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REF. NO.

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IMPLICATIONS OF
INCREASED TRUCK WEIGHT AND SIZE
IN IOWA

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OFFICE OF POLICY ANALYSIS
IOWA DOT
(515) 296-1322
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IMPLICATIONS OF INCREASED TRUCK WEIGHTS AND SIZE IN IOWA

General

Permitting increased truck weights in Iowa will result in both increased costs and benefits. The additional costs will be in the form of increased highway wear. Heavier trucks will cause accelerated deterioration of highways and bridges. Benefits will accrue in the form of increased capacity of the truck fleet and fuel savings which will result in lowered truck operating costs to transport a given amount of commodities and thereby lowered shipping costs.

The purpose of this study is to determine the magnititude of these costs and benefits and also identify the beneficiaries that should pay the increased costs.

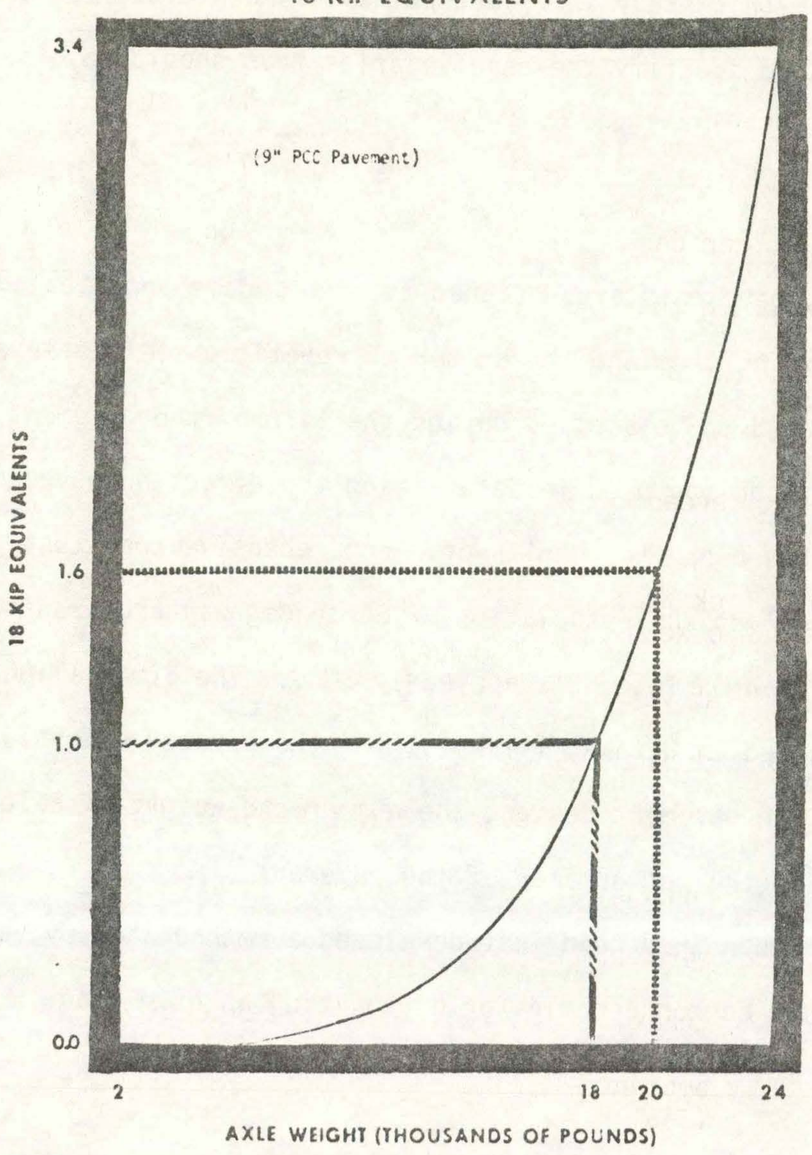
I. Costs

Pavement: Highway pavements are designed to accommodate anticipated axle weights that will be placed on them and the number of repetitions of these axle loads that will be expected to be applied during the life of the pavement, usually 20 years. The methodology used in determining the effect on pavement of various loads is based on the results of a comprehensive road test program carried out by the American Association of State Highway and Transportation Officials (AASHTO) in the late 50's and early 60's. The $20 million research program was conducted at Ottawa, Illinois, for the purpose of evaluating the relationship between pavement design, the number and weight of axle loads carried by the pavement and the performance of the pavement.

The work at the AASHTO Road Test developed a method whereby various loads can be brought to a common denominator by equating an axle load in relation to an equivalent number of 18,000-lbs. (18 kips) single axle load applications. This is commonly referred to as the 18-kip equivalency factor of a particular axle load. The result of the studies showed that a small increase in axle load results in a much larger increase in the 18-kip equivalent factor.

The following graph shows the relationship between axle loads and 18-kip equivalency factors for 9-inch Portland Cement Concrete (PCC) pavement. For example, increasing a single axle load from 18,000 lbs. to 20,000 lbs. (11% increase) results in increasing the 18-kip equivalency factor from 1.00 to 1.60, a 60% increase. Or expressed differently, a 20,000-lb. single axle load has the same impact on a pavement as that of 1.6 18,000-lb. axles.

RELATIONSHIP BETWEEN AXLE WEIGHT AND 18 KIP EQUIVALENTS



In order to design a pavement for a particular road, the traffic that will be using the road over the life of the pavement is estimated and converted to 18-kip equivalencies. The pavement and the subgrade is then designed to withstand the 18-kip loading expected in 20 years.

The result of higher traffic or heavier loads or both on an existing pavement is that the service life of the pavement will be shortened. The traffic that has the greatest influence on pavement life is truck traffic. An increase in passenger car traffic has practically no impact on pavement service life. According to the result of the AASHTO Road Test, the average loaded truck causes wear equal to that caused by 2,500 cars. Even if such loaded trucks made up only five percent of all traffic, they would nonetheless inflict more than 99 percent of all the wear sustained by the pavement.

Truck Wear	0.05 @ 2,500 =	125.00
Auto Wear	0.95 @ 1 =	0.95
TOTAL WEAR		125.95
Truck Share	$\frac{125.00}{125.95}$	= 99.25%

In estimating the added wear cost resulting from increased truck weights, the following assumptions were used:

1. The types of trucks that could take advantage of higher axle loads and gross loads are: 3-axle single units (SU-3), 4-axle truck-tractor semitrailer combinations (TTST-4), and 5-axle truck-tractor semitrailer combinations (TTST-5).

2. The total amount of commodities to be hauled will not change with higher truck load limits.

3. Construction and maintenance costs for a road surface or structure vary directly with the number of axle loadings it will sustain during its expected life.

The basic data used in calculating increased wear cost was obtained from the Iowa Truck Weight Studies. The data included:

a) Average axle and gross weights by vehicle type and highway system.

b) Percent loaded vehicles by type of vehicle and highway system.

c) Vehicle miles of travel for each truck type on each highway system.

From this data, the following was calculated:

a) Loaded vehicle miles of travel: Vehicle miles of travel for each truck type on each highway system was multiplied by the appropriate percent of loaded vehicles to determine the loaded vehicle miles of travel under present load limits.

b) Average axle loads for each truck type under the proposed limits (20,000 lbs. single, 34,000 lbs. tandem and 80,000 lbs. gross--maximum weights): The average axle load was assumed to be the same percentage of the proposed limits as the present average is of the present maximum limits.

c) Loaded vehicle miles of travel under proposed load limits by vehicle type and highway system:

$$\text{Present loaded vehicle miles of travel} \times \frac{\text{Present avg. gross load}}{\text{Proposed avg. gross load}} =$$

Estimated vehicle miles of travel under proposed load limits

d) 18-kip equivalents for each truck type on each type of pavement under present and proposed axle load limits.

e) Increased wear cost: By dividing the pavement cost plus the cost of one resurfacing by the number of 18-kip equivalent applications each pavement type can withstand in its expected life, the cost per 18-kip load was determined.

This cost per 18-kip load was then multiplied by the 18-kip equivalent of each truck type under the present and proposed load limits and with the respective loaded vehicle miles of travel to determine the pavement cost under present and proposed load limits. The difference between the pavement costs under the proposed and present load limits equals the increased pavement wear cost due to increased load limits.

$$\frac{\text{Cost of pavement + one resurfacing}}{\text{No. of 18-kip equivalent load pavement can withstand}} = \text{Cost per 18-kip load}$$

Proposed limits: Cost per 18-kip equiv. X No. of 18-kip equiv. X loaded VMT = Proposed pavement cost

Present limits: Cost per 18-kip equiv. X No. of 18-kip equiv. X loaded VMT = Present pavement cost

Increased pavement cost due to higher load limits--difference

The increased maintenance cost and wear cost for structures were determined in a similar manner.

Bridges: Bridges react to increased loading in a very different manner than pavements. The principal difference in assessing bridge wear is the fact that vehicle gross weight and the distribution of this weight govern the response of bridge structural members, rather than the magnitude of the load on any single axle. Single axles do govern the stress in the bridge deck slab, but these are seldom the critical element in a bridge with respect to load capacity. It is important, therefore, that the magnitude of a vehicle's gross load be tailored to the overall length of the vehicle and the spacing between individual axles. For this reason, a formula was developed based on the results of the aforementioned AASHTO Road Test that is utilized in computing the maximum allowable gross weight of vehicles and axle groups.

The so-called bridge formula reads:

$$W = 500\left(\frac{LN}{N-1} + 12N + 36\right)$$

Where: W = Total weight permitted, in pounds
L = Distance between extreme of group of axles
N = Number of axles in the group

The "bridge formula" is so arranged that it will protect modern highway bridges from undue overstress.

The following table shows maximum gross loads for various axle spacings and number of axles.

April 7, 1978

COMPARISON OF MAXIMUM GROSS LOADS

Distance in Feet Between the Extreme of Any Group of Axles	Present Iowa Code Maximum Gross Weight Including Tolerances [1]	Maximum Gross Weight Table [2] Weight Formula W = 500 (LN/N-1 + 12N + 36) Rounded to Nearest 500 lbs.				
		2-axle	3-axle	4-axle	5-axle	6-axle
4	32,960	34,000				
5	32,960	34,000				
6	32,960	34,000				
7	32,960	34,000				
8	35,219	38,000	42,000			
9	36,266	39,000	42,500			
10	34,930	40,000	43,500			
11	39,134		44,000			
12	41,356		45,000	50,000		
13	42,434		45,500	50,500		
14	43,500		46,500	51,500		
15	44,566		47,000	52,000		
16	45,620		48,000	52,500	58,000	
17	46,675		48,500	53,500	58,500	
18	47,719		49,500	54,000	59,000	
19	48,750		50,000	54,500	60,000	
20	49,783		51,000	55,500	60,500	66,000
21	50,803		51,500	56,000	61,000	66,500
22	51,824		52,500	56,500	61,500	67,000
23	52,833		53,000	57,500	62,500	68,000
24	53,830		54,000	58,000	63,000	68,500
25	54,828		54,500	58,500	63,500	69,000
26	55,815		55,500	59,500	64,000	69,500
27	56,802		56,000	60,000	65,000	70,000
28	57,777		57,000	60,500	65,500	71,000
29	58,741		57,500	61,500	66,000	71,500
30	59,681		58,500	62,000	66,500	72,000
31	60,785		59,000	62,500	67,500	72,500
32	61,888		60,000	63,500	68,000	73,000
33	62,992			64,000	68,500	74,000
34	64,096			64,500	69,000	74,500
35	65,200			65,500	70,000	75,000
36	66,303			68,000 [3]	70,500	75,500
37	67,407			68,000 [3]	71,000	76,000
38	68,511			68,000 [3]	72,000	77,000
39	69,615			68,000	72,500	77,500
40	70,718			68,500	73,000	78,000
41	71,822			69,500	73,500	78,500
42	72,926			70,000	74,000	79,000
43	73,280			70,500	75,000	80,000
44	73,280			71,500	75,500	80,500
45	73,280			72,000	76,000	81,000
46	73,280			72,500	76,500	81,500
47	73,280			73,500	77,500	82,000
48				74,000	78,000	83,000
49				74,500	78,500	83,500
50				75,500	79,000	84,000
51				76,000	80,000	84,500
52				76,500	80,500	85,000
53				77,500	81,000	86,000
54				78,000	81,500	86,500
55				78,500	82,500	87,000
56				79,500	83,000	87,500
57				80,000	83,500	88,000
58					84,000	89,500
59					85,000	89,500
60					85,500	90,000

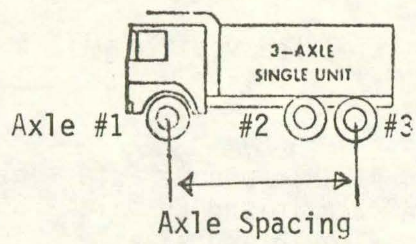
[1] The maximum gross weight in the present Iowa Code is based on a previous AASHTO formula W = 1,025(L + 24) - 3L

[2] The maximum gross weight table is based on the more refined AASHTO bridge formula W 500(LN/N-1 + 12N + 36)

[3] Federal modification to the bridge formula. It allows 34,000 lbs. each on two sets of tandems spaced 36' or more.

Source: Office of Policy Analysis
Iowa DOT
(515)296-1454

Example



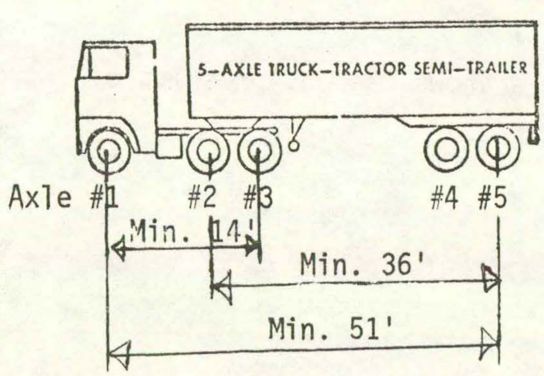
Based on the axle load limits (20,000 lbs. single/34,000 lbs. tandem) the maximum gross weight of this vehicle is 54,000 lbs. (20,000 lbs. + 34,000 lbs.). In order to carry this maximum load, the spacing between #1 and #3 axles will have to be at least 24 feet.

This is easily determined from the foregoing table. First, the desired load of 54,000 lbs. is located in the 3-axle column and the distance in feet between the axles is found in the first column directly opposite the 54,000 lbs. If the distance between the #1 and #3 axles is say, 20 feet, the maximum gross load of this vehicle is 51,000 lbs.

When applying the bridge formula to a 4- or 5-axle truck-tractor semitrailer combinations (TTST's), not only the distance between the extreme axles has to be considered, but also the distance between the internal axles.

Example

5-Axle TTST



In order for this combination to carry the maximum allowable gross load of 80,000 lbs. with an axle load of 34,000 lbs. on each of the tandem axles and 12,000 lbs. on the steering axle, the vehicle will have to have the following minimum axle spacings:

Distance between #1 axle and #5 axle - 51 feet
Distance between #2 axle and #5 axle - 36 feet
Distance between #1 axle and #3 axle - 14 feet

With present equipment, which is limited to an overall length of 55 feet, there is normally little problem with obtaining the required spacing between #1 axle and #3 axle or between the #2 axle and the #5 axle. However, the 51-foot required spacing between the #1 axle and #5 axle is practically impossible with an overall length limit of 55 feet. The practical maximum is around 48 feet, which limits the overall gross load of a 5-axle TTST to 78,000 pounds.

The bridge formula is part of the Federal Code which governs the maximum axle and gross loads that any state can allow on the Interstate System. However, a slight modification was made to the bridge formula in the federal law. The modification consists of allowing 68,000 lbs. on two consecutive sets of tandem axles which have a minimum distance of 36 feet between extreme axles of the two tandems. The original bridge formula would have required the distance to be 39 feet before 68,000 lbs. could be carried on four axles. The reason for this modification was to make it feasible for existing equipment to take full advantage of the 34,000-lb. tandem axle limit.

Summary: The following table shows the cost results of increased truck weights:

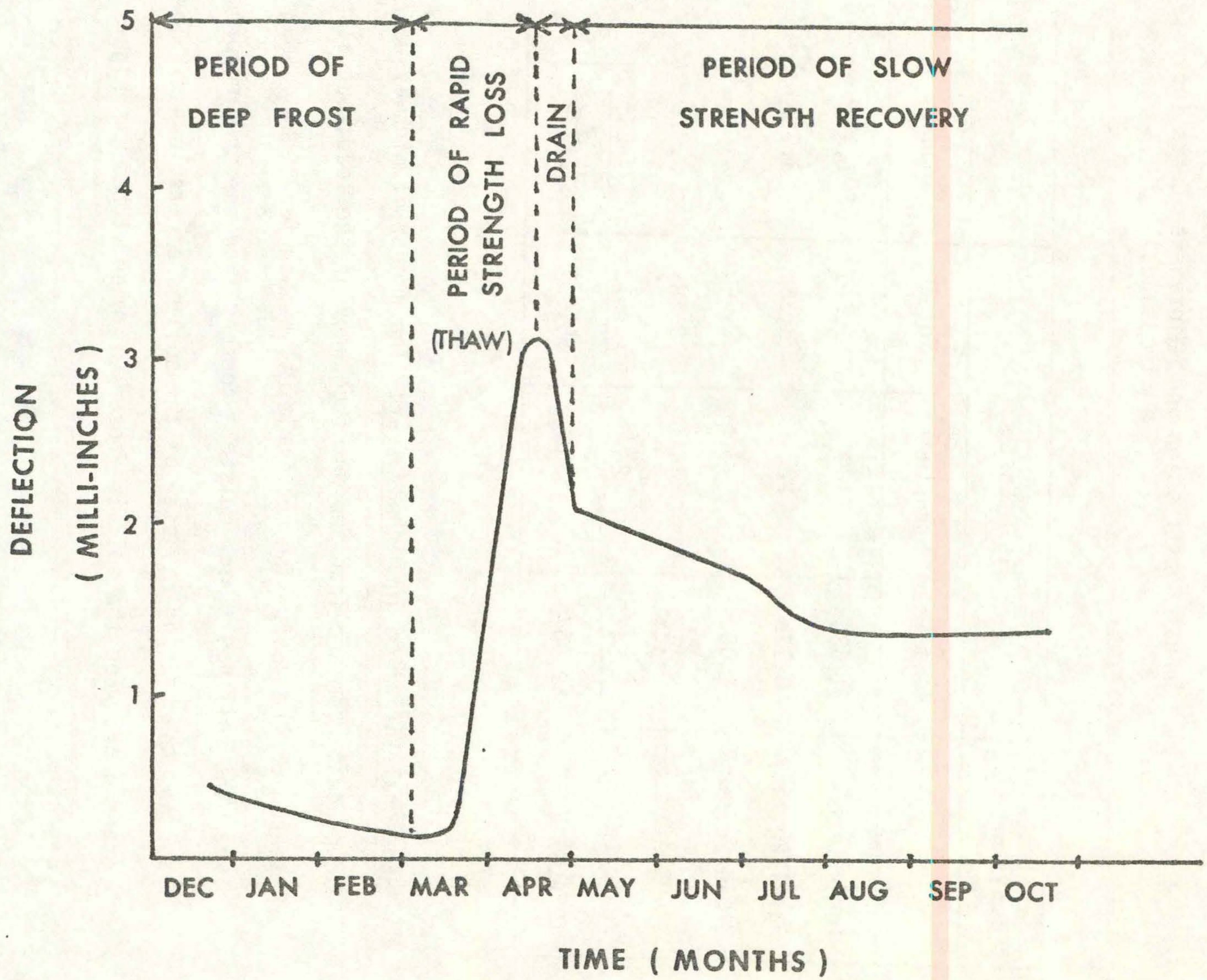
COST RESULTS

Annual Construction and Maintenance Costs Increase
($ in Thousands)

System	1978 Costs			1980 Costs		
	Roadway	Structures	Total	Roadway	Structures	Total
Interstate	$1,580	$190	$1,770	$ 1,992	$237	$ 2,209
Rural Primary	3,135	227	3,362	3,912	283	4,195
Urban Primary	1,003	43	1,046	1,251	54	1,305
Secondary	3,142	44	3,186	3,912	55	3,976
Municipal	547	26	573	683	32	715
TOTALS	$9,407	$530	$9,937	$11,739	$661	$12,400

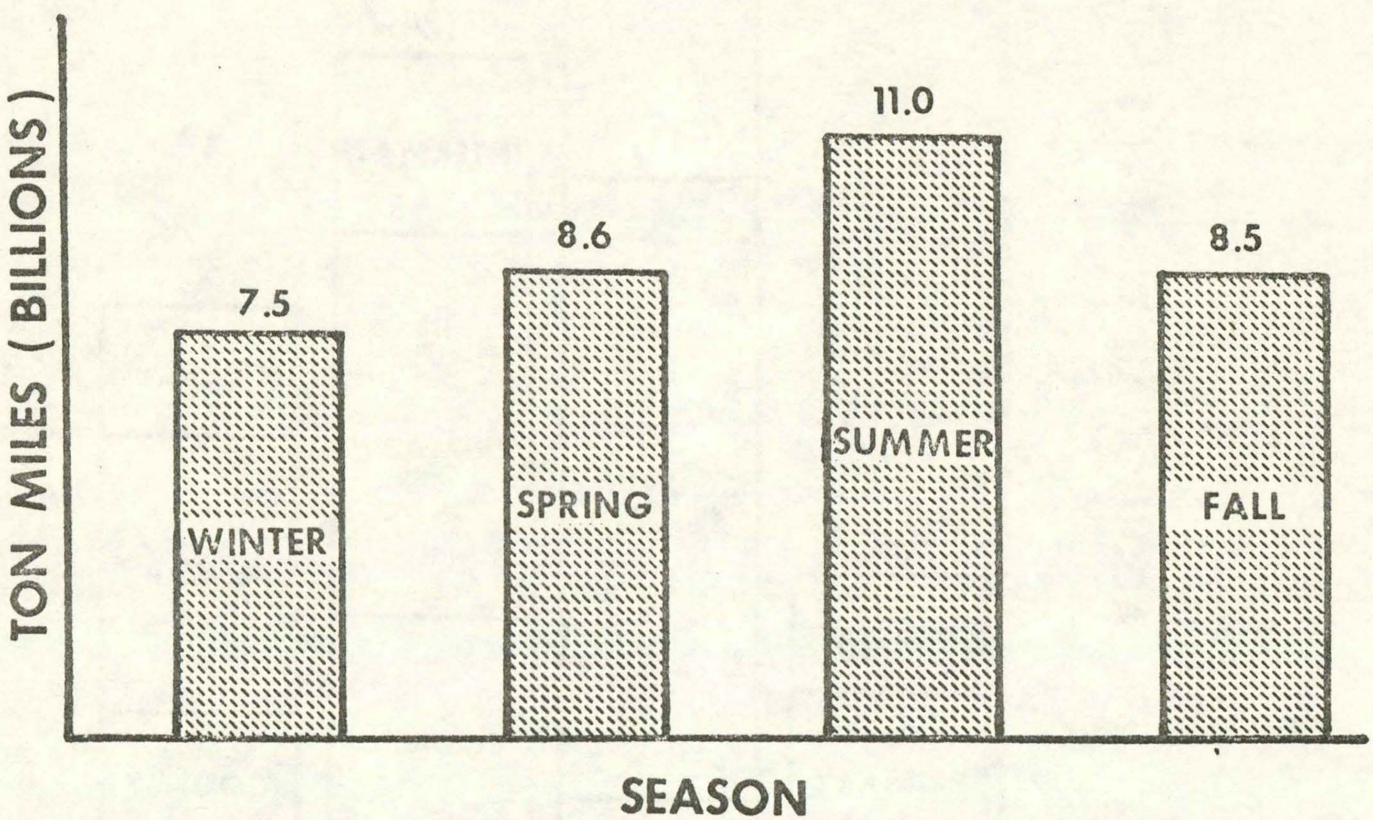
Seasonal Variation in Highway Wear: The amount of highway wear is not only dependent upon the load and the frequency of the load, but also on the season of the year. The most critical season for highway wear is the spring when the soil has a high moisture content from the thawing process. In this period, the bearing capacity of the soil is at its lowest. The winter on the other hand, when the soil is frozen, is when it has its highest bearing capacity.

SEASONAL DEFLECTION OF FLEXIBLE PAVEMENTS



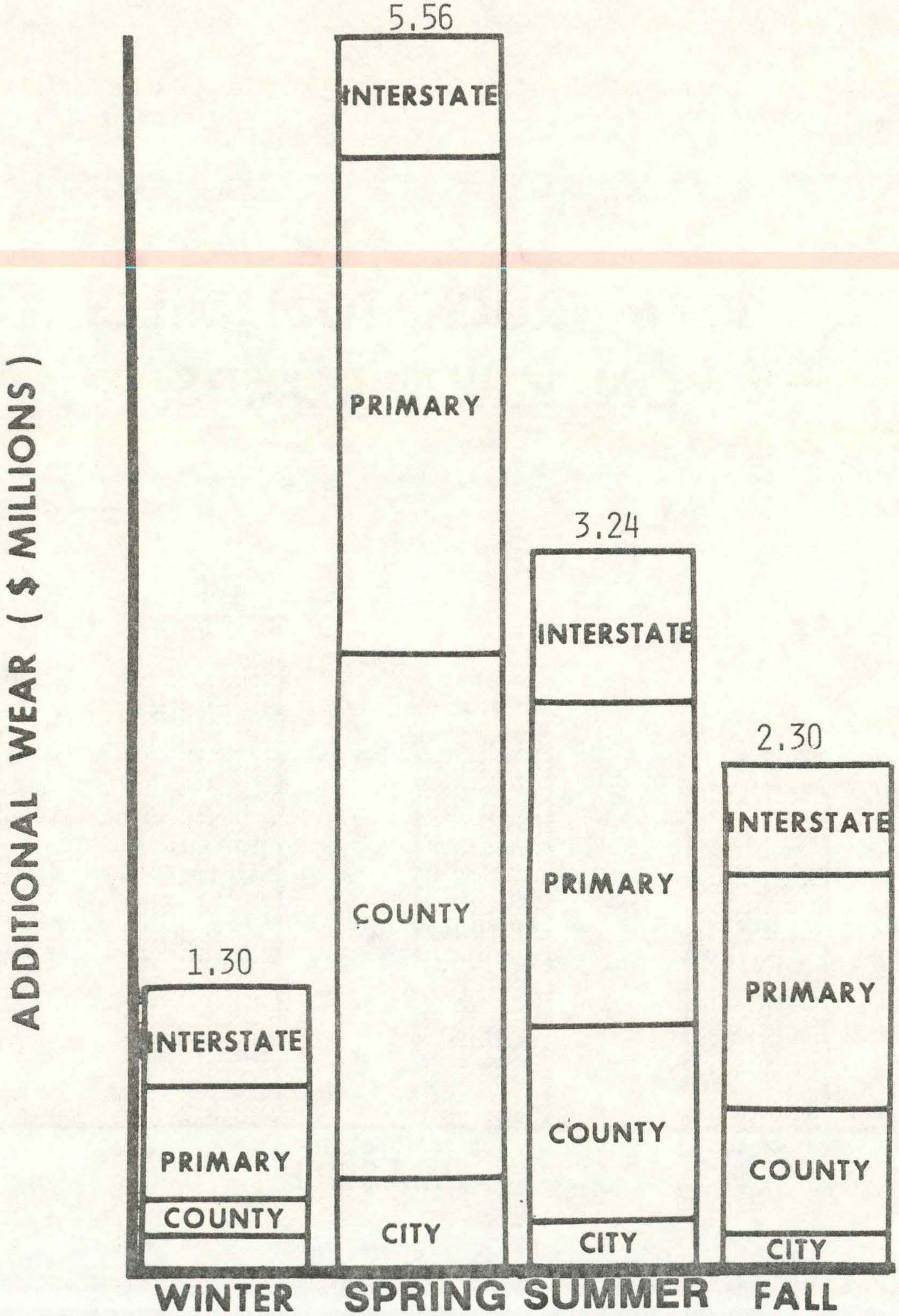
The amount of goods hauled on the highways also varies by season with summer being the season with highest goods movement and winter the lowest.

1976 TRUCK TON MILES ON IOWA ROADS



ADDITIONAL WEAR BY SYSTEM AND SEASON

BASED ON 1980 COSTS



The result in increased highway wear cost due to increased truck weight limits by season based on both the variation of wear and amount of goods transported by season is shown in the following table.

INCREASED WEAR

20,000 LB. SINGLE/34,000 TANDEM

(MILLIONS)

BASED ON 1980 COSTS

	WINTER	SPRING	SUMMER	FALL	TOTAL
INTERSTATE	$0.46	$0.54	$0.69	$0.54	$2.23
PRIMARY	0.69	2.26	1.48	1.07	5.50
COUNTY	0.09	2.43	0.88	0.56	3.96
CITY	0.06	0.34	0.19	0.12	0.71
TOTAL	$1.30	$5.57	3.24	2.29	$12.40

II. Benefits

The benefit from allowing increased truck weights on Iowa's highways is that transportation cost savings will accrue because the capability to move greater loads will result in less trips to move the same amount of goods. Nine 80,000-lb. trucks will move approximately the same amount of goods as ten 73,280-lb. trucks.

The operating cost and fuel consumption for the heavier trucks will be somewhat higher per mile of travel, but the decrease in number of trips will more than compensate for this increase. The net result will be a reduction in transportation cost per ton mile.

The beneficiary of transportation cost savings in the first instance is the trucking industry; however, it is anticipated that these benefits will be passed on to shippers and the general public in the form of lower shipping cost or a slower rate of increase in shipping costs.

Based on an anticipated reduction in vehicle miles of travel, benefits were calculated by system as shown in the following table.

TOTAL BENEFITS

System	(1980 Dollars)
Primary	
Interstate	$21.6 M
Other Primary	24.2 M
Total Primary	$45.8 M
Secondary	$ 3.2 M
Municipal	$ 2.5 M
TOTAL	$51.5 M

The benefit cost (B/C) ratio shows how many dollars in net benefit (lower operating costs) are received for each dollar of net costs (increased highway wear).

$$\frac{\text{Total Net Benefits}}{\text{Total Net Costs}} = \text{B/C Ratio}$$

BENEFIT COST RATIOS

System	B/C Ratio
Primary	
Interstate	9.8
Other Primary	4.4
Total Primary	5.9
Secondary	0.8
Municipal	3.5
TOTAL	4.2

The benefit cost ratio shows that for each dollar in increased highway wear, society will receive 4.2 dollars in benefits in the form of reduced transportation costs.

Return on investment could be improved by embargoing all or some of the highway system during the spring, the most critical season for highway wear. The following table shows the benefit/cost ratio for spring embargo of various systems.

RANGE OF AVAILABLE B/C RATIOS

		B/C Ratio
1.	No embargo	4.2
2.	Secondary roads embargoed in the spring	5.1
3.	Secondary & municipal embargoed in spring	5.2
4.	Secondary, municipal & primary embargoed in spring	6.0
5.	All systems embargoed in the spring	5.7

The highest benefit cost ratio will be achieved if all systems except the Interstate are embargoed in the spring.

Energy: The proposed increase in truck axle loads and gross weight would result in a reduction in fuel consumption. These fuel savings would result from a reduction of vehicle miles of travel required to transport the same amount of goods on a fewer number of trucks with heavier payloads.

Using the latest available data on fuel consumption by truck type, estimated annual savings would be:

ANNUAL FUEL SAVINGS
(Gallons)

System		
Interstate	- Gas	89,200
	- Diesel	3,747,600
Rural Primary	- Gas	177,000
	- Diesel	2,587,300
Urban Primary	- Gas	58,900
	- Diesel	516,100
Secondary	- Gas	91,400
	- Diesel	261,500
Municipal	- Gas	57,200
	- Diesel	227,000
Total	- Gas =	473,700
	- Diesel =	7,339,500
Total Fuel Saved	=	7,813,200

In 1978, the total amount of fuel consumed for highway purposes was approximately 1.9 billion gallons. The potential fuel savings from the proposed increased truck weights would amount to approximately 0.4 percent of the total consumption.

III. Safety

Safety of highway operation is an immediate concern that is strongly related to proposed charges in legal vehicle weight limits. Currently available statistics indicate that heavy trucks have a substantially higher involvement in fatal accidents than passenger cars and light trucks on a per vehicle basis; however, safety must be viewed in a relative sense. Therefore, in evaluating the safety aspect of the proposed change in legal weight limits, one must determine whether the safety aspect of the highway system is enhanced or degraded by the proposed change.

Some of the safety concerns involved with heavier trucks that have been raised are as follows:

Front axle loads: With the increased load on the steering axle with higher load limits, will this cause steering problems and increased tire blowouts, resulting in additional accidents?

From the experience that the Teamsters Union, insurance industry, and the trucking industry have had with front axle loads, there appears to be no problem with steering as long as the manufacturer's load ratings of steering axles are not exceeded. Presently, steering axles are being utilized with load ratings adequate to handle the additional load with increased truck weights.

Tires are also designed and rated to carry specified loads. It should be pointed out that it is against federal law to exceed the load rating of a tire.

In regard to tire blowout, the insurance companies indicate that the number one cause of tire failure is improper maintenance, such as underinflation and rims not matched with the tires. Weight on front tires does not appear to be a safety problem.

Rear-end collisions: One of the safety concerns that has been raised in connection with increased truck weights is that with heavier trucks there might be an increase in rear-end collisions due to the slower acceleration of trucks and their greater speed reduction on grades.

In response to this concern, fatal truck accident records were investigated for 1976 and 1977 and it was found that out of 13 fatal truck accidents in which a car rear-ended a truck, none of them were caused by slow-moving trucks. From this, it is reasonable to conclude that it is unlikely that a relatively small increase in truck weight will cause any increase in rear-end collisions.

Stopping distance: Will the proposed increased truck weights result in longer stopping distance and thereby increase accidents?

Braking performance has obvious impacts on safety. Braking distance is a function of brake design, tire traction and road surfaces, truck configuration, etc., not the gross weight of the vehicle. There should, therefore, be no increase in stopping distance as long as brake capacity is not exceeded.

Accident severity: It is unquestionable that severity of an accident will be much greater when a heavy truck and a light passenger car are involved than in an accident involving two passenger cars. This is due to the great difference in weight. It has long been felt that large trucks are a hazard to automobile traffic and that their danger probably increases with their size and weight. However, a 1977 study by the National Highway Traffic Safety Administration based on data supplied by the Bureau of Motor Carrier Safety contradicts this notion and concludes that severity does not vary significantly with either size or weight of the truck involved.

Safety Conclusions: Since, as stated previously, an increase in truck weights of the proposed magnitude addressed herein will not significantly increase the frequency nor the severity of truck accidents, the net result of the proposed increased legal axle and gross weights should be a reduction in truck accidents. This is due to the reduction in truck trips to transport the same amount of commodities. The anticipated reduction in vehicle miles of travel by trucks should result in the following annual reduction in number of accidents:

Fatal	Injury	All
1	14	49

IV. Department of Transportation's Position

The Department of Transportation recognizes that increased truck weights will result in increased capacity of the truck fleet which will lower transportation costs and therefore be beneficial to Iowa's economy. However, there are also increased costs in the form of increased highway wear associated with higher truck weights.

The Department of Transportation therefore supports increased legal axle and gross weights under the provision that additional pavement wear costs be recovered through increased user fees.

The Department of Transportation's position on increased truck weights and size is as follows:

* Maximum gross weight - 80,000 lbs.
* Gross vehicle weight subject to the federal modified bridge formula.
* Axle gross weights - Single: 20,000 lbs.
Tandem: 34,000 lbs.
* Eliminate the present 8% and 3% enforcement tolerances on gross weights and axle weights, respectively.
* Increase the truck-tractor semitrailer combination length limit to a minimum of 58 feet to facilitate the use of existing truck equipment in taking full advantage of 80,000-pound gross weight and still staying within the requirements of the federal bridge formula.
* Semitrailer maximum overall length - 45 feet
* Recover the additional pavement wear costs from those users that can potentially take advantage of the higher axle and gross weights through a combination of increased registration fees and fuel tax.