Interstate Gross Weight Limit 80,000 (see page 2)		83,500	88,000	93,000	98,500	104,000
58			84,000	89,000	94,000	99,000	104,500
59				85,000	89,500	94,500	99,500	105,000
60				85,500	90,000	95,000	100,500	105,500

Example (see page 7): at L = 20, the 3-axle value is 51,000.

Tandem Axle Weight (see pages 3 & 4) applies to rows L = 4 through L = 8.

Highway Safety Considerations

Changes in TS&W regulations can affect highway safety by:

1) increasing or decreasing the amount of truck traffic;

2) causing or requiring changes in vehicle design and vehicle performance that may affect crash rates and severity;

3) causing trucks to shift to highways with higher or lower crash rates.

Crash rates per vehicle-mile increase slightly with gross weight primarily because loading a truck heavier raises its center of gravity and thereby increases the possibility of rollover. However, crash rates per payload ton-mile decrease with a gross weight increase because fewer truck trips are required to haul a given amount of freight.

Key Findings

• There needs to be increased flexibility of weight limits and vehicle configurations to allow greater payloads.

• There are concerns about the infrastructure impacts of increased weight limits, particularly on local roads and bridges.

• There are safety concerns about proposed increases in truck weight or length.

The key finding of the technical analyses was that four heavier truck configurations were found feasible and generated net statewide benefits. A set of changes to spring load restrictions and other related TS&W regulations were also developed and found to offer net benefits. The evaluation considered transport savings, pavement costs, bridge inspection costs, rating and posting impacts, bridge fatigue and deck wear effects, increased bridge design load requirements, safety, and congestion.

Table 3 shows the ESAL values for flexible pavements for the configurations being considered in this study. All the configurations under consideration in this study are better for pavements than the current five-axle tractor-semitrailer at 80,000 pounds based on ESAL factors.

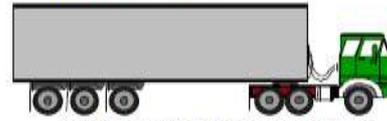**Table 3. Equivalent Single-Axle Load Values for Flexible Pavements**

Configuration	Total ESALs
Current 5-axle tractor-semitrailer at 80,000 lbs.	2.4
6-axle tractor-semitrailer at 90,000 lbs.	2.0
7-axle tractor-semitrailer at 97,000 lbs.	1.5
8-axle double at 108,000 lbs.	1.8
Single unit 6- and 7-axle respectively	0.7 and 0.9

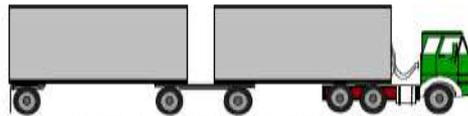Figure III-10. Comparison of Longer Combination Vehicles With Conventional Trucks
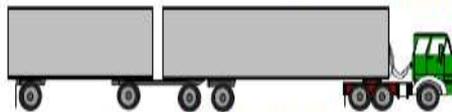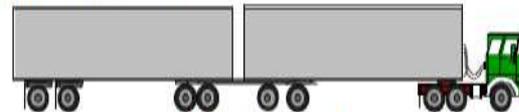
Impacts of Proposed Vehicle Configurations

• Increased payloads and fewer truck trips will lower transport costs significantly.

• Additional axles and fewer truck trips will result in less pavement wear and possible safety increase.

• A modest increase in bridge postings and future design costs will be necessary.

Summary
• Challenge is to find balance in truck size and weight versus impacts.
• Additional axles and fewer truck trips will result in less pavement wear and possible increase in safety.
• Higher GVW roadways can theoretically require less pavement thicknesses than lower GVW roadways.

Road Type	Lane Mileage	Sq. Ft. of Pavement	Replacement Cost per sq. ft.	Total Replacement Cost	Design Life in ESALS
State Highway	1000	63,660	$4.75	$302,385	200,000

A typical 80,000 pound 5-axle TST has a payload of 49,500 pounds and generates 2.4 ESAL per trip.

A 5-axle TST at 90,000 pounds has a payload of 59,500 pounds and generates 4.1 ESAL per trip.

If the annual agricultural harvest generates 100,000,000 pounds of produce, how many trips will each vehicle make to move the products to market?
_____ trips by 5-axle 80,000 lb TST
_____ trips by 5-axle 90,000 lb TST

How many ESALs will each vehicle generate?
_____ ESALs by the 5-axle 80,000 lb TST
_____ ESALs by the 5-axle 90,000 lb TST

How many years will the highway pavement last under use by each vehicle type?
_____ years with the 5-axle 80,000 lb TST
_____ years with the 5-axle 90,000 lb TST

What is the annual cost for replacing the highway pavement for each vehicle type?
_____ per year for the 5-axle 80,000 lb TST
_____ per year for the 5-axle 90,000 lb TST

Road Type	Lane Mileage	Sq. Ft. of Pavement	Replacement Cost per sq. ft.	Total Replacement Cost	Design Life in ESALS
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A 5-axle TST at 90,000 pounds has a payload of 59,500 pounds and generates 4.1 ESAL per trip.

If the annual agricultural harvest generates 100,000,000 pounds of produce, how many trips will each vehicle make to move the products to market?

   2020   trips by 5-axle 80,000 lb TST
   1681   trips by 5-axle 90,000 lb TST

How many ESALs will each vehicle generate?

   4848   ESALs by the 5-axle 80,000 lb TST
   6892   ESALs by the 5-axle 90,000 lb TST

How many years will the highway pavement last under use by each vehicle type?

   41.3   years with the 5-axle 80,000 lb TST
   29.0   years with the 5-axle 90,000 lb TST

What is the annual cost for replacing the highway pavement for each vehicle type?

   $7322   per year for the 5-axle 80,000 lb TST
   $10,427   per year for the 5-axle 90,000 lb TST

NORTH DAKOTA

LOCAL TECHNICAL ASSISTANCE PROGRAM

Road Type	Lane Mileage	Sq. Ft. of Pavement	Replacement Cost per sq. ft.	Total Replacement Cost	Design Life in ESALS
State Highway	1000	63,660	$4.75	$302,385	200,000

A typical 80,000 pound 5-axle TST has a payload of 49,500 pounds and generates 2.4 ESAL per trip.

A 6-axle TST at 90,000 pounds has a payload of 58,500 pounds and generates 2.0 ESAL per trip.

If the annual agricultural harvest generates 100,000,000 pounds of produce, how many trips will each vehicle make to move the products to market?
_____ trips by 5-axle 80,000 lb TST
_____ trips by 6-axle 90,000 lb TST

How many ESALs will each vehicle generate?
_____ ESALs by the 5-axle 80,000 lb TST
_____ ESALs by the 6-axle 90,000 lb TST

How many years will the highway pavement last under use by each vehicle type?
_____ years with the 5-axle 80,000 lb TST
_____ years with the 6-axle 90,000 lb TST

What is the annual cost for replacing the highway pavement for each vehicle type?
_____ per year for the 5-axle 80,000 lb TST
_____ per year for the 6-axle 90,000 lb TST

Road Type	Lane Mileage	Sq. Ft. of Pavement	Replacement Cost per sq. ft.	Total Replacement Cost	Design Life in ESALS
State Highway	1000	63,660	$4.75	$302,385	200,000

A typical 80,000 pound 5-axle TST has a payload of 49,500 pounds and generates 2.4 ESAL per trip.

A 6-axle TST at 90,000 pounds has a payload of 58,500 pounds and generates 2.0 ESAL per trip.

If the annual agricultural harvest generates 100,000,000 pounds of produce, how many trips will each vehicle make to move the products to market?

___2020____ trips by 5-axle 80,000 lb TST
___1710____ trips by 6-axle 90,000 lb TST

How many ESALs will each vehicle generate?

___4848____ ESALs by the 5-axle 80,000 lb TST
___3420____ ESALs by the 6-axle 90,000 lb TST

How many years will the highway pavement last under use by each vehicle type?

___41.3____ years with the 5-axle 80,000 lb TST
___58.5____ years with the 6-axle 90,000 lb TST

What is the annual cost for replacing the highway pavement for each vehicle type?

___$7322____ per year for the 5-axle 80,000 lb TST
___$5169____ per year for the 6-axle 90,000 lb TST

Thank You!