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EFFECTS OF RAISING LOAD
LIMITS ON PAVEMENTS AND
BRIDGES IN INDIANA

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TO: H. L. Michael, Director
Joint Highway Research Project

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FROM: E. J. Yoder, Research Engineer
Joint Highway Research Project

Project: C-36-73H

The attached report entitled "Effects of Raising Load Limits on Pavements and Bridges in Indiana" presents the results of the study conducted to determine the economic impact on maintenance costs on Indiana highways if load limits were to be raised. This study was conducted in accordance with a request made by Mr. G. K. Hallock, Chief Engineer for the Indiana State Highway Commission.

The study evaluated possible changes in maintenance costs that might arise if heavier loads were to be permitted on Indiana highways. Pavement maintenance costs were determined for all highways on the Indiana state highway system including interstates, U.S. routes and state routes. This was done utilizing road life data on file in the ISHC offices. Traffic data from the loadometer stations, soil test data on file in the JHRP offices and physical data from the Research and Training Center were used to evaluate impacts of increased weights on Indiana pavements. Bridges were evaluated based largely on a comprehensive search of the literature.

The report presents estimates of increased costs that might result if the weight limits were increased in Indiana. The conclusions apply to all highways on the state system and a discussion of possible impacts on the county systems is presented.

Respectfully submitted,

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ABSTRACT

Indiana's present weight limits for trucks are 18,000 lbs. on a single axle, 32,000 lbs. on a tandem axle and 73,280 lbs. gross vehicle weight. Many states have increased their weight limits to 20,000 lbs. on a single axle, 34,000 lbs. on a tandem axle and with gross limits of 80,000 lbs. This study was conducted to determine possible economic impacts on maintenance of Indiana highways and bridges if weight limits were to be increased in Indiana.

Extensive use was made in this research of work reported by other investigators. The road life records of the Indiana State Highway Commission were searched and pavement sections were evaluated using these data coupled with truck weight information from the weight stations, soil information and performance data on file in the JHRP offices.

Pavement sections were selected using statistical techniques wherein all types of pavements on the state system were considered. The types of pavements evaluated included continuously reinforced concrete pavements, jointed reinforced concrete pavements, asphalt pavements and concrete pavements overlaid with asphalt. The pavement sections were evaluated on a regional basis and climatic effects on possible increased costs were studied.

In the case of bridges, the study examined the impact of increasing maximum loads considering needs for structural reinforcement, and bridge deck deterioration.

Changes in routine maintenance, which consists of day-to-day operations as well as changes in major maintenance were evaluated. The results of the investigation have indicated that both routine and major maintenance costs will increase if larger loads are permitted on Indiana highways. Cost estimates are

presented for interstate pavements, U.S. and state routes carrying more than 4,000 vehicles per day and U.S. and state routes carrying less than 4,000 vehicles per day.

With regard to bridges additional costs will result primarily in bridge deck repair. In addition, it is suggested that additional costs may be expected in the future since there will be a need for upgrading structures presently unqualified or marginally qualified for the current road limits.

It is pointed out in the report that pavement maintenance costs are keyed directly to the price for asphalt concrete and information is presented how maintenance costs will increase if there is a substantial increase in price of materials in future years.

Although the study concentrated on highways within the state system alone, a short discussion is presented relative to possible impacts on county roads if the state weight limits were to be increased. This latter figure is presented in terms of dollars per lane mile increases which will permit the counties to estimate added maintenance costs.

EFFECTS OF RAISING LOAD LIMITS ON PAVEMENTS AND BRIDGES IN INDIANA

INTRODUCTION

Indiana's present weight limits of 18,000 lbs. on a single axle, 32,000 lbs. on a tandem axle and 73,280 lbs. gross vehicle weight are based on the limits placed on the Interstate System by the Federal Aid Highway Act of 1956. At the time of the 1956 Act, twenty-five states qualified to retain higher limits under a "grandfather clause" that was in the Act.

Prompted by the energy crisis, the Federal Aid Highway Act of 1974 raised the above limits by approximately 10% to 20,000 lbs. on a single axle, 34,000 lbs. on a tandem axle and a gross limit of 80,000 lbs. Thirteen states presently employ the original 1956 limits while 25 states continue to use grandfather clause exceptions which permit loads in excess of the new limits. Of the states that border Indiana, three have limits equal to or in excess of the 80,000 lbs. gross proposed in 1974. These states include Michigan which was exempted under the grandfather clause and Ohio and Kentucky who have both adopted the 80,000 lbs. limit. To the west, Illinois presently maintains the 1956 limits as does Indiana.

In recent years engineers and economists have evaluated the effect of increased truck weight on maintenance costs of pavements and bridges. Much of this work has been done under contract with the Federal Highway Administration or Department of Transportation (11,28,43). The Federal Department of Transportation has a major on-going research project to evaluate the truck size and weight issue on a national basis. This research was mandated by the Congressional Budget Office in the guidelines set up for cost allocation studies (13).

PURPOSE AND SCOPE

This paper describes a research project of the Joint Highway Research Project at Purdue University which evaluated the effects of increasing Indiana's statute weight limitations on maintenance costs. Extensive use was made in this project of the work reported by Whiteside et.al. in NCHRP Report 141 for the Highway Research Board (44), Carmichael, et.al. for the Texas Highway Department (11,12) and Layton, et.al. for the Oregon Highway Department (28).

The road life records of the Indiana State Highway Commission were searched and sections of pavement were selected for evaluation using statistical techniques. These sections of pavement were analyzed using the method of Carmichael, et.al. (11,12) and estimates of the ranges in costs that might accrue should the load limits be increased in Indiana were made.

The Joint Highway Research Project has conducted performance surveys of Indiana pavements periodically over the past several decades. In recent years research has been directed towards setting up techniques for a pavement evaluation system. Information from these surveys, along with those conducted by the ISHC Research and Training Center were used extensively in this study.

Additional field observations of pavement performance were not made for this study. Rather, use was made of remaining road life studies of the Federal Highway Administration coupled with performance data on file at Purdue and Indiana State Highway Commission. The scope was limited to evaluating the highway system as presented in the road life records in the ISHC offices.

In the case of the bridges, the study examined the impact of increasing maximum single axle loads from 18,000 to 20,000 lbs. and tandem axles from 32,000 to 34,000 lbs. and gross loads from 73,280 lbs. to 80,000 lbs. It was based on a review of the literature.

For purposes of clarity, the remaining portion of this report is divided into two parts. Part I deals with effects of increased load limits on pavement costs and Part II deals with effects of increased axle load limits on bridge costs. Descriptions of the analyses are presented in each part along with specific assumptions that were made.

The study was limited to evaluation of added load related costs that might result on the state system of Indiana highways including Interstates, U.S. and State Routes. This report deals with maintenance costs alone, and does not consider changes in economic benefits which might result if weight laws were changed.

PART I

EFFECTS OF INCREASED LOADS ON PAVEMENT MAINTENANCE COSTS

MAINTENANCE COSTS DEFINED

Maintenance operations of the Indiana State Highway Commission are varied and include many items. For example snow removal, mowing, right-of-way maintenance and many other functions are carried out on a routine basis by the Maintenance Division of the Indiana State Highway Commission. This study was directed to maintenance functions related to the pavement itself. These functions include maintaining the pavement in a serviceable condition on a routine day-by-day basis, and at intervals when the pavement is strengthened by application of an overaly or perhaps by reconstruction. For this study two types of maintenance operations are considered, (1) routine and (2) major maintenance.

Routine Maintenance is correction of pavement distress at irregular intervals whenever distress is observed. This maintenance includes patching of all types, surface seals, crack sealing, repair of blow-ups and all other operations that are applied to the pavement itself during the life of the pavement. Ideally these are applied on a routine basis but, in many cases, no maintenance is applied as long as adequate pavement serviceability is maintained.

Butler (10), in a study for the Federal Highway Administration developed equations for estimating routine maintenance costs. The technique relies upon statistical relationships of actual maintenance costs under a variety of conditions.

Major Maintenance includes resurfacing coupled with end of period maintenance that might need to be made prior to application of the resurface. This end of period maintenance might consist of patching, resurfacing and wedging of rutted

sections, removal of badly deteriorated pavement and other operations. Resurface (referred to as rehabilitation by some) is defined as a major resurfacing of the pavement surface to restore its surface to its original, as constructed condition. Resurface funds are expended at a specific point in time and when the pavement reaches an unacceptable serviceability level.

Major maintenance costs (resurfacing) can be estimated by utilizing the AASHTO performance equations (5).

PERFORMANCE AND COSTS

Although pavement maintenance may be required for reasons other than load conditions, including material breakdown and climatic effects, the number of heavy load applications is the primary factor which determines maintenance costs for a given set of conditions. The AASHTO pavement design equations can be used to estimate required resurfacing and from this estimates of costs can be made. Although routine maintenance requirements, i.e. patching, crack sealing and others, cannot be predicted on the basis of performance equations, major maintenance costs, including resurfacing, can be predicted by means of the AASHTO equations. It is important, therefore, to review performance concepts and the inherent implications of these concepts as they apply to estimating costs.

Present Serviceability Index

The Present Serviceability Index (PSI) is based upon the concept of correlating user opinions with measurements of road roughness, cracking, patching and rutting. The Present Serviceability Index is derived by rating a series of pavements by a group of individuals using the rating scheme as illustrated on Figure 1(a). On this scale a rating of 5 indicates a "perfect" pavement where a rating of 0 is an exceedingly poor pavement. The rating of a specific pavement can be represented by any number between 0 and 5. Correlations of these rating numbers with physical measurements form the basis of the PSI (45).

FIGURE 1 PAVEMENT SERVICEABILITY
 (a) CONDITION SCALE
 (b) SERVICEABILITY CHANGES

Changes in Serviceability with Age

Figure 1(b) illustrates serviceability changes with time. Referring to Figure 1(b), starting at year 0, the pavement has a high initial serviceability index although it rarely approaches a value of 5.0. As traffic is applied to the road serviceability decreases until such a time that the pavement becomes extremely rough and there is a need to apply a resurface. At this point in time (y_1) the serviceability index is restored to its initial value and then decreases again as loads are applied.

Effect of Routine Maintenance on Performance

As indicated in Figure 1, the rate of decline of serviceability is dependent upon the amount of routine maintenance that is applied to the pavement. If the pavement is not maintained on a routine basis the serviceability decreases at an increasing rate, compared to pavements that are maintained. In each case, however, the initial serviceability index can be restored by applying a smooth surface to the pavement. Time to required resurface (y_1' and y_2') is increased if routine maintenance is applied.

Effect of Soils, Climate and Pavement Properties on Performance

The design of a pavement structure is based upon an evaluation of all of the factors which might affect the serviceability of the pavement during its life. These factors include evaluation of loads, soils, materials, and climate. Soil strength is affected by climatic variations which include rainfall and freezing temperatures. Further, the thickness of the final pavement structure is dependent upon the properties of the pavement itself. All of these factors are interrelated.

It is important to note that the factors of soils, climate and paving materials influence performance and that these must be accounted for in the analysis.

AXLE LOADS, EQUIVALENT AXLE LOADS AND PERFORMANCE

Changes of load has an effect on change in serviceability. If loads heavier than originally anticipated in the design are applied at some point in time the pavement will deteriorate more rapidly with two net effects. First, routine maintenance costs will increase and, second, the life of the pavement be decreased. On the other hand, if the pavement is designed for the newer and heavier loads, the change in serviceability will be essentially the same as that of the original pavement.

The equivalent wheel load concept has been used for design for many years. One of the primary purposes of conducting the AASHO Road Test at Ottawa, Illinois was to evaluate this concept. The equivalent wheel load factors developed at the test road form the basis of the AASHTO Interim Guide pavement design procedure.

The equivalent wheel load factor relates the number of repetitions of any axle load to the number of 18,000 lb. single axle load repetitions which will result in the same pavement performance. The general equation for F is:

$$F = \left(\frac{W_1}{W_2} \right)^4 \quad (1)$$

W_1 and W_2 are two axle loads of a given type (single, tandem, tridem). A standard load of 18,000 lbs. on a single axle is used in most computations.

The equivalence factors developed at Ottawa conform essentially to those computed by Equation (1) but the tabulated values vary depending on pavement type, axle configuration and terminal serviceability. Prior to the road test, 32,000 lbs. on a tandem axle were considered to be equivalent to 18,000 lbs. on a single axle. Results of the road test, however, showed that this was not strictly the case. Typical values for axles under consideration in this study are listed below.

	10" Concrete	SN=5 Flexible
9,000 pound single (steering)	0.12	0.06
12,000 pound single (steering)	0.18	0.19
18,000 pound single	1.00	1.00
20,000 pound single	1.58	1.51
32,000 pound tandem	1.50	0.86
34,000 pound tandem	1.95	1.09

Figure 2 shows typical truck types and total equivalency factors for two loading conditions. Loads are those corresponding to the present limits in Indiana and possible new limits for the state.

Present Load Limits	New Load Limits
73,280 pounds gross	80,000 pounds gross
18,000 pounds single	20,000 pounds single
32,000 pounds tandem	34,000 pounds single
9,000 pounds steering (typical)	12,000 pounds steering (typical)

The equivalence factors in Figure 2 assume that each truck is loaded to its maximum value. It should be recalled that truck weights on a highway vary depending on cargo type and many other factors. Trucks dead-heading are generally empty and gross weights are much less than the maximum. Further, a truck may cube out before weight limits are reached. Typical distribution of truck weights on Indiana highways is illustrated in Figure 5 on page 17.

TRUCK TYPE	EAL PER TRUCK	
	18S, 32T 73.28 GROSS	20S, 34T 80.00 GROSS
20	1.12	1.76
3A	1.62	2.13
2-S1	2.12	3.34
3-S1	2.62	3.71
3-S2	3.12	4.08
2-S1-2	2.52	3.38

FIGURE 2. EXAMPLES OF EAL PER TRUCK FOR TWO LOADING CONDITIONS. (LOADS ARE IN KIPS, CONCRETE PAVEMENT 10" THICK, TERMINAL SERVICEABILITY = 2.5, ALL TRUCKS ASSUMED TO BE LOADED EITHER TO MAXIMUM GROSS WEIGHT OR MAXIMUM AXLE WEIGHT).

Total equivalent single axle loads (Σ EAL) on a highway is the sum of all values for the vehicles using the road. The equivalence factors for all trucks, buses and other heavy vehicles must be determined using truck weigh station data.

The life of the pavement is determined primarily by the total EAL's that will use the pavement. Equations A-1 through A-9 in the appendix of this report show the relationship between EAL and pavement life.

PAVEMENT COST ANALYSIS

The potential for increased maintenance costs on Indiana highways was evaluated using the NULOAD computer program developed for the Federal Highway Administration (11,12). This computer program evaluates the effect of legal load limit changes on maintenance costs for flexible, rigid and overlay pavements. The procedure evaluates traffic in terms of equivalent single axle loads (EAL) for both the present load limits and for new load limits.

Figure 3 shows the methodology of the basic analysis. Traffic data under the present and higher load limits were coupled with climate, soils, and pavement property data and the life cycle performance of the pavement structure was predicted utilizing the AASHTO equations. From this, routine maintenance and major maintenance needs were estimated and these then were translated into costs using the unit costs of materials for the state of Indiana. Data in the Appendix outline procedures for estimating maintenance needs.

DATA USED IN THE ANALYSIS

In the analysis use was made of road inventory data as compiled in the Road Life Section of the Indiana State Highway Commission. These data were analyzed

FIGURE 3 METHODOLOGY OF COST ANALYSIS

along with traffic and physical data to arrive at the estimates. Procedures for compiling the basic data are described in the subsequent subsections.

Traffic (Truck Weights)

Highways on the state highway system were divided into three categories (1) interstate highways, (2) U.S. and State routes with ADT > 4,000 and (3) U.S. and State routes with ADT < 4,000. Distinction between primary and secondary roads did not conform to ISHC classification since it was based on simple traffic categories. This division is obviously arbitrary but needed to be made to make certain that an adequate sample was taken of the highways in the state.

Use was made of Loadometer station data from the weight stations shown in Figure 4. Data from the 1977 survey were used in this study and this established the base year for the analysis.

Data from the weight stations are tabulated by the FHWA every other year and are published on forms which give standardized information on a nationwide basis. The FHWA weight forms are utilized in the NULOAD program.

- W1. Loadometer location and description of road.
- W2. Number and percentage, by type, of vehicles counted.
- W3. Average total vehicle weights, average loaded and empty weights.
- W4. Axle types and weights and EAL equivalents.
- W5. Number of vehicles counted compared to vehicles weighed by type.

Equivalent 18,000 lb. single axle loads (EAL) were calculated for the present and new traffic using the AASHTO equivalency factors. For the U.S. and State routes truck factors of 5% and 4% were taken from the Federal NIHPS report (15). Estimates were made of the number of trucks using each facility through use of traffic flow maps. Traffic distribution within the truck stream was assumed to be the same on all facilities but the number of trucks on each highway varied according to type of facility.

FIGURE 4. LOCATIONS OF WEIGH STATIONS

Truck Weight Shift

It is necessary to evaluate the probable shift in load distributions on a highway that might result from increasing the load limits. It is very doubtful that an increase in the legal load limit on Indiana highways would precipitate an immediate shift to higher loads. In many cases trucks may "cube out" before higher axle loads result. Further, changes in load limits would probably decrease the number of trucks needed to carry a particular cargo and, hence, number of load applications could decrease. On the other hand, higher load limits will result in heavier loads on trucks, and hence, the EAL for a given truck will also increase.

Whiteside, et.al., (44) in a report prepared for NCHRP outlined a procedure for estimating the traffic shift that might result from changing the load limits. The basic assumptions applied in the NCHRP study are as follows:

1. Total payloads will remain the same after limit changes.
2. The empty weight of the trucks will increase, assuming legal weights are increased, to provide for the strength and durability of the vehicle in use under heavier payloads.
3. Individual trucks will carry greater payloads per trip, and, therefore, operate with higher axle weights and higher gross weights.
4. Operation under the new limits will change somewhat in proportion to the change in the practical maximum gross weight of each vehicle class, which is defined as the sum of the individual axle legal weights, with the front or steering axle weights set at a reasonable amount, consistent with that class of vehicle and what past roadside weighing has shown as being normal practice.

Historical data were searched in the NCHRP study using data from before and after size and weight law changes. A definite pattern was developed which showed

that a shift to heavier trucks was accompanied by a small shift on the light weight portion of the distribution. Figure 5 shows a typical traffic distribution shift as analyzed by these techniques. Since the time of the NCHRP study, researchers in Texas (40) suggested a modification of the truck shift which results in a somewhat lower estimation of equivalent single axle loads. For this study the NCHRP method was used.

Soils

The AASHTO design method which was used utilizes soil strength values for the subgrade. The distribution of parent materials determined by the Joint Highway Research Project on previous studies is shown in Figure A-1 of the Appendix.

For flexible pavements use is made of soil support values and the values shown in Table A-1 in the Appendix were used for this purpose. The procedure for determining the support value is outlined in the Appendix.

For concrete pavements the modulus of subgrade reaction was obtained from correlations with the subgrade support value (45). Concrete pavements built prior to 1943 were largely constructed directly on the subgrade and the modulus values from the correlations were used in the computations. Pavements constructed after 1943 nearly always contained a subbase for control of pumping. A conservative value of 300 pci was used for the modulus for the later case.

Climatic

The effect of climate on pavement performance has been documented over an extensive period of time (45). For Indiana, the primary effect of climate results from freezing temperatures.

It is important to note that the effect of frost and other environmental considerations are interrelated with load applications. Design concepts used by

FIGURE 5. EXAMPLE OF TRUCK WEIGHT SHIFT. PRESENT GROSS WEIGHT 73,780 LBS., NEW GROSS WEIGHT 80,000 LBS. (STATION 069, SEE FIGURE 4).

the Indiana State Highway Commission includes effects of freezing, freezing-and-thawing and loss of support during the frost-melt period. In the study reported herein, the effect of climate on load related costs was evaluated using two techniques.

The first method consisted of stratifying the pavements in the state on a regional basis from north to south. A separate analysis was made of pavements in the north, central and southern portions of the state.

Second, use was made of the regional factor of the AASHTO Interim Guide. The regional factor modifies the pavement design on the basis of climatic variations. It is to be recalled further that the AASHO Road Test was conducted at Ottawa, Illinois where the climatic conditions are similar to those of Indiana. Likewise, the soil conditions at the Road Test site are essentially the same as those in a major portion of the state, namely glacial drift and associated soils.

Climate has an effect on pavement performance that is non-load associated. For example, scaling due to de-icing materials, D-line cracking are not load associated. In this study, an estimation of increased maintenance costs resulting from increased traffic was made and non-load associated factors were not considered. The interrelationships of climate and loads are recognized and the results should be interpreted accordingly. Climate was accounted for primarily through the technique of evaluating added costs on a regional basis.

Figure 6 illustrates the techniques adopted for this study. The upper left hand map of the state shows a generalized distribution of soils of the state. This map is a modification of the detailed map shown in the Appendix. The upper right hand and lower left hand maps show contours of freezing index and average annual rainfall for the state. It is to be noted that the soils are distributed in a north-south direction as is rainfall and freezing temperatures.

FIGURE 6 SOILS - ROCKS AND CLIMATE
 (a) DISTRIBUTION OF SOILS AND ROCKS
 (b) MEAN FREEZING INDEX (DEGREE-DAYS)
 (c) MEAN RAINFALL (INCHES / YEAR)
 (d) AASHTO REGIONAL ZONES

Because of the unique interrelationship among soil type, freezing index and rainfall in the state of Indiana, it was possible to divide the state into three regions as shown in the lower right hand map. The regional factors assigned to the state were 1.5, 1.1 and 1.0 from north to south.

The southern boundary of the northern region extends on a line from just north of Kentland in Newton County through Monticello in White County north of Marion and Grant County and north of Portland in Jay County. The southern boundary of the central region extends from a line just south of Newport in Vermillion County through a point north of Franklin in Johnson County and from there north of Lawrenceburg in Dearborn County.

Pavement Types Evaluated

The pavements on the state highway system were placed into one of four design categories as outlined below. The actual classification of each pavement studied was made after search of the road life data in the offices of the Indiana State Highway Commission.

1. Flexible Pavements included pavements with an asphalt surface on a non-stabilized base and subbase on the natural subgrade. Also included are full-depth asphalt pavements.
2. Jointed Reinforced Concrete Pavements are concrete pavements without an overlay and with joints, typically spaced at 40' intervals. In some cases plain pavements were placed in this category but these were minimal since the older plain pavements have been overlaid.
3. Continuously Reinforced Concrete Pavements are pavements without joints and containing continuous steel.
4. Overlay Pavements are concrete pavements with an appreciable amount of asphaltic concrete overlay.

The largest mileage of pavements on the state secondary roads are flexible and on the primary system they are concrete.

Highways Studied

Due to the large mileage of pavements in the state, use was made of statistical techniques to sample typical pavements from each of the climatic and pavement type strata mentioned in previous paragraphs. The number of pavement sections evaluated in each category are listed in Table 1. Soil strength values for each pavement were taken from Figure A-1 and Table A-1 in the appendix.

Cost Data

The computations utilized price data for various elements of the pavement and maintenance items. These were obtained using the U.P.A. tabulation of typical prices as recorded for state highways. The latest information is based upon 1978 dollars and, hence, all estimates of maintenance costs are presented in terms of 1978 dollars.

INCREASED PAVEMENT MAINTENANCE COSTS

As illustrated in Figure 1, the time at which a pavement will require a resurface depends in part upon whether or not routine maintenance is applied to the pavement. Figure 2 illustrates that ΣEAL is dependent upon any changes in the loading conditions. This analysis considered routine maintenance costs and resurfacing costs that are required under both the present weight limits and the new weight limits should they be allowed in Indiana.

Computations were made of increased total maintenance costs with and without routine costs included in the computations. It is to be emphasized that the costs reported herein are the added costs that would be required for maintenance should the load limits be increased and that these costs are those that can be attributed directly to load changes.

Table 1. Number of Sections Included in Study

	North			Central			South		
	Inter- state	U.S. and State Rds.		Inter- state	U.S. and State Rds.		Inter- state	U.S. and State Rds.	
		ADT > 4,000	ADT < 4,000		ADT > 4,000	ADT < 4,000		ADT > 4,000	ADT < 4,000
CRCP	1	2	--	10	--	--	2	4	--
Jointed Concrete	17	1	1	15	3	3	4	2	2
Overlay Concrete	4	24	15	3	17	14	7	14	16
Flexible	--	4	21	--	3	26	2	6	59

No attempt was made to categorize costs on the basis of urban vs. rural pavements since consideration was given to all pavements on the state system. Cost changes were determined separately for Interstate pavements and other U.S. and State routes.

The estimates of increased costs are shown in Table 2. These values are presented for two cases, (1) resurface costs assuming no appreciable increase in routine costs in the interim, and (2) resurface costs along with accelerated routine maintenance costs. With these categories forming the limits of the estimates, the increased costs in 1978 dollars can be expected to range between \$10,670,000 and \$12,240,000 per year.

Effect of Future Increased Unit Prices

The computations for the entire state highway system was made using 1978 costs obtained from the U.P.A. price summary. An average figure for the cost of asphalt concrete of various types during this time period was \$25 per ton in-place. The true cost of asphalt concrete for a given situation depends upon the component considered (i.e., base, surface, coated aggregate and so on), location within the state and other factors.

A sensitivity analysis showed that price of asphalt concrete was one of the most important variables in the analysis. The cost of resurface was determined using prices of \$20, \$22.5, \$25, \$30, and \$40 per ton. It was found that the cost of resurface bears a direct lineal relationship to asphalt concrete prices. Routine costs, however, do not vary linearly with the cost of asphalt concrete since these costs include many other functions of maintenance exclusive of overlay.

Table 2. Estimated Increased Annual Pavement Maintenance Costs*

Road Type	Increased Costs (Millions Dollars)	
	Resurface Only	Resurface Plus Routine Maintenance
Interstate	2.88	3.15
U.S. and State Routes		
ADT > 4,000	3.29	3.68
ADT < 4,000	4.50	5.41
TOTAL	10.67	12.24

- *NOTES: (1) All cost values are increased costs resulting from increased load limits.
- (2) Costs based on 1978 dollars.
- (3) Asphalt concrete prices \$25 per ton in-place. Resurface costs increase in direct proportion to asphalt concrete costs. See Figure A-4 in appendix for effect of asphalt concrete costs.

No attempt was made to estimate the price of asphalt concrete in future years and the primary conclusions are based upon 1978 prices as previously mentioned. Figure A-4^d in the appendix shows the ranges in increased costs that would result on a statewide basis for increases in asphalt concrete prices up to as high as \$50 per ton.

Cost Estimates Prepared by Other States

A detailed search of the literature was made to determine costs estimates that have been made by other state highway departments when they considered raising weight limits from the 73,280 lbs. gross to the 80,000 lbs. gross limit. This survey was in part successful but it is apparent that most states have not attempted analyses of this type. The Iowa DOT estimated annual increased costs of maintaining pavements of 8.8 million to 12 million dollars if load limits were changed from 73,280 lbs. to 80,000 lbs. gross. Mississippi estimates that the increased maintenance costs for the same increase in loads would be 5 million dollars annually. A study in Texas of maintenance costs that might result if the load limits were raised from a gross of 80,000 lbs. to 120,000 lbs. suggested an increase in pavement costs of \$2,529,000,000 per year.

Impact on County Roads

This study evaluated the effects of increased load limits on state highways. The estimates required a detailed knowledge of the pavement structure, soil conditions and truck weights. Information of this type is not available for county roads as a general rule.

Annual increased maintenance costs for flexible highways on the state system carrying less than 4,000 vehicles per day and with 4% trucks averaged \$215 per lane mile. The grand average for all pavements on the state system by comparison was \$475 per lane mile annually.

Since factual information relating to pavement thickness and truck weights on the statewide county system is not available, an estimate for the county system as a whole is not feasible at the present time. However, for county roads carrying appreciable truck traffic, estimates based on an annual increase of \$215 per lane mile appears justified.

PART II

EFFECTS OF INCREASED LOADS ON BRIDGE MAINTENANCE COSTS

SOURCES OF COST INCREASES

Bridges are the primary highway structures of concern in evaluating the impact of proposed increases in vehicle weight limits. Although culverts and retaining walls may also be adversely affected, the costs associated with these secondary structures will be slight when compared to bridges.

Increasing weight limits would probably produce some adverse effects on existing bridges. Costs associated with these effects are classified as upgrading costs and routine maintenance costs. Upgrading costs are those incurred in strengthening existing structures to safely carry the increased loads, replacing structures that cannot be adequately strengthened, and repairing or replacing structural elements prematurely damaged by fatigue. Increased routine maintenance costs associated with higher weight limits are primarily due to increased bridge deck deterioration.

UPGRADING COSTS

Upgrading costs associated with increased weight are either strength related or fatigue related. Strength related costs are those incurred in providing sufficient strength and safety to carry the increased loads, and result from strengthening existing bridges or replacing existing bridges that cannot be strengthened. Fatigue related costs are those resulting from a significant reduction in bridge life due to repeated application of increased loads.

Changes in axle spacing and axle loads would have a much greater effect on bridges than changes in gross vehicle weight. Increased loads also have a greater effect on short spans than on long spans since the dead load of short spans represents a smaller percentage of the total load than that of long spans.

Hence an increase in live load would produce a greater percentage increase in total load for short spans. Short spans also tend to be stiffer, resulting in greater impact load effects. For purposes of this study, it was assumed that axle spacing would remain essentially unchanged and effects of span length were, thus, ignored.

Most bridges in the United States are designed in accordance with AASHTO specifications, providing some degree of uniformity in bridge design and capacity across the country. A recent report by the U.S. General Accounting Office (16) states that of the nation's Interstate bridges 31 percent are inadequate to carry the 1956 load limits without a reduction in serviceable life, 54 percent are adequate for the 1956 loads but inadequate for the increased 1975 loads, and 15 percent are adequate for the 1975 loads. The corresponding percentages for primary roads are 64, 27 and 9 percent, respectively. In assessing upgrading costs, it was assumed in this study that structures have adequate strength for existing load limits with no reduction in serviceable life.

Strength Related Costs

NCHRP Report 141 (44) provides a method for evaluating existing bridges with respect to possible load increases. The method assumes that the bridge design loads stress key structural elements to the maximum allowable stresses permitted by AASHTO. It then provides for the determination of overstress produced by the increased loads. The amount of overstress is compared to conservative permissible overstress factors. A bridge with an overstress factor less than the permissible overstress factor is considered to be serviceable.

The report suggests the following permissible overstress factors:

Reinforced concrete, flexure:	0.35	shear:	0.30
Structural steel, flexure:	0.23	shear:	0.23
Prestressed concrete, flexure:	0.12	shear:	0.30

Permissible overstress factors for the substructure (piers and foundations) can be assumed to be at least as large as those for the superstructure.

Assuming that axle spacings remain unchanged, an 11 percent increase in axle loads and gross vehicle weight (live load) would produce an overstress factor of less than 0.11 because the total load increase (dead and live) is less than 11 percent. Since this factor is smaller than any of the specified permissible overstress factors, it can be concluded that bridges designed to safely carry the present load limits are adequate to carry an 11 percent increase in live load with no additional strengthening.

As mentioned previously, the above method assumes that design loads produce the maximum allowable stresses permitted by AASHTO. Actual stress measurements, however, have shown that such is not the case. An investigation of six Interstate bridges in Tennessee has revealed that actual stresses are only about one-half of those permitted by AASHTO (17). Other studies (18,26,30) have reached the same general conclusion. Studies conducted in Ontario, Canada, have concluded that the AASHTO loadings do not relate to the actual induced stresses in bridges. The Ministry of Transportation and Communication concluded the AASHTO design to be ultra-conservative. They concluded the AASHTO distribution factors, the outdated deflection criteria, and the antiquated working stress design were ample reason for expecting a much greater load-carrying capacity than the design. These studies (1,2,7) resulted in raising the axle loads to 20 kips single-axle, 35 kips dual-axle and 44 kips triple-axle, with maximum gross vehicle weight determined by the "Ontario Bridge Formula".

It has been generally concluded that raising maximum loads from the 1956 limits to the 1975 limits will produce no strength related upgrading costs in structures designed for the 1956 limits. This conclusion should also remain valid for the vast majority of axle spacings and span lengths because of the conservative nature of the AASHTO design specifications and the low actual stresses that result.

Fatigue Related Costs

Fatigue damage, or the fatigue life of structures, depends primarily on the nature of the structural element, the induced stress range and the number of load applications. Damage is not immediate, but rather cumulative in nature. Research indicates that fatigue damage to bridges caused by increased traffic and/or increased axle loads is typically corrected by periodic major rehabilitation, not by maintenance.

Many studies (17,18) have been conducted on the fatigue strength and life of bridges. A typical conclusion of such studies is: "Results of this study of specific test bridges indicate that the effect of current traffic loading on bridge life is insignificant with respect to fatigue failure of longitudinal stringers..." (14). Under current traffic conditions the bridges examined were found to have fatigue lives well in excess of 1,000 years. This apparently excessive margin of safety against fatigue failure is due to the low actual live load stresses that result from use of the AASHTO design specifications. Alternate, less conservative, fatigue design procedures that account for lower stress ranges and random loading have been suggested (18,31).

According to Whiteside et.al., "Assuming that the relationship between the logarithmic value of the fatigue cycles and the stress range is linear and the stress range value at 2×10^8 cycles for zero-to-tension stresses is equal to one-third the value at 2×10^6 cycles, an overload at a stress level of 30 percent will reduce the fatigue life of a bridge to about one-fifth of its original value" (44). Under these same assumptions, the proposed 11 percent load increase would reduce fatigue life to about one-half of its original value. Thus an original fatigue life of 1,000 years under current traffic conditions will be reduced to about 500 years if all vehicle loads are increased by 11 percent and traffic volume remains unchanged. Since this reduced value is an

order of magnitude greater than the average bridge design life of 50 years, it may be concluded that the proposed 11 percent weight increase will have no effect on fatigue related costs.

Fatigue design has not been an important design feature until recently because very few cases of fatigue failure have been reported. The increasing use of welded joints, however, has produced a drastic reduction in fatigue life because the crack initiation stage has been eliminated by the incipient flaws that exist in such joints. This situation is further aggravated by the cumulative nature of fatigue damage, whereby damage that is currently being experienced is not evident until some future time.

Total Upgrading Costs

Based on currently available information, it is concluded that bridges designed in accordance with AASHTO specifications for the 1956 load limits can safely carry the proposed 1975 load limits with no additional upgrading. The former limits were raised only after several studies concluded that they could be raised. Furthermore, it should be noted that states adopting the increased limits did so with no structural upgrading program and suffered no catastrophic consequences. This experience confirms the conclusion that no strength related upgrading costs will be incurred with structures designed for the 1956 limits.

The potential for some upgrading costs does exist. Structures that are marginally qualified for the 1956 limits may have to be upgraded to safely carry increased loads. Determination of the associated costs will first require identification of such structures, followed by application of a method such as that proposed in NCHRP Report 141 (44). It is also possible that fatigue damage which has yet to manifest itself has been occurring as a result of the increased loads, leading to potentially significant fatigue related costs at some future date.

ROUTINE MAINTENANCE COSTS

The primary source of load-related maintenance costs can be expected to be associated with concrete bridge deck deterioration. Deck rehabilitation procedures are expensive and cause public inconvenience. Analytical techniques are not yet available for evaluating deck deterioration associated uniquely with loads, nevertheless, increased loads can cause widespread distress to decks.

Causes of Bridge Deck Deterioration

The deterioration of concrete bridge decks is a problem that has received extensive study. Although authorities cannot definitely state the causes of deterioration, most agree on the major types of deterioration and possible causes. The three major types of observed bridge deck deterioration are scaling of surface mortar, cracking in the transverse direction and surface spalling.

Scaling can be caused by either freeze-thaw action or the presence of chloride deicers. It is especially severe when both factors act in combination. Most engineers agree that scaling is not related to loads, and scaling has been observed on bridge decks unopened to traffic. The problem appears to result from improper materials and construction practices, and it can be minimized by the proper use of air entrainment and, when required, linseed oil treatment.

Transverse cracking is evidenced by reasonably straight cracks perpendicular to the centerline of the roadway and generally occurring over primary slab reinforcement. Transverse cracks are primarily the result of volume changes of the concrete, such as those produced by shrinkage, or consolidation of the concrete while it is in a plastic state. Instances of such cracking prior to the opening of bridges to traffic have been reported. The rate of loading in the formation of such cracks is a matter of dispute. Even though traffic loads may not be a primary cause of transverse cracking, such cracking is aggravated by traffic loads. Traffic loading repeatedly opens and closes such cracks and tends

to increase their dimensions. Transverse cracking, in itself, is not considered a serious structural defect but it permits easy access to the underlying reinforcing steel by deicing salts.

A spall, or pothole, is a depression caused by a separation and removal of the surface concrete. Surface spalling is probably the most serious bridge deck durability problem today. Spalling weakens the deck and exposes the reinforcing steel. Spalling is caused by corrosion of the reinforcing steel in the presence of salt solutions at transverse cracks, and insufficient cover is a primary cause. Spalling is often observed to be most severe on heavily travelled bridge lanes.

INCREASED BRIDGE MAINTENANCE COSTS

All factors lead to the conclusion that an increase in load limits would accelerate the rate of concrete bridge deck deterioration. Bridge deck maintenance and rehabilitation constitutes a large majority of structure maintenance costs and, hence, an increase of these costs should be expected.

There is no direct technique for estimating such costs but Whiteside, et.al. (44) have suggested that structure maintenance costs are linearly related to maximum permitted gross vehicle weights and that the application of this allows an estimate of the probable boundary limit of changing maintenance costs.

In recent years, the state of Indiana has spent the following sums of money on bridge repairs:

1976 - \$ 8,022,200
1977 - \$18,732,800
1978 - \$23,428,100
1979 (through April 17) - \$ 5,971,100

Assuming that the weight limits would increase 11%, the state can expect an increase in structure maintenance costs from 2-3 million dollars per year.

Based on present information, it is reasonable to conclude that raising the weight limits will have no significant immediate effect. This conclusion is

substantiated by the experience of states that have already adopted the 1975 limits. Their experience also confirms the conclusion that no immediate structural upgrading costs will be incurred with an 11 percent increase in load limit.

Isolating the long term effects of increased load limits will be extremely difficult. Although it is generally held at present that the proposed increased loads will have no discernable effect on fatigue related costs, it is possible that this situation may change with additional experience. The effect of increased loads on maintenance costs is probably being felt, to some extent, at the present time due to the substantial number of overweight trucks presently operating in Indiana. Maintenance costs can be expected to increase with increased loads, and an 11 percent load increase may eventually produce an increase in maintenance costs of up to 10 percent. A general dollar figure, in terms of present maintenance costs, may range between 2-3 million dollars.

Additional future costs may also be expected. These will arise in part from upgrading structures presently unqualified or marginally qualified for the current load limits to the new higher standards. Future construction will also cost more if the same standards of safety are to be maintained.

SUMMARY, INCREASED MAINTENANCE COSTS

The detailed analysis of maintenance requirements for pavements in Indiana under the present load limits and under suggested higher load limits have indicated that substantial increases in maintenance costs can be expected. This is verified by a search of available information published by other states under similar conditions.

The estimated increase in maintenance costs for pavements can be expected to range between 10.67 and 12.24 million dollars annually in 1978 dollars. This, however, will no doubt increase depending largely upon the effect of the present energy shortage, and in particular shortage of petroleum which will influence the cost of asphalt concrete.

In the case of bridges, the conservative nature of the AASHTO design method minimizes the probability of increased costs required to strengthen bridges under new load limits. Increased cost resulting from damage to bridge decks are estimated to be from 2 to 3 million dollars.

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APPENDIX

SUPPORTING DATA

SOIL SUPPORT VALUES, INDIANA SOILS

The soil support values used in the study were determined using the concept of soil parent material areas. The Joint Highway Research Project has conducted a soil mapping program for the Indiana State Highway Commission over the past 30 years. During this period of time Engineering Soil maps have been developed both on a county and statewide basis. The state soil map is illustrated in Figure A-1.

In a study conducted in 1967 (42) soil support values were established for the various parent material units as shown in Table A-1.

The soil support values were established by opinions of state highway personnel, Purdue personnel and practicing engineers. Each of the Engineers was asked to estimate the soil support value that should be assigned to a specific soil unit. Correlations of the soil support values with California Bearing Ratio and other parameters (45) and in turn correlation of these values with test values obtained from on-site investigations have substantiated these support values. For rigid pavements it is necessary to utilize correlations of the soil support value (through the CBR) with the modular subgrade reaction (Figure A-2).

FIGURE A-1

Table A-1. Soil Support Values for the Major Soil Units of Indiana

Major Soil Unit		Soil Support Value
Water Transported	1. Porous Substrata (sands and gravel)	6.8
	2. Sands (except Kankakee sands)	6.2
	3. Kankakee Sands	5.6
	4. Lakebeds	4.0
Ice Transported	5. Young drift till plains (silty-clays) Moraines	4.9
	6. Areas of sand, gravel, and till eskers	6.3
	7. Old drift silts and silty-clays	5.0
Wind Transported	8. Sand: some water-deposited sand areas include windblown sands	6.0
	9. Loess - Silt	5.3
Residual	10. Limestone Interbedded limestone and shale Limestone, sandstone, and shale	4.9
	11. Sandstone and some shale Interbedded shale and sandstone	5.1

FIGURE A-2 CORRELATION OF
TEST VALUES

AASHTO DESIGN EQUATIONS

The equations used in the analysis to predict pavement life, and from this design overlay thickness, are those appearing in the AASHTO Interim Guide. These are reproduced below. These equations are accepted for design of highway pavements in the United States. They are based upon performance of the test pavements at the AASHO test pavements at Ottawa, Illinois.

Flexible Pavements

The general AASHO Road Test equation is

$$G_t = \beta(\log W_t - \log \rho) \quad (A-1)$$

where:

G_t = a function (the logarithm) of the ratio of loss in serviceability at time t to the potential loss taken to a point where $p_t = 1.5$.

β = a function of design and load variables that influence the shape of the p -versus- W serviceability curve.

W_t = axle load applications at end of the time t .

ρ = a function of design and load variables that denotes the expected number of axle load applications to a serviceability index of 1.5.

p_t = serviceability at end of time t .

At the AASHO Road Test, the terms β and ρ in equation (A-1) were related to the load and pavement variables for flexible pavements as follows:

$$\beta = 0.40 + \frac{0.081(L_1+L_2)^{3.23}}{(\overline{SN}+1)^{5.19} L_2^{3.23}} \quad (A-2)$$

and

$$\begin{aligned} \log \rho = 5.93 + 9.36 \log(\overline{SN}+1) - 4.79 \log(L_1+L_2) \\ + 4.33 \log L_2 \end{aligned} \quad (A-3)$$

where

L_1 = load on one single axle or on one tandem-axle set, kips.

L_2 = axle code (1 for single axle and 2 for tandem axle).

$\overline{SN}$ = structural number.

$$\log W_{t18} = 9.36 \log (SN+1) - 0.20 + 0.40 + \frac{G_t}{1094 (SN+1)^{5.19}} + \log \frac{1}{R} + 0.372(S_i - 3.0) \quad (A-4)$$

The structural thickness of the pavement is expressed by the general equation:

$$SN = a_1 D_1 + a_2 D_2 + a_3 D_3 \quad (A-5)$$

where

a_1, a_2, a_3 = coefficients of relative strength.

D_1 = thickness of bituminous surface course, inches.

D_2 = thickness of base course, inches.

D_3 = thickness of subbase, inches.

For this study the coefficients used were:

$$a_1 = 0.44$$

$$a_2 = 0.14$$

$$a_3 = 0.11$$

Rigid Pavements

$$\beta = 1.00 + \frac{3.63(L_1 + L_2)^{5.20}}{(D+1)^{8.46} L_2^{3.52}} \quad (A-6)$$

and

$$\log \rho = 5.85 + 7.35 \log(D+1) - 4.62 \log(L_1 + L_2) + 3.28 \log L_2 \quad (A-7)$$

where

L_1 = load on one single axle or on one tandem axle set, kips.

L_2 = axle code (1 for single axle and 2 for tandem axle).

D = thickness of slab, inches.

$$\log W'_{t18} = 7.35 \log (D+1) - 0.06 + \frac{G_t}{1 + \frac{1.624 \times 10^7}{(D+1)^{8.46}}} + (4.22 - 0.32p_t) \left[\log \left(\frac{S'_c J}{S_c J'} \right) \left(\frac{D^{0.75} - 18.42/Z^{0.25}}{D^{0.75} - 18.42/Z'^{0.25}} \right) \right] \quad (A-8)$$

Substituting in equation (A-8) the values for the physical constants

($Z = E/k, S_c$, and J) that represent Road Test condition as follows:

$E = 4.2 \times 10^6$ psi (static test @ 28 days).

$k = 60$ pci (gross, 30-in.-dia. plate).

$S_c = 690$ psi (28 day, 1/3-point loading).

$J = 3.2$ (assumed value for protected corner)

gives

$$\log W'_{t18} = 7.35 \log (D+1) - 0.06 + \frac{G_t}{1 + \frac{1.624 \times 10^7}{(D+1)^{8.46}}} + (4.22 - 0.32p_t) \left[\log \left(\frac{S'_c}{215.63J} \right) \left(\frac{D^{0.75} - 1.132}{D^{0.75} - \frac{18.42}{Z^{0.25}}} \right) \right] \quad (A-9)$$

METHOD OF CALCULATING MAINTENANCE COST

The estimation of major maintenance costs is accomplished through use of the AASHTO pavement design equations (5). The AASHTO equations are presented in equations A-1 through A-9.

Performance of the pavements is assumed to conform to the performance equations from the AASHO Road Test. Design of asphaltic concrete overlays over flexible pavements was done by subtracting the existing pavement structure thickness from the total thickness required by a new design analysis. Subgrade support values were assigned to each structure using the parent material soil area concept.

For asphaltic concrete overlays over rigid pavements, the procedure is based on an empirical formula that assigns structural equivalency of thickness of asphaltic concrete and portland cement concrete as illustrated in Equation A-1. For this study a value of F equal to was used.

$$t = 2.5 (Fh_n - h_e) \quad (A-10)$$

where

h_n = required thickness of pavement.

h_e = existing thickness of pavement.

F = factor depending on traffic and subgrade support. A value of 0.8 was used in this analysis.

Routine maintenance cost estimates were accomplished using prediction models proposed by Butler (10). Butler developed a computer program called EAROMAR which includes a set of equations which predicts maintenance work loads using information from actual costs across the country. These models have primary application for freeway conditions and therefore are most appropriate for the

interstate system. The equations developed by Butler are presented in equations A-11 through A-16 (11).

Flexible Pavement Work Load Models

- a. Square yards of Bituminous Skin Patching per year per lane mile

$$\text{SY Patching/LM} = 1100 / (1 + e^{-(\text{Age}-10)/1.16}) \quad (\text{A-11})$$

- b. Crack Sealing in Bituminous Pavements per year per lane mile

$$\text{Lineal ft. of crack sealing/LM} = 1000 / (1 + e^{-(\text{Age}-10)/1.16}) \quad (\text{A-12})$$

- c. Bituminous Base and Surface Repair per year per lane mile

$$\text{Cubic Yds./LM} = 5 / (1 + e^{-(\text{Age}-10)/1.16}) \quad (\text{A-13})$$

Rigid Pavement Work Load Models

- a. Square yards of Patching per year per lane mile

$$\text{SY Patching/LM} = 34 / (1 + e^{-(\text{Age}-10)/1.25}) \quad (\text{A-14})$$

- b. Concrete Pavement Joint Sealing per year per lane mile

$$W = ((5280 * L/S) * ML) \quad (\text{A-15})$$

Where:

W = Lineal feet/year/lane mile.

L = Lane width, feet.

S = Joint spacing, feet.

ML = Frequency for joint sealing, number of times per year

(sealing joints every other year would produce a value of

ML = 0.5).

Note: 1 ft = .305 m, 1 cy = .765 m³

- c. Mudjacking Concrete Pavements/Year

$$Y = 0.25(0.5 \text{ Age})^2 e^{-0.5 \text{ Age}} \quad (\text{A-16})$$

Where:

Y = Cumulative Percent of Pavement to be Mudjacked in Previous Years

(Model based on the assumption that 1 percent will be mudjacked over life of pavement).

d. Blowups Per Year

$B = 0$ for Age less than 4 years.

$B = 0.005 (Age - 4)$, for Age 4 to 25 years.

$B = 0$ for Age more than 25 years.

Composite Pavements

The same models are used for composite pavements as for concrete pavements, except that full and partial depth concrete patches are replaced with the bituminous skin patching model, and the joint sealing is replaced by the crack sealing model.

It is to be pointed out that the routine maintenance models are time dependent only and do not account for traffic as such. The cost of maintenance activities for various load conditions, however, can be estimated by techniques proposed by Layton et.al. (28). For example, accelerated maintenance can be computed assuming that a pavement will receive the same prescribed amount of routine maintenance whether the life cycle is shortened by heavier loads or not. Likewise, the inverse is true since the total maintenance dollar might be spread out over a larger number of years.

Major maintenance costs are determined on the basis of the required thickness of overlay of asphalt including the overlay thickness required to raise the shoulder. Unit cost of in-place asphalt concrete, granular material are input to the computer program. The costs used are those taken from the U.P.A. cost index as published by the Indiana State Highway Commission (22).

PAST RESURFACING COSTS IN INDIANA

In addition to the routine maintenance costs computed using EAROMAR, the estimates are based in part on historical data of the actual cost of resurfacing pavements in recent years. The cost of resurfacing pavements during the fiscal year between July 1, 1978 and June 30, 1979 was \$53,144,801 expended on RS Contracts through the Maintenance Division and \$16,276,900 which were included on projects that were funded through the Design Division. This results in a total expenditure for that fiscal year of \$69,421,701.

Costs per mile for resurfacing are given in Table A-2 and are illustrated in Figure A-3.

Table A-2. Overlay Cost Expended July 1, 1978 Through June 30, 1979

Division	Miles Overlayed	Cost	Cost Per Mile
Maintenance Division	916.3	\$53,144,801	\$ 57,999
Design Division			
Primary and Secondary	14.7	\$ 3,043,900	\$207,100
Interstate	51.5	\$13,233,000	\$256,700
TOTALS	982.5	\$69,421,701

FIGURE A-3. RESURFACE EXPENDITURES
ISHC DIVISION OF MAINTENANCE

FIGURE A-4 EFFECT OF PRICE OF ASPHALT ON INCREASED COSTS OF PAVEMENT MAINTENANCE.

COVER DESIGN BY ALDO GIORGINI