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16. Abstract

This study assesses the economic impact of overweight permitted vehicles hauling sugarcane on Louisiana highways. The highway routes being used to haul these commodities were identified, and statistically selected samples were used in the analysis. Approximately 270 control sections on Louisiana highways carry sugarcane are involved in the transport of this commodity. Three different gross vehicle weight (GVW) scenarios were selected for this study including: 80,000 lb., 100,000 lb. and 120,000 lb. The maximum current allowable GVW is 80,000 lb. while the maximum 100,000 lb. GVW is the permitted load for sugarcane trucks and is currently the highest load level permitted by Louisiana laws.

The methodology for analyzing the effect of these loads on pavements was taken from the *1986 AASHTO Design Guide* and involves determining the overlay thickness required to carry traffic from each GVW scenario for the overlay design period. Differences in the life of an overlay were calculated for different GVW scenarios and overlay thickness and costs were determined for a 20 year analysis period. These costs were developed for samples taken from all the control sections included in the study. These net present worth costs from the samples were expanded to represent the cost for all control sections carrying sugarcane.

Results indicate that the damage from each sugarcane truck with a GVW of 100,000 lb. to pavement overlay is at about \$2,072/year and to bridge fatigue cost is at about \$3,500/year. Therefore, the current sugarcane trucks permit fee of \$100 per year is not adequate and should be increased to recover these costs. The legislature should not consider raising the GVW level to 120,000 lb. because the pavement overlay costs increase by two folds (double) and the bridge repair costs become very large. Moreover, the magnitude of the damage caused by the 120,000 lb. GVW for a FHWA Type 9 truck makes the risk of bridge damage and even bridge failure too significant to ignore. The project staff recommends that the legislature keep the GVWs at the current level but increase the permit fees sufficiently to cover the additional pavement and bridge costs or change the configuration of the axle on the trailer from a tandem to a triple, effectively changing the vehicle from a FHWA Type 9 to a Type 10 vehicle. Under these circumstances, the permit fee can be reduced to zero and a tax incentive of \$683 can be given to each truck for the conversion. It is recommended to allocate more highway funding for handling the extra damage caused by the increase of truck load limits.

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Evaluating the Effects of Heavy Sugarcane Truck Operations on Repair Cost of Low Volume Highways

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ABSTRACT

This study assesses the economic impact of overweight permitted vehicles hauling sugarcane on Louisiana highways. The highway routes being used to haul these commodities were identified and statistically selected samples were used in the analysis. Approximately 270 control sections on Louisiana highways that carry sugarcane are involved in the transport of this commodity. Three different gross vehicle weight (GVW) scenarios were selected for this study including: 80,000 lb., 100,000 lb., and 120,000 lb. The current maximum allowable GVW is 80,000 lb. while the maximum 100,000 lb. GVW is the permitted load for sugarcane trucks and is currently the highest load level permitted by Louisiana laws.

The methodology for analyzing the effect of these loads on pavements was taken from the *1986 AASHTO Design Guide* and involves determining the overlay thickness required to carry traffic from each GVW scenario for the overlay design period. Differences in the life of an overlay were calculated for different GVW scenarios and overlay thickness and costs were determined for a 20 year analysis period. These costs were developed for samples taken from all the control sections included in the study. The net present worth costs from the samples were expanded to represent the cost for all control sections carrying sugarcane.

Results indicate that the damage from each sugarcane truck with a GVW of 100,000 lb. to pavement overlay is at about $2,072/year and the bridge fatigue cost is about $3,500/year. Therefore, the current sugarcane trucks permit fee of $100 per year is not adequate and should be increased to recover these costs. The legislature should not consider raising the GVW level to 120,000 lb. because the pavement overlay costs increase two-fold and the bridge repair costs become very large. Moreover, the magnitude of the damage caused by the 120,000 lb. GVW for a FHWA Type 9 truck makes the risk of bridge damage and even bridge failure too significant to ignore.

The project staff recommends that the legislature keep the GVWs at the current level but increase the permit fees sufficiently to cover the additional pavement and bridge costs or change the configuration of the axle on the trailer from a tandem to a triple, effectively changing the vehicle from a FHWA Type 9 to a Type 10 vehicle. Under these circumstances, the permit fee can be reduced to zero and a tax incentive of $683 can be given to each truck for the conversion. It is recommended to allocate more highway funding for handling the extra damage caused by the increase of truck load limits.

ACKNOWLEDGMENTS

This report could not have been completed without the assistance of personnel from Districts 02, 03, 07, 08, 58, 61, and 62. Personnel from the district administrator, construction engineering, maintenance, materials, and traffic all contributed to the successful completion of the project. Each district provided personnel to meet with project investigators to estimate the pavement cross sections for each control section in the district carrying sugarcane, later they developed the history of pavement construction and rehabilitation, and then made traffic volume and classification counts on each control section included in the study. Without this timely assistance, we simply could not have performed the study. In addition to district personnel, the authors are grateful to Denny Silvio and Debbie Sanders of the Department of Transportation and Development (DOTD) permits office for their assistance in determining how many overweight sugarcane permits were issued.

In addition to DOTD personnel, representatives of the American Sugarcane League developed estimates of the tonnage of sugarcane that was hauled over each of the control sections and identified the control sections to be included in the study. The authors especially want to thank Charlie Melancon, former President of the Sugarcane League, for his help in coordinating the collection of the 2002 sugarcane harvest data.

Lastly, we want to express our gratitude to the Project Review Committee members, many of whom provided direct assistance to the project team as we developed information needed to complete the study.

IMPLEMENTATION STATEMENT

The results from this project can be immediately implemented by the Louisiana legislature. A review of the pavement costs compels the legislature to define the level of subsidy to be provided to the sugarcane industry by the state of Louisiana. In analyzing the effect of the current GVW defined by Louisiana statutes, project staff determined that the current 100,000 lb. GVW prescribed for sugarcane trucks provides a minimum subsidy of $5,445 per vehicle per year. This minimum value is based on the data from the permit office on how many of the agricultural harvest permits are for sugarcane trucks. Therefore, the current sugarcane trucks permit fee of $100 per year is not adequate and should be increased to $5,545 to recover the pavement overlay costs and bridge fatigue costs. Since this permit fee is so large, the project staff recommends that the legislature keep the allowed GVW at the current level but stipulate the change in the configuration of the axle on the trailer from a tandem to a triple, effectively changing the vehicle from a FHWA Type 9 to a Type 10 vehicle. Under these circumstances, the permit fee can be reduced to zero and a tax incentive of about $683 can be given to each truck for the conversion.

When investigating the effect of increasing the GVW from 100,000 lb. to 120,000 lb., the added cost of overlays doubled when compared to current conditions. In addition, bridge repair costs will likely increase significantly. As a result, project staff recommends that no consideration be given to increasing the GVW from current levels to 120,000 lb., primarily because the magnitude of impact from the 120,000 lb. GVW for a FHWA Type 9 truck makes the risk of bridge damage too significant to ignore.

TABLE OF CONTENTS

ABSTRACT iii
ACKNOWLEDGMENTS v
IMPLEMENTATION STATEMENT vii
TABLE OF CONTENTS ix
LIST OF TABLES xi
INTRODUCTION 1
OBJECTIVE 5
SCOPE 7
METHODOLOGY 9
    Pavement Data for Analysis 16
        Overlay Design 21
DISCUSSION OF RESULTS 23
    Louisiana State Highway LA 10 23
        Calculation of ESALs for Current Pavement Condition 23
        Calculations of ESALs Used under Current GVW Conditions 24
        Calculation of Number of Years Required by Scenario Two to Use the Remaining Design Traffic 27
        Calculation of ESALs for the Next Performance Period 29
        Overlay Design 31
        Calculation of Number of Years Required by Scenario One to Use the Remaining Design Traffic 33
        Calculation of ESALs and Overlay Required for the Next Performance Period under Scenario One 36
        Calculation of Number of Years Required by Scenario Three to Use the Remaining Design Traffic 38
        Calculation of ESALs and Overlay Required for the Next Performance Period Under Scenario Three 42
    Developing Statewide Costs for Control Section Data for Each ADT Group 45
        Scenario Two Net Present Worth of Overlay Costs for Control Sections 45
        Statewide Net Present Worth of Overlay Costs for All GVW/Truck Type Scenarios 48
        Interpretation of Statewide Net Present Worth of Overlay Costs 50
        Bridge Fatigue Costs 53
    Trailer Axle Configurations 55
        Adding an Extra Axle to Truck/Trailer 56
        Use of Lighter Trailers 58
        Mill Delivery System 59
CONCLUSIONS 61
RECOMMENDATIONS 63
ACRONYMS, ABBREVIATIONS, & SYMBOLS 65
REFERENCES 67
APPENDIX A 69

LIST OF TABLES

Table 1 Control sections carrying 2002 harvest season sugarcane by LADOTD District 10
Table 2 ADT groupings of control sections along with mean, standard deviation of structural number (SN), and required sample size 10
Table 3 Control sections included in the detailed study by DOTD District 13
Table 4 Axle load and configurations for each of the 3 different GVW Scenarios and 14
Table 5 Control sections with ADT less than 2,000 included in the detailed study 18
Table 6 Control sections with ADT from 2,000 to 7,000 included in the detailed study 19
Table 7 Control sections with ADT greater than 7,000 included in the detailed study 19
Table 8 Vehicle classification and truck factors for use in designing flexible pavements 20
Table 9 ESAL calculation for current pavement condition on LA 10 24
Table 10 Calculation of ESALs starting in 1996 for a period of 10 years under present GVW conditions (Scenario Two) 26
Table 11 Calculation of number of years required by Scenario Two to use the remaining design traffic 28
Table 12 Calculation of ESALs starting in 2010 for a period of 20 years under present GVW conditions (Scenario Two) 30
Table 13 Overlay design for LA 10 under current conditions (Scenario Two) for the next performance period 31
Table 14 Calculation of ESALs starting in 1996 for a period of 10 under Scenario One 34
Table 15 Calculation of number of years required by Scenario One to use the remaining design traffic 35
Table 16 Calculation of ESALs starting in 2016 for a period of 20 years under Scenario One........ 37
Table 17 Overlay design for LA 10 under Scenario One for the next performance period 38
Table 18 Calculation of ESALs starting in 1996 for a period of 10 years under Scenario Three 40
Table 19 Calculation of number of years required by Scenario Three to use the remaining design traffic 41
Table 20 Calculation of ESALs starting in 2006 for 20 years under Scenario Three 43
Table 21 Overlay design for LA 10 under Scenario Three for the next performance period............ 44
Table 22 Dimensions and Scenario Two overlay costs for 11 control sections with ADT less than 2,000 46
Table 23 Dimensions and Scenario Two overlay costs for 10 control sections with ADT from 2,000 to 7,000 47
Table 24 Dimensions and Scenario Two overlay costs for 13 control sections with ADT greater than 7,000 47
Table 25 Net present worth of overlays for all control sections carrying sugarcane for all GVW/FHWA truck type combinations 48
Table 26 Summary of the product of number of lanes, lane width, and control section length for each ADT group for 271 control sections carrying sugarcane 49
Table 27 statewide net present worth of overlays for all control sections carrying sugarcane for all GVW/FHWA truck type combinations 50
Table 28 Statewide annual cost of overlays for all control sections carrying sugarcane for all GVW/FHWA truck type combinations 51
Table 29 Calculation of equivalent truck loads for both truck types for all the three scenarios 57

INTRODUCTION

Sugarcane is grown in 24 parishes of Louisiana and is currently hauled to market by truck trailer combinations (FHWA Type 9 vehicle, commonly known the 18-wheeler) familiar to all who live in mid- to south Louisiana. Current state laws allow truck operators hauling certain agricultural commodities to purchase overweight permits and haul at gross vehicle weights (GVW) in excess of the legislated GVW limit of 80,000 lb. Sugarcane truckers may purchase an overweight permit for $100/year and then carry sugarcane at a GVW of 100,000 lb. The study that was performed for the Louisiana Governor's Oversize and Excess Weight Vehicle Task Force showed that the cost of pavement damage produced by trucks hauling sugarcane in excess of 80,000 lb. far exceeded the $100/year vehicle harvest permit charged for the overweight permit *[1]*. The results of that study indicated that the cost of pavement damage was greatest on roads designed for light, land access traffic. Since the pavement damage cost exceeded the permit fee, these vehicles are essentially subsidized by the Louisiana traveling public as a result of action by the Louisiana legislature, which regulates both vehicle weights and the cost of permit fees charged for overweight loads *[2]*.

Please see below for the text of the law pertaining to Sugarcane Permits. I've highlighted the portion that stipulates the requirement for the third trailer axle. Note that the new deadline is in fact 2012.

§387.7. Special permits; vehicles hauling sugarcane

A. Notwithstanding any other provision of law to the contrary and provided that there are no objections raised by the federal government, the secretary shall issue annual special permits to persons who own or operate vehicles which haul sugarcane. Such permits may be issued to either the pulling unit or the trailer contained in the combination which shall have a minimum of eighteen wheels. These permits shall be issued in accordance with the following provisions:

(1) The permits shall be issued at the truck permit office of the Department of Transportation and Development.

(2) The fee for the permits shall be one hundred dollars per permit per year.

(3) The permit shall authorize the operation of the vehicle combination at a gross weight not to exceed one hundred thousand pounds.

(4)(a) The secretary may impose a civil penalty of up to five cents per pound for each violation of the one hundred thousand pound limit.

(b) Beginning August 1, 2005, a first violation of the one hundred thousand pound limit shall result in the civil penalty imposed in accordance with the provisions of this Section and a warning that a second violation shall result in the penalty and the forfeiture of the permittee's eligibility to apply for and receive an annual special permit for the following year. A second violation of the one hundred thousand pound limit shall result in the penalty and the forfeiture of the permittee's eligibility to apply for and receive an annual special permit for the following year. A third violation shall result in the penalty and the permanent revocation of the permittee's eligibility to apply for and receive an annual special permit.

(c) Any owner or operator who has a civil penalty levied against him for a violation of the permitted weight limit of this Section shall be entitled to appeal the penalty in accordance with the provisions of R.S. 32:389.

(d) The Department of Transportation and Development, in cooperation with the Department of Public Safety and Corrections, office of state police, shall promulgate rules and regulations as are necessary, in accordance with the Administrative Procedure Act, to implement the provisions of this Section, subject to oversight by the House and Senate Transportation, Highways and Public Works Committees. The office of state police shall be responsible for promulgating rules and regulations regarding enforcement procedures.

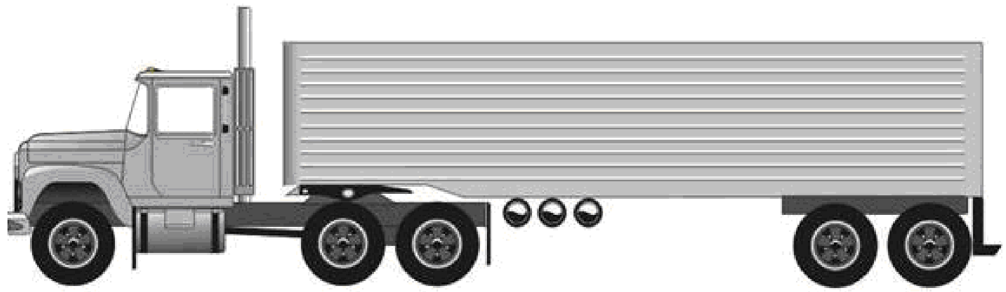
(5) The permit shall be specific to the vehicle that is indicated by the permit applicant upon application.

B. Beginning August 1, 2012, the secretary shall not issue any annual special permits to any owner or operator of a vehicle hauling sugarcane who has not added an additional single axle on the sugarcane trailer for a total of six axles for the vehicle and trailer combination.

Acts 1995, No. 584, §1; Acts 2003, No. 1219, §1, eff. July 1, 2003; Acts 2004, No. 300, §1, eff. June 18, 2004; Acts 2005, No. 330, §1; Acts 2007, No. 365, §1, eff. July 10, 2007.

As the 1999 study involved only three control sections carrying sugarcane, the Louisiana Department of Transportation and Development instituted this study to provide a more detailed evaluation of the effect of sugarcane trucks on the cost of damage to roadways over which they travel *[1]*. In addition, there is a need to evaluate the consequences of changing the vehicle type used to transport sugarcane. Currently the FHWA Type 9 vehicle is used to transport sugarcane. The FHWA Type 9 vehicle shown in

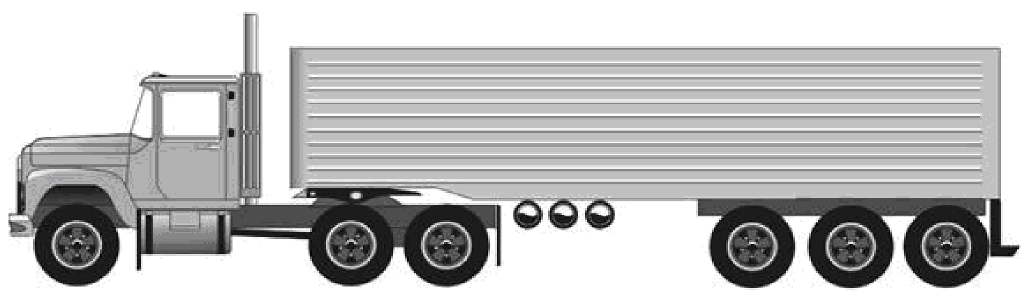
Figure **1** has a steering axle and two load axles, one on the tractor and one on the semi-trailer. Both of these load axles are tandem axles with dual tires.



Tandem Axle **Tandem axle**

Figure 1
FHWA Type 9 truck

The FHWA Type 10 vehicle shown in
Figure **2** also has a steering axle and two load axles, but the load axle on the semi-trailer is a triple axle with dual tires instead of a tandem axle with dual tires.



Tandem Axle **Triple axle**

Figure 2
FHWA Type 10 truck

It is a well-established fact that, at the same GVW, triple axles produce much less pavement damage than tandem axles.

In this study, investigators will determine the pavement costs associated with changing the load axle on the semi-trailer from a tandem to a triple axle. Moreover, pavement costs will be developed for two other GVW scenarios. Pavement costs will be developed for a GVW of 80,000 lb., assuming that one option available to the Louisiana legislature is to rescind all overweight permits and return to the limits applied to non-agricultural and non-natural resource truckers. Pavement costs will also be developed for 120,000 lb. GVW, assuming that there is interest in evaluating this option. One reason for investigating this option is that the number of truck loads required to transport the annual sugarcane harvest can be substantially reduced if each truck payload could be increase by 20,000 lb. The three cases are referred as follows:

Case Study	**Gross Vehicle Weight (GVW)**		
	80,000 lb.	100,000 lb.	120,000 lb.
Scenario 1	FHWA Type 9		
Scenario 2 Scenario 2a		FHWA Type 9 FHWA Type 10	
Scenario 3 Scenario 3a			FHWA Type 9 FHWA Type 10

OBJECTIVE

The main objectives of this research are to:

1. Estimate the additional rehabilitation costs to roads damaged by heavy sugarcane trucks.

2. Develop truck-axle configurations which produce less pavement damage by permitted overweight trucks.

SCOPE

The scope of this study is to determine the pavement costs associated with changing the load axle on the semi-trailer from a tandem to a triple axle. Pavement costs for a GVW of 80,000 lb., assuming that one option available to the Louisiana legislature is to rescind all overweight permits and return to the limits applied to non-agricultural and non-natural resource truckers. Pavement costs will also be developed for 120,000 lb. GVW, assuming there is interest in evaluating this option. One reason for investigating this option is that the number of truckloads required to transport the annual sugarcane harvest can be substantially reduced if each truck payload could be increased by 20,000 lb. The three cases are referred to as follows:

	Gross Vehicle Weight (GVW)		
	80,000 lb.	100,000 lb.	120,000 lb.
Scenario 1	FHWA Type 9		
Scenario 2		FHWA Type 9	
Scenario 3			FHWA Type 9
Scenario 2a		FHWA Type 10	
Scenario 3a			FHWA Type 10

This report concentrates on determining the overlay costs on highways that the DOTD is responsible for constructing, rehabilitating, and maintaining.

METHODOLOGY

The methodology used to assess the pavement damage caused by hauling sugarcane on Louisiana highways is similar to the one used to assess the impact of hauling timber, lignite coal, and coke fuel on Louisiana highways and bridges *[5]*. However, since none of the parish governments conducted traffic surveys to measure average daily traffic or determine the number and types of truck traffic (classification counts) traveling over parish roads, it was not possible to assess the impact of sugarcane trucks on pavement costs. So the balance of the methodology was applied only to state highways for which average daily traffic and vehicle classification counts were conducted by each district of the DOTD at the request of project staff. The following steps were followed in performing this assessment:

1. Met with the American Sugarcane League to set up meetings with sugar mills and representatives familiar with farms producing sugarcane processed by each sugar mill during the 2002 harvest season.

2. Met with representatives of each sugar mill to estimate the quantity of sugarcane hauled from each farm, identify probable highway routes over which the sugarcane was transported, and estimate the amount of sugarcane hauled over each portion of each highway route during the 2002 harvest season.

3. Took information from steps 1 and 2 and put it on maps of the local area or parish. Each route was marked and the sugarcane tonnage transported and the direction of haul marked for each entry.

4. Once data from all the sugar mills was collected, summary tables were prepared that contained a listing of each highway route, parish road, or street over which sugarcane was hauled, the tonnage hauled, and direction of the haul. For state routes, each highway was divided into control sections and information for each control section was tabulated separately.

5. For each control section, parish road, or street, appropriate state or parish officials were contacted and pavement cross section data and traffic data secured. The pavement cross section data included the type and thickness of surface (hot mix asphalt, concrete, or surface treatment), type and thickness of base (gravel or soil cement bases were the most typical), and estimated or most recent average daily traffic data (the number of automobiles and trucks per day over each road section).

The number of control sections in each district over which sugarcane was transported in 2002 is shown in Table 1.

Table 1
Control sections carrying 2002 harvest season sugarcane by LADOTD District

District No.	No. of Control Sections Carrying Sugarcane in 2002
2	31
3	113
7	20
8	17
61	86
62	4
TOTAL	271

6. The control sections were divided into three groups of average daily traffic (ADT). For each group the structural number, a measure of pavement strength, was calculated; the average and the standard deviation of structural number were computed; and the sample size of control sections from each ADT group estimated. The procedure used in this study is described in detail in reference *[4]*. The number of control sections in each ADT group is shown in Table 2.

Table 2
ADT groupings of control sections along with mean, standard deviation of structural number (SN), and required sample size

ADT Range	# of Control Sections	Calculated Mean of SN	Calculated Standard Deviation of SN	# of Control Sections Required
Less than 2000	88	3.670	1.424	11
2000 to 7000	91	4.129	1.593	10
Greater than 7000	92	6.224	2.627	13
TOTALS	271			34

7. A detailed analysis was conducted to determine the cost of pavement overlays required to carry the normal traffic loads plus the sugarcane tonnage under three different GVW scenarios using 2 different vehicles (FHWA Type 9 and FHWA Type 10 vehicles). These combinations produced the following five different GVW scenarios for which detailed pavement analyses were conducted:

	Gross Vehicle Weight (GVW)		
	80,000 lb.	100,000 lb.	120,000 lb.
Scenario 1	FHWA Type 9		
Scenario 2		FHWA Type 9	
Scenario 3			FHWA Type 9
Scenario 2a		FHWA Type 10	
Scenario 3a			FHWA Type 10

8. The axle loads for the five different scenarios were evaluated for each control section using the GVW, axle load, and axle type combinations shown in Table 4.

   a. Each GVW was split into axle loads. For example, the axle loads for the 80,000 lb. GVW were divided into the following:

      Steering axle load = 12,000 lb.

      Tractor tandem axle load = 34,000 lb.

      Semi-trailer tandem axle load = 34,000 lb.

      Total Load = 80,000 lb.

   b. For each axle load and type, the load equivalence factor was determined from the American Association of State Highway and Transportation Officials 1986 pavement design guide and a truck factor determined by summing the individual load equivalence factors *[5]*.

   c. The average empty weight of each truck was estimated e.g., the average empty weight for the FHWA Type 9 sugarcane truck was 37,300 lb.

d. The payload per vehicle was determined by subtracting the empty weight from the GVW for each scenario.

e. The number of trucks required to carry the sugarcane harvest transported over each control section was determined by dividing the total sugarcane transported in the control section by the payload per truck.

9. Each DOTD district collected traffic data on each control section during February of 2006. Data collected included ADT and the distribution of each vehicle class, and because the sugarcane hauling season ended in January 2006, no sugarcane trucks were included in the current ADT. Because no sugarcane trucks were transporting sugarcane in February, the calculated number of sugarcane trucks was added to the measured truck traffic to produce the total traffic applied to each control section.

   This number of trucks was added to the number of trucks of this type in the current traffic stream to develop a new distribution of vehicles for that control section. This new distribution was used to calculate the number of equivalent axles that the overlay must carry during the overlay performance period.

Table 3
Control sections included in the detailed study by DOTD District

Dist	Route No.	Control Section	Overlay HMA Thickness	Total Surface Thickness, in.	Base Type & Thickness	ADT, veh/day	Parish
2	LA 56	247-03		5" HMA	10" Concrete	6,679	Terrebonne
	LA 20	065-06		5" HMA	8" Concrete	9,954	Lafourche
	LA 3087	829-28		6" HMA	10" Flouralite Base	15,000	Lafourche
3	LA 356	849-08	3.5" Asphalt	3.5" HMA	8.5" Soil cement	260	St.Landry
	LA 343	393-07	3.5" Asphalt	3.5" HMA	8.5" Soil cement	535	St.Landry
	LA 10	219-08	3.5" Asphalt	3.5" HMA	12" Soil cement	830	St.Landry
	LA 679	402-03	6" Asphalt	6" HMA	8.5" Soil cement	1,890	St.Martin
	LA 700/35	207-03	3.5" Asphalt	3.5" HMA	8.5" Soil cement	1,940	Vermillion
	LA 344	823-14	3.5" Asphalt	3.5" HMA	8.5" Soil cement	1,980	Iberia
	LA 686	850-02	3.5" Asphalt	3.5" HMA	8.5" Soil cement	2,700	St.Martin
	US 71	008-06	3.5" Asphalt	8" HMA	8" Concrete	2,800	St.Landry
	LA 10,182	032-04	3.5" Asphalt	5.5" HMA	8.5" Soil cement	2,950	St.Landry
	LA 89	397-04	3.5" Asphalt	3.5" HMA	8.5" Soil cement	4,000	Vermillion
	LA 83	236-01	5" Asphalt	5" HMA	8.5" Soil cement	4,100	Iberia
	LA 82	194-07	6" Asphalt	6" HMA	8.5" Soil cement	4,200	Vermillion
	LA 14	055-05	6" Asphalt	6" HMA	8" Concrete	8,200	Vermillion
	LA 182	004-06	6" Asphalt	6" HMA	8" Concrete	10,000	St.Mary
	LA 182	004-04	6" Asphalt	6" HMA	9" Concrete	10,200	Iberia
	LA 94	850-32	3.5" Asphalt	3.5" HMA	8.5" Soil cement	14,100	St.Martin
	US 90	424-04		9" Concrete	8.5" Soil cement	27,800	Iberia
	I 10	450-04	2" Asphalt	9" HMA	10" Concrete	41,150	Acadia
7	I 10	450-91		10" Concrete	8.5" Soil cement	57,835	Calcasieu
8	LA 1176	805-09	3" Asphalt		8.5" Soil cement	580	Avoyelles
	LA 29,115	033-01	3.5" Asphalt		8.5" Soil cement	8,281	Avoyelles
61	LA 401	233-01		3.5" HMA	8.5" Soil cement	340	Assumption
	LA 405	824-06		3.5" HMA	8.5" Soil cement	640	Iberville
	LA 1000	804-21		3.5" HMA	8.5" Soil cement	770	Assumption
	LA 10	219-30		3.5" HMA	8.5" Soil cement	1,220	Point Coupe
	LA 983	839-17		3.5" HMA	8.5" Soil cement	2,100	Point Coupe
	LA 1	052-02		3.5" HMA	8.5" Soil cement	5,100	Point Coupe
	LA 308	407-09		3.5" HMA	8.5" Soil cement	6,400	Ascension
	LA 1	050-06		3.5" HMA	8.5" Soil cement	13,600	Iberville
	US 190	008-01		3.5" HMA	8.5" Soil cement	17,800	W.Baton Rouge
	US 90	424-06		3.5" HMA	8.5" Soil cement	24,700	Assumption

Table 4
Axle load and configurations for each of the 3 different GVW Scenarios and 2 truck types

Axle	GVW and Axle Load Scenario				
	80,000 lb. GVW	100,000 lb. GVW		120,000 lb. GVW	
	FHWA Type 9	FHWA Type 9	FHWA Type 10	FHWA Type 9	FHWA Type 10
Steering	12,000 lb.	12,000 lb.	12,000 lb.	12,000 lb.	12,000 lb.
Truck Load Axle	34,000 lb. Tandem	44,000 lb. Tandem	44,000 lb. Tandem	54,000 lb. Tandem	54,000 lb. Tandem
Semi-Trailer Axle	34,000 lb. Tandem	44,000 lb. Tandem	44,000 lb. Triple	54,000 lb. Tandem	54,000 lb. Triple

10. Using a calculation procedure included in the *1986 AASHTO Pavement Design Guide*, project staff calculated the overlay thickness required to carry the traffic stream identified in step 9 and the time in the analysis period when the overlay needed to be constructed. Depending on the pavement history three different types of overlay periods were identified:

    a. Overlay periods of eight years, typical for roads with intermediate to high ADTs and with significant percentages of trucks.

    b. Overlay periods of twenty years, typical for roads with low ADTs and with low percentages of trucks. These roads are often constructed or reconstructed using standard sections consisting of 8.5-in. of soil cement with 3.5-in. of hot mix asphalt surfacing.

    c. Overlay periods of fifteen years, typical of concrete pavements overlaid with hot mix asphalt. These pavements do not require structural overlays but experience reflection cracking at joints and cracks. As a result, these pavements get very rough and require overlays about every 15 years to smooth them out.

11. Once each section is analyzed and the thickness of each overlay determined and the time when the overlay is required, the present worth of each overlay is determined using an interest rate of five percent per year. The present worth of all overlays applied from 2006 to 2026 for each section is totaled to determine the net present worth for that control section.

12. Once the present net worth for all control sections in each ADT group from step 11 are added up, this sum is multiplied by the surface area of all control sections in that ADT group and divided by the surface area of the control sections from step 12. The resulting total represents the statewide overlay costs for all control sections in that ADT group. These calculations are performed for all three ADT groups and added up to get the statewide total of overlay costs for a particular GVW and axle configuration scenario. The net present worth costs are most easily understood if they are multiplied by an appropriate interest factor to convert them from the present time to an annual cost.

13. Data from step 12, which was determined for each of the five different GVW and axle configuration scenarios, can easily be compared to evaluate the costs associated with increasing the GVW or changing the axle load configuration. In addition these data can be used to compare the cost of overlays for the DOTD under various scenarios with the permit fees paid by the industry.

14. The difference between the cost of permits paid by the industry under each scenario and the cost of overlays required by the DOTD to keep the roads in satisfactory condition under each scenario represents the annual subsidy provided to the sugarcane industry by the legislature.

Note: In this study 34 sample control sections were included, but by the end of project completion date, the data of only 31 control sections were received for analysis. The remaining three control sections were located in the Terrebonne and Lafourche parishes of district 2. Among the three control sections, one control section falls in the ADT category two and the remaining two fall in category three. As these two categories represent high volume roads, the pavement damage costs incurred by these control sections would not have been very significant. The total length of the three control sections not included in the analysis was 6.31 miles. So it can be assumed that the effect of pavement damage costs of these three control sections would have minimal effects on the overall cost.

Pavement Data for Analysis

The roads carrying sugarcane were identified with the help of the American Sugarcane League and the representatives of the sugar mills. The pavement cross-section data of each control section carrying sugarcane were collected by interviewing personnel from each district. The control sections were divided into three groups of average daily traffic (ADT) as:

88 control sections with ADT less than 2,000

91 control sections with ADT between 2,000 and 7,000

92 control sections with ADT greater than 7,000.

For each group, the structural number was calculated and the minimum sample size of control sections from each ADT group was estimated using the central limit theorem of statistics *[6]*. According to this theorem, if the sum of the variables has a finite variance, then it will be approximately normally distributed. In this study, the mean (m) and standard deviation (σ) of the structural numbers (SN) of all the control sections were calculated. To be within 20 percent of the mean 90 percent of the time for each of the three ADT groups, the following formula was used to calculate the sample size.

$$n^{0.5} = \frac{1.645}{0.2} \text{ x } \frac{\sigma}{m} \qquad (1)$$

This can be explained in detail by an example. For the group of control sections with ADT less than 2,000,

Mean, m = 3.670

Standard deviation, σ = 1.424

To be within 20 percent of the SN, it would be,

0.2 x 3.670 = 0.734 *SN* (or roughly 2 in. of hot mix asphalt).

Therefore, by using the above formula, the sample size is 11 for the ADT group less than 2,000. A similar procedure was used to calculate the sample size of the remaining two ADT groups. For the ADT group between 2,000 and 7,000 the sample size was 10 and for the ADT group greater than 7,000 it was 13. After the sample size of each ADT group was determined, the control sections to be included in the detailed cost analysis were selected. A random number selection program was run to select these sample sections from the list of control sections in each category.

(The program was written in Visual Basic and defined a function “calcrandnum.” The function executed the program using the “RND” syntax which generated random numbers. Three variables “upp,” “low,” and “r” were required as inputs. The number of control sections in each ADT group was “upp,” and “low” was one, the number of the first control section in the range. The sample size required in each ADT group was “r.”)

The program was then executed to produce a set of “r” random numbers, and Table 5 contains the list of the selected control sections with ADT less than 2,000. Table 6 and Table 7 contain the list of control sections for the other two categories respectively. The district personnel at the DOTD collected 24-hour traffic classification counts on each control section between January and March of 2006.

(Data collected included ADT and the number of vehicles in each vehicle class. Because the sugarcane hauling season ended in January 2006, no sugarcane trucks were counted in the collected traffic data. Therefore, the calculated number of sugarcane trucks required to haul the payload was added to the measured truck traffic to produce the total traffic applied to each control section).

Table 8 contains the thirteen classes of vehicles used in DOTD classification counts. In addition, Table 8 contains the truck factor for each vehicle type for the terminal Present Serviceability Index of both 2.0 and 2.5. Other data required for this analysis included the traffic growth rate, standard deviation, structural coefficient, soil resilient modulus, serviceability index, and reliability values that are provided by the Louisiana Department of Transportation and Development (LADOTD).

Table 5
Control sections with ADT less than 2,000 included in the detailed study

Route No.	Control Section No.	No. of Lanes	Lane width, ft.	Length, mi.	ADT	Parish	Dist
LA 356	849-8	2	11	2.77	260	St. Landry	3
LA 401	233-1	2	10	9.43	340	Assumption	61
LA 343	393-7	2	10	7.47	535	St. Landry	3
LA 405	824-6	2	10	11.56	640	Iberville	61
		2	11	3.46			
LA 1000	804-21	2	9	1.6	770	Assumption	61
LA 10	219-8	2	12	4.07	830	St. Landry	3
LA 10	219-30	2	9	1.15	1,220	Point Coupe	61
		2	12	3.29			
		2	10	3.54			
LA 679	402-3	2	11	4.66	1,890	St. Martin	3
LA 700/35	207-3	2	12	0.32	1,940	Vermillion	3
		2	10	0.19			
		2	11	7.4			
LA 344	823-14	2	10	6.44	1,980	Iberia	3
LA 1176	805-09	2	10	3.98	580	Avoyelles	8

Table 6
Control sections with ADT from 2,000 to 7,000 included in the detailed study

Route No.	Control Section No.	No. of Lanes	Lane width, ft.	Length, mi.	ADT	Parish	Dist
LA 983	839-17	2	11	1.7	2,100	Point Coupe	61
LA 686	850-2	2	12	7.81	2,700	St. Martin	3
US 71	8-6	2	12	10.91	2,800	St. Landry	3
LA 10,182	32-4	4	12	0.75	2,950	St. Landry	3
LA 89	397-4	2	11	3.09	4,000	Vermillion	3
LA 83	236-1	2	10	7.15	4,100	Iberia	3
LA 82	194-7	2	10	2.15	4,200	Vermillion	3
LA 1	52-2	2	12	10.84	5,100	Point Coupe	61
LA 308	407-9	2	12	0.36	6,400	Ascension	61
LA 56	247-03	2	12	1.88	6,679	Terrebonne	2

Table 7
Control sections with ADT greater than 7,000 included in the detailed study

Route No.	Control Section No.	No. of Lanes	Lane width, ft.	Length, mi.	ADT	Parish	Dist
LA 14	55-5	2	12	10.63	8,200	Vermillion	3
LA 182	4-6	2	12	13.12	10,000	St. Mary	3
LA 182	4-4	2	12	3.73	10,200	Iberia	3
LA 1	50-6	4	12	12.27	13,600	Iberville	61
LA 94	850-32	2	11	0.51	14,100	St. Martin	3
US 190	8-1	4	10	2.92	17,800	W. Baton Rouge	61
US 90	424-06	4	12	3.7	24,700	Assumption	61
US 90	424-4	4	12	21.01	27,800	Iberia	3
I 10	450-4	4	12	27.16	41,150	Acadia	3
LA 29, 115	33-01	2	11	13.59	8,281	Avoyelles	8
LA 20	65-06	2	11	4.74	9,954	Lafourche	2
LA 3087	829-28	4	12	3.2	15,000	Lafourche	2
I 10	45091	4	12	43.74	57,835	Calcasieu	7

Table 8
Vehicle classification and truck factors for use in designing flexible pavements

FHWA CLASS	VEHICLE DEFINITION			TRUCK FACTORS	
				PSI = 2.5	PSI = 2.0
1	SINGLE UNIT VEHICLES		MOTORCYCLE	0.0005	0.0004
2			CARS	0.0005	0.0004
3			2 AXLE - 4 TIRE	0.0188	0.0143
4			BUSES	0.1932	0.1694
5			2 AXLE - 6 TIRE	0.1932	0.1694
6			3 AXLE	0.4095	0.3836
7			4 OR MORE AXLE	0.4095	0.3836
8	SINGLE TRAILER VEHICLE		4 OR LESS AXLE	0.8814	0.8523
9			5 AXLE	1.1	1.045
10			6 OR MORE AXLE	1.45	1.45
11	MULTI-TRAILER VEHICLE		5 OR LESS AXLE	1.84	1.84
12			6 AXLE	1.84	1.84
13			7 OR MORE AXLE	1.84	1.84

Overlay Design

Under Scenario Two, an overlay was designed to carry the 18-kip ESALs applied during the next performance period using the AASHTO method of overlay design. According to the AASHTO method, the thickness of overlay was calculated as follows *[5]*:

a. Flexible overlay on a flexible pavement:

$$h_{ol} = \frac{SN_{ol}}{a_{ol}} = \frac{SN_y - F_{RL}SN_{xeff}}{a_{ol}} \tag{2}$$

b. Flexible overlay over a rigid pavement, using visual condition factor method:

$$h_{ol} = \frac{SN_{ol}}{a_{ol}} = \frac{SN_y - F_{RL}(a_{2r}Do + SN_{xeff - rp})}{a_{ol}} \tag{3}$$

where,

h_{ol}	=	Overlay Thickness, inches;
SN_{ol}	=	Required Structural Number of Overlay;
SN_y	=	Total structural number required to support the overlay traffic over the existing sub-grade conditions, calculated using the AASHTO flexible pavement design;
a_{ol}	=	Structural layer coefficient of HMA overlay;
F_{RL}	=	Remaining life factor;
SN_{xeff}	=	Total effective structural number of existing pavement structure above the sub-grade prior to overlay;
a_{2r}	=	Structural Layer coefficient of existing cracked PCC pavement layer
Do	=	Existing PCC layer thickness, inches; and
$SN_{xeff\text{-}rp}$	=	Effective structural capacity of all of the remaining pavement layers above the sub-grade, except for the existing PCC layer.

The value of SNxeff was calculated with the pavement structural information before the design of overlay. For overlaying an existing pavement, it was assumed that two inches of the existing surface would be removed by milling immediately before the overlay was placed. The structural coefficient of the existing HMA materials was reduced to 0.33 to reflect the distressed condition of the pavement and its reduced structural capacity. A macro has been written to calculate the value of SNy using the AASHTO design equation.

DISCUSSION OF RESULTS

Louisiana State Highway LA 10

The analysis on the state highway LA 10, in District 3, is described below to demonstrate the methodology and the calculation procedure used in this study. In 2006, 87,185 tons of sugarcane, equal to 174,370,000 lb., were hauled on LA 10. As per the pavement history data obtained from the DOTD, LA 10 was last overlaid in the year 1996 and was supposed to perform for a period of twenty years. A detailed analysis was carried out for all the three GVW cases and the results were compared accordingly. The terminal serviceability index (pt) for this highway was 2.0. To determine the truck factor for a sugarcane truck loaded at the GVW, a structural number (SN) of 4.0 was assumed to represent these roads. The 20 year analysis period included in the sample calculation is from 2006 to 2026. As a result, the overlay thickness required to carry the traffic for this 20 year period is determined and the 2006 net present worth is calculated for each of the three GVW scenarios.

Calculation of ESALs for Current Pavement Condition

Initially, the number of ESALs based on the pavement capacity when it was last overlaid was calculated. The results presented in Table 9 show that the pavement capacity was 435,683 ESALs to carry traffic from 1996 to 2016 under Scenario Two GVW conditions.

Table 9
ESAL calculation for current pavement condition on LA 10

Existing Pavement

Layers	Thickness, in.	Structural Coefficient	Drainage Factor	SN
1	3.5	0.33	1	1.155
2	12	0.14	0.9	1.512
3	0	0	0	0
			SN_{xeff}	2.667

Overlay Material Design

Remaining Life Factor(F_{RL})	0.6
Asphalt Modulus, psi (a_{ol})	0.44
Roadbed Modulus, psi	9,176
Reliability (%)	85
Overall Std. Deviation (So)	0.47
Initial PSI (p_i)	4
PSI at the end of Overlay (p_t)	2
Δ PSI	2
ESAL	435683

Calculations of ESALs Used under Current GVW Conditions

For a sugarcane truck loaded to 100,000 lb. GVW, the following axle configuration was used and the load equivalence factors are obtained from the *AASHTO Design Guide* for SN = 4.0 and Pt = 2.0 *[5]*.

Steering Axle (12,000 lb.) = 0.183

Tandem Axle (44,000 lb.) = 3.18

Tandem Axle (44,000 lb.) = 3.18

ESALs per truck = 6.543 ESALs

Max. payload per truck = GVW – tare weight of truck

= 100,000 – 37,300 = 62,700 lb.

Therefore, the number of trucks required to carry sugarcane transported on LA 10 in 1996 under Scenario Two with a GVW of 100,000 lb. =

$$\frac{174{,}370{,}000 \text{ lb. of sugarcane}}{62{,}700 \text{ lb./truck load}} = 2781 \text{ trucks/year} = 8 \text{ trucks/day}$$

For the traffic distribution and 1996 ADT, the number of 18-kip ESALs served between 1996 and 2006 under Scenario Two is calculated as shown in Table 10. From the table, it can be observed that 304,664 ESALs have been served in these 10 years and 131,019 ESALs of capacity remain under current GVW conditions. The annual growth factor for sugarcane traffic is calculated as 2.34, based on the annual growth of the sugarcane harvest.

Table 10
Calculation of ESALs starting in 1996 for a period of 10 years under present GVW conditions (Scenario Two)

Sugarcane on LA 10

Performance Period:	10	Years		
Average Daily Traffic in 1996:	757		Last Overlaid in :	1996
Directional Distribution Factor:	50	%		
Lane Distribution Factor:	100	%		
Annual Growth of Non-SC Traffic:	2.13	%/year		
Growth Factor for Non-SC Traffic:	11.02			
Annual Growth of SC Traffic:	2.34	%/year		
Growth Factor for SC Traffic:	11.12			

FHWA Class	%ADT	ADT Per Class	% Annual Growth	Growth factor	T.F	18-kip ESAL
1	0.22	2	2.13	11.0150	0.0004	1
2	60.22	456	2.13	11.0150	0.0004	366
3	26.43	200	2.13	11.0150	0.0143	5,747
4	1.88	14	2.13	11.0150	0.1694	4,854
5	5.22	40	2.13	11.0150	0.1694	13,454
6	0.22	2	2.13	11.0150	0.3836	1,258
7	0.00	0	2.13	11.0150	0.3836	-
8	1.29	10	2.13	11.0150	0.8523	16,748
9a (Non-SC)	4.10	23	2.13	11.0150	1.045	49,081
9b(Carrying SC)		8	2.34	11.1215	6.543	202,369
10	0.21	2	2.13	11.0150	1.45	4,738
11	0.05	0	2.13	11.0150	1.84	1,512
12	0.00	0	2.13	11.0150	1.84	-
13	0.16	1	2.13	11.0150	1.84	4,536
	100	757				304,664

Calculation of Number of Years Required by Scenario Two to Use the Remaining Design Traffic

A simulation was run in Microsoft Excel to determine the number of years it would take for Scenario Two traffic to apply the remaining ESALs. The results presented in Table 11 show that under Scenario Two, where sugarcane is carried by eight trucks per day, approximately four and half years are required to use the remaining ESALs. Notice in Table 11 that in 4.32 years, the Scenario Two traffic produces 131,136 ESALs, slightly larger than the 131,019 ESALs remaining life.

Table 11
Calculation of number of years required by Scenario Two to use the remaining design traffic

Sugarcane on LA 10

Performance Period:	4.32	Years	ESALs:	131019
Average Daily Traffic:	934		year:	2006
Directional Distribution Factor:	50	%		
Lane Distribution Factor:	100	%		
Annual Growth of Non-SC Traffic:	2.13	%/year		
Growth Factor for Non-SC Traffic:	4.48			
Annual Growth of SC Traffic:	2.34	%/year		
Growth Factor for SC Traffic:	4.49			

FHWA Class	%ADT	ADT Per Class	% Annual Growth	T.F	Growth Factor	18-kip ESAL
1	0.22	2	2.13	0.0004	4.48	1
2	60.22	562	2.13	0.0004	4.48	183
3	26.43	247	2.13	0.0143	4.48	2,876
4	1.88	18	2.13	0.1694	4.48	2,429
5	5.22	49	2.13	0.1694	4.48	6,732
6	0.22	2	2.13	0.3836	4.48	629
7	0.00	0	2.13	0.3836	4.48	-
8	1.29	12	2.13	0.8523	4.48	8,381
9a Non SC Trucks	4.10	31	2.13	1.045	4.48	26,082
10	0.21	2	2.13	1.45	4.48	2,371
11	0.05	1	2.13	1.84	4.48	757
12	0.00	0	2.13	1.84	4.48	-
13	0.16	2	2.13	1.84	4.48	2,270
9b SC Trucks		8	2.34	6.543	4.49	78,426
	100	934				131,136

year simulator

No. of Years required to reach Scenario 2 ESALs = 4.32

The current overlay can carry traffic till = 2010.32

Calculation of ESALs for the Next Performance Period

As the current overlay can carry traffic till 2010, the ESALs required for a 20 year performance period from 2010 to 2030 were calculated and shown in Table 12. The traffic was projected using the traffic growth factors calculated for LA 10 from the ADT versus time file. The ADT in the year 2010 was calculated by multiplying with the appropriate growth factors for non-sugarcane and sugarcane traffic. These ESALs are generated in the same procedure as discussed earlier in this report. Results show that the pavement needs to carry 779,129 ESALs for the next performance period.

Table 12
Calculation of ESALs starting in 2010 for a period of 20 years under present GVW conditions (Scenario Two)

Sugarcane on LA 10

Performance Period:	20	Years	
Average Daily Traffic in 2006:	1023	Last Overlaid in	2010
Directional Distribution Factor:	50	%	
Lane Distribution Factor:	100	%	
Annual Growth of Non-SC Traffic:	2.13	%/year	
Growth Factor for Non-SC Traffic:	24.61		
Annual Growth of Sugarcane Traffic:	2.34	%/year	
Growth Factor for Sugarcane Traffic:	25.14		

FHWA Class	%ADT	ADT Per Class	% Annual Growth	Growth factor	T.F	18-kip ESAL
1	0.22	2	2.13	24.61	0.0004	4
2	60.22	616	2.13	24.61	0.0004	1,107
3	26.43	270	2.13	24.61	0.0143	17,368
4	1.88	19	2.13	24.61	0.1694	14,668
5	5.22	53	2.13	24.61	0.1694	40,657
6	0.22	2	2.13	24.61	0.3836	3,801
7	0.00	0	2.13	24.61	0.3836	-
8	1.29	13	2.13	24.61	0.8523	50,611
9a (Non-SC)	4.10	34	2.13	24.61	1.045	160,918
9b(Carrying SC)		8	2.34	25.14	6.543	457,403
10	0.21	2	2.13	24.61	1.45	14,316
11	0.05	1	2.13	24.61	1.84	4,569
12	0.00	0	2.13	24.61	1.84	-
13	0.16	2	2.13	24.61	1.84	13,707
	100	1023				779,129

Overlay Design

The pavement design follows AASHTO design process as discussed before. Design lane ESALs were developed and included in the Table 12 based on the projected traffic. The values for reliability and terminal serviceability were provided by the DOTD and vary with the functional classification of the road. Since LA 10 is a rural major collector, reliability (R) was taken as 85 percent and the Pi and Pt values were taken as 4 and 2, respectively. The remaining life factor, FRL, was taken as 0.6. The overlay thickness calculated was 3.91 inches, as shown in
Table 13

Table 13
Overlay design for LA 10 under current conditions (Scenario Two) for the next performance period

Existing Pavement

Layers	Thickness, in.	Structural Coefficient	Drainage Factor	SN
1a*	0	0.44	1	0
1b	1.5	0.33	1	0.495
2	12	0.14	0.9	1.512
***After milling 2"**			**SN_{xeff}**	2.007

Overlay Material Design

Remaining Life Factor(F_{RL})	0.6
Asphalt Modulus, psi (a_{ol})	0.44
Roadbed Modulus, psi	9,176
Design Lane Traffic, ESALs	779,129
Reliability (%)	85
Overall Std. Deviation (So)	0.47
Initial PSI (p_i)	4
PSI at the end of Overlay (p_t)	2
Δ PSI	2
SNy	2.92
Overlay thickness	3.91
Wearing course thickness after milling 2"	5.41

Calculation of Number of Years Required by Scenario One to Use the Remaining Design Traffic

For a sugarcane truck at 80,000 lb. GVW, the following axle configuration and ESALs are obtained from the *AASHTO Design Guide* with SN = 4.0 and Pt = 2.0 *[5]*.

Steering Axle (12,000 lb.) = 0.183

Tandem Axle (34,000 lb.) = 1.08

Tandem Axle (34,000 lb.) = 1.08

ESALs per truck = 2.343 ESALs

Max. payload per truck = GVW – tare weight of truck

= 80,000 – 37,300 = 42,700 lb.

Therefore, the number of trucks required to carry sugarcane in 1996 under Scenario Two with a GVW of 80,000 lb. =

$$\frac{174{,}370{,}000 \text{ lb. of sugarcane}}{42{,}700 \text{ lb. /truck load}} = 4084 \text{ trucks/year} = 11 \text{ trucks/day}$$

A simulation was run in Microsoft Excel, as in the case of Scenario One, to calculate the number of years required for the Scenario One traffic to equal the remaining ESALs in the 1996 overlay, designed for Scenario Two. Table 14 shows the number of ESALs used by Scenario One from 1996 to 2006. The results presented in Table 15 show that the remaining 234,475 ESALs have been used for 10.71 years. In Table 15, it can be observed that Scenario One produces a slightly larger number of ESALs than is available in the remaining life.

Table 14
Calculation of ESALs starting in 1996 for a period of 10 under Scenario One

Sugarcane on LA 10

Performance Period:	10	Years		
Average Daily Traffic in 1996:	757		Last Overlaid in :	1996
Directional Distribution Factor:	50	%		
Lane Distribution Factor:	100	%		
Annual Growth of Non-SC Traffic:	2.13	%/year		
Growth Factor for Non-SC Traffic:	11.02			
Annual Growth of SC Traffic:	2.34	%/year		
Growth Factor for SC Traffic:	11.12			

FHWA Class	%ADT	ADT Per Class	% Annual Growth	Growth factor	T.F	18-kip ESAL
1	0.22	2	2.13	11.0150	0.0004	1
2	60.22	456	2.13	11.0150	0.0004	366
3	26.43	200	2.13	11.0150	0.0143	5,747
4	1.88	14	2.13	11.0150	0.1694	4,854
5	5.22	40	2.13	11.0150	0.1694	13,454
6	0.22	2	2.13	11.0150	0.3836	1,258
7	0.00	0	2.13	11.0150	0.3836	-
8	1.29	10	2.13	11.0150	0.8523	16,748
9a (Non-SC)	4.10	20	2.13	11.0150	1.045	41,584
9b(Carrying SC)		11	2.34	11.1215	2.343	106,409
10	0.21	2	2.13	11.0150	1.45	4,738
11	0.05	0	2.13	11.0150	1.84	1,512
12	0.00	0	2.13	11.0150	1.84	-
13	0.16	1	2.13	11.0150	1.84	4,536
	100	757				201,207

Table 15
Calculation of number of years required by Scenario One to use the remaining design traffic

Sugarcane on LA 10

Performance Period:	10.71	Years	ESALs:	234475.43
Average Daily Traffic:	934		year:	2006
Directional Distribution Factor:	50	%		
Lane Distribution Factor:	100	%		
Annual Growth of Non-SC Traffic:	2.1	%/year		
Growth Factor for Non-SC Traffic:	11.89			
Annual Growth of SC Traffic:	2.34	%/year		
Growth Factor for SC Traffic:	12.01			

FHWA Class	%ADT	ADT Per Class	% Annual Growth	T.F	Growth Factor	18-kip ESAL
1	0.22	2	2.13	0.0004	11.89	2
2	60.22	562	2.13	0.0004	11.89	488
3	26.43	247	2.13	0.0143	11.89	7,651
4	1.88	18	2.13	0.1694	11.89	6,461
5	5.22	49	2.13	0.1694	11.89	17,910
6	0.22	2	2.13	0.3836	11.89	1,675
7	0.00	0	2.13	0.3836	11.89	-
8	1.29	12	2.13	0.8523	11.89	22,295
9a Non SC Trucks	4.10	27	2.13	1.045	11.89	61,301
10	0.21	2	2.13	1.45	11.89	6,307
11	0.05	1	2.13	1.84	11.89	2,013
12	0.00	0	2.13	1.84	11.89	-
13	0.16	2	2.13	1.84	11.89	6,038
9b SC Trucks		11	2.34	2.343	12.01	102,376
	100	934				234,516

year simulator

Number of Years required to reach Scenario 1 ESALs 10.71

The current overlay can carry traffic till 2016.71

Calculation of ESALs and Overlay Required for the Next Performance Period under Scenario One

As the Scenario One traffic consumes the remaining design ESALs by 2016.71, the next overlay designed will carry traffic until 2037. ESAL calculations similar to those conducted for Scenario Two were followed to generate data for Scenario One and are included in Table 16. Results show that the pavement needs to carry 597,023 ESALS for the next performance period. The overlay thickness was calculated using the same procedure as discussed earlier in this report and was found to be 3.64 in., as shown in Table 17.

Table 16
Calculation of ESALs starting in 2016 for a period of 20 years under Scenario One

Sugarcane on LA 10

Performance Period:	20	years		
Average Daily Traffic:	1171		Last Overlaid in	2017
Directional Distribution Factor:	50	%		
Lane Distribution Factor:	100	%		
Annual Growth of Non SC Traffic:	2.13	%/year		
Growth Factor for non SC Traffic:	24.61			
Annual Growth of Sugarcane Traffic:	2.34	%/year		
Growth Factor for Sugarcane Traffic:	25.14			

FHWA Class	%ADT	ADT Per Class	% Annual Growth	Growth factor	T.F	18-kip ESAL
1	0.22	3	2.13	24.61	0.0004	5
2	60.22	705	2.13	24.61	0.0004	1,266
3	26.43	309	2.13	24.61	0.0143	19,872
4	1.88	22	2.13	24.61	0.1694	16,783
5	5.22	61	2.13	24.61	0.1694	46,518
6	0.22	3	2.13	24.61	0.3836	4,349
7	0.00	0	2.13	24.61	0.3836	-
8	1.29	15	2.13	24.61	0.8523	57,907
9a (Non-SC)	4.10	37	2.13	24.61	1.045	172,521
9b(Carrying SC)		11	2.34	25.14	2.343	240,510
10	0.21	3	2.13	24.61	1.45	16,380
11	0.05	1	2.13	24.61	1.84	5,228
12	0.00	0	2.13	24.61	1.84	-
13	0.16	2	2.13	24.61	1.84	15,683
	100	1170				597,023

Table 17
Overlay design for LA 10 under Scenario One for the next performance period

Existing Pavement

Layers	Thickness, in.	Structural Coefficient	Drainage Factor	SN
1a*	0.00	0.44	1	0
1b	1.50	0.33	1	0.495
3	12.00	0.14	0.9	1.512
***After milling 2"**			**SN_{xeff}**	2.007

Overlay Material Design

Remaining Life Factor(F_{RL})	0.6
Asphalt Modulus, psi (a_{ol})	0.44
Roadbed Modulus, psi	9,176
Design Lane Traffic, ESALs	597,023
Reliability (%)	85
Overall Std. Deviation (So)	0.47
Initial PSI (p_i)	4
PSI at the end of Overlay (p_t)	2
Δ PSI	2
SNy	2.80
Overlay thickness	3.64
Wearing course thickness after milling 2"	5.14

Calculation of Number of Years Required by Scenario Three to Use the Remaining Design Traffic

For a sugarcane truck at 120,000 lb. GVW, the following axle configuration and ESALs are obtained from the *AASHTO Design Guide* with SN = 4.0 and Pt = 2.0 *[5]*.

Steering Axle (12,000 lb.) = 0.183

Tandem Axle (54,000 lb.) = 7.55

Tandem Axle (54,000 lb.) = 7.55

ESALs per truck = 15.283 ESALs

Max. payload per truck = GVW – tare weight of truck

= 120,000 – 37,300 = 82,700 lb.

Therefore, the number of trucks required to carry sugarcane in 1996 under Scenario Two with a GVW of 80,000 lb. =

$$\frac{174{,}370{,}000 \text{ lb. of sugarcane}}{82{,}700 \text{ lb./truck load}} = 2108 \text{ trucks/year} = 6 \text{ trucks/day}$$

A simulation was run in Microsoft Excel, as discussed earlier in this report, to calculate the number of years required for the Scenario Three traffic to equal the remaining ESALs in the 1996 overlay, designed for Scenario Two. Table 18 shows that 464,541 ESALs were used by Scenario Three from 1996 to 2006 and are larger than the pavement capacity of 435,683 ESALs, as designed in the year 1996. This is also evident from Table 19, which shows that the remaining ESALs are zero and the pavement has to be overlaid in 2006.

Table 18
Calculation of ESALs starting in 1996 for a period of 10 years under Scenario Three

Sugarcane on LA 10

Performance Period:	10	Years		
Average Daily Traffic in 1996:	757		Last Overlaid in :	1996
Directional Distribution Factor:	50	%		
Lane Distribution Factor:	100	%		
Annual Growth of Non-SC Traffic:	2.13	%/year		
Growth Factor for Non-SC Traffic:	11.02			
Annual Growth of Sugarcane Traffic:	2.34	%/year		
Growth Factor for Sugarcane Traffic:	11.12			

FHWA Class	%ADT	ADT Per Class	% Annual Growth	Growth factor	T.F	18-kip ESAL
1	0.22	2	2.13	11.0150	0.0004	1
2	60.22	456	2.13	11.0150	0.0004	366
3	26.43	200	2.13	11.0150	0.0143	5,747
4	1.88	14	2.13	11.0150	0.1694	4,854
5	5.22	40	2.13	11.0150	0.1694	13,454
6	0.22	2	2.13	11.0150	0.3836	1,258
7	0.00	0	2.13	11.0150	0.3836	-
8	1.29	10	2.13	11.0150	0.8523	16,748
9a (Non-SC)	4.10	25	2.13	11.0150	1.045	52,952
9b(Carrying SC)		6	2.34	11.1215	15.283	358,375
10	0.21	2	2.13	11.0150	1.45	4,738
11	0.05	0	2.13	11.0150	1.84	1,512
12	0.00	0	2.13	11.0150	1.84	-
13	0.16	1	2.13	11.0150	1.84	4,536
	100	757				464,541

Table 19
Calculation of number of years required by Scenario Three to use the remaining design traffic

Sugarcane on LA 10

Performance Period:	0.00	Years	ESALs	0
Average Daily Traffic:	934		year:	2006
Directional Distribution Factor:	50	%		
Lane Distribution Factor:	100	%		
Annual Growth of Non-SC Traffic:	2.13	%/year		
Growth Factor for Non-SC Traffic:	0.00			
Annual Growth of Sugarcane Traffic:	2.34	%/year		
Growth Factor for Sugarcane Traffic:	0.00			

FHWA Class	%ADT	ADT Per Class	% Annual Growth	T.F	Growth Factor	18-kip ESAL
1	0.22	2	2.13	0.0004	0.00	-
2	60.22	562	2.13	0.0004	0.00	-
3	26.43	247	2.13	0.0143	0.00	-
4	1.88	18	2.13	0.1694	0.00	-
5	5.22	49	2.13	0.1694	0.00	-
6	0.22	2	2.13	0.3836	0.00	-
7	0.00	0	2.13	0.3836	0.00	-
8	1.29	12	2.13	0.8523	0.00	-
9a Non SC Trucks	4.10	32	2.13	1.045	0.00	-
10	0.21	2	2.13	1.45	0.00	-
11	0.05	1	2.13	1.84	0.00	-
12	0.00	0	2.13	1.84	0.00	-
13	0.16	2	2.13	1.84	0.00	-
9b SC Trucks		6	2.34	15.283	0	-
	100	934				-

year simulator

Number of years required to reach Scenario 3 ESALs **0.00**

The current overlay can carry traffic till **2006.00**

Calculation of ESALs and Overlay Required for the Next Performance Period Under Scenario Three

As the Scenario Three traffic consumes all the design ESALs by 2006 itself, the next overlay designed will carry traffic from 2006 until 2026. ESAL calculations similar to those generated for Scenario One and two are generated for Scenario Three and are included in Table 20. Traffic was projected using the appropriate traffic growth factors. Results show that the pavement needs to carry 1,109,632 ESALS for the next performance period. The overlay thickness was calculated using the same procedure as discussed earlier in this report and was found to be 4.29 in., as shown in Table 21.

Table 20
Calculation of ESALs starting in 2006 for 20 years under Scenario Three

Sugarcane on LA 10						
Performance Period:		20	years			
Average Daily Traffic:		934		Last Overlaid in	2006	
Directional Distribution Factor:		50	%			
Lane Distribution Factor:		100	%			
Annual Growth of Non-SC Traffic:		2.13	%/year			
Growth Factor for Non-SC Traffic:		24.61				
Annual Growth of Sugarcane Traffic:		2.34	%/year			
Growth Factor for Sugarcane Traffic:		25.14				
FHWA Class	%ADT	ADT Per Class	% Annual Growth	Growth factor	T.F	18-kip ESAL
1	0.22	2	2.13	24.61	0.0004	4
2	60.22	562	2.13	24.61	0.0004	1,011
3	26.43	247	2.13	24.61	0.0143	15,856
4	1.88	18	2.13	24.61	0.1694	13,391
5	5.22	49	2.13	24.61	0.1694	37,118
6	0.22	2	2.13	24.61	0.3836	3,471
7	0.00	0	2.13	24.61	0.3836	-
8	1.29	12	2.13	24.61	0.8523	46,206
9a (Non-SC)	4.10	32	2.13	24.61	1.045	152,451
9b(Carrying SC)		6	2.34	25.14	15.283	810,014
10	0.21	2	2.13	24.61	1.45	13,070
11	0.05	1	2.13	24.61	1.84	4,260
12	0.00	0	2.13	24.61	1.84	-
13	0.16	2	2.13	24.61	1.84	12,780
	100	934				1,109,632

Table 21
Overlay design for LA 10 under Scenario Three for the next performance period

Existing Pavement

Layers	Thickness, in.	Structural Coefficient	Drainage Factor	SN
1a*	0.00	0.44	1	0
1b	1.50	0.33	1	0.495
2	12.00	0.14	0.9	1.512
***After milling 2"**			**SN_{xeff}**	2.007

Overlay Material Design

Remaining Life Factor(F_{RL})	0.6
Asphalt Modulus, psi (a_{ol})	0.44
Roadbed Modulus, psi	9,176
Design Lane Traffic, ESALs	1,109,632
Reliability (%)	85
Overall Std. Deviation (So)	0.47
Initial PSI (p_i)	4
PSI at the end of Overlay (p_t)	2
Δ PSI	2
SNy	3.09
Overlay thickness	4.29
Wearing course thickness after milling 2"	5.79

Developing Statewide Costs for Control Section Data for Each ADT Group

To develop an estimate of the statewide rehabilitation cost for all highways used to transport sugarcane, the cost for all control sections in each category was first developed.

Scenario Two Net Present Worth of Overlay Costs for Control Sections

The net present worth of overlay cost for an individual control section is a product of the number of lanes, lane width, length of the control section, and the net present worth of the cost of the overlay per lane mile of length.

NPW = (# of lanes)*(lane width, ft)*(length, mi)*(NPW overlay cost, $/12-ft lane-mile)

While this formula may seem unduly complicated, it must be recognized that the surface area, especially the length of control sections, varies widely and for a fair evaluation, an accurate measure of the total overlay cost for each control section must be developed. The net present worth of overlays, for control sections carrying sugarcane in FHWA Type 9 trucks at 100,000 lb. GVW, are shown in Table 22, Table 23, and Table 24 for control sections in each of the ADT groups. Similar data for study control sections was developed for the other four GVW/truck type scenarios; these are shown in the Appendix.

Table 22
Dimensions and Scenario Two overlay costs for 11 control sections with ADT less than 2,000

Control Section No.	No. of Lanes	Lane width, ft.	Length, mi.	Product of (Col.2 * Col.3 * Col.4)	Scenario 2 NPW of Overlay Cost/ 12-ft-lane-mile	Scenario 2 Total NPW of Overlay Cost of each Control Section, [(Col.5/12)*Col.6]
(Col.1)	(Col.2)	(Col.3)	(Col.4)	(Col.5)	(Col.6)	(Col.7), $
849-8	2	11	2.77	60.94	70,734	359,211
233-1	2	10	9.43	188.6	79,090	1,243,031
393-7	2	10	7.47	149.4	88,534	1,102,248
824-6	2	10	11.56	307.32	84,764	2,170,806
	2	11	3.46			
804-21	2	9	1.6	28.8	0	0
219-8	2	12	4.07	97.68	61,840	503,378
219-30	2	9	1.15	170.46	89,275	1,268,151
	2	12	3.29			
	2	10	3.54			
402-3	2	11	4.66	102.52	75,644	646,252
207-3	2	12	0.32	174.28	76,532	1,111,500
	2	10	0.19			
	2	11	7.4			
823-14	2	10	6.44	128.8	52,624	564,831
805-09	2	10	3.98	79.6	44,053	292,218
				1,488.40		9,261,626

Table 23
Dimensions and Scenario Two overlay costs for 10 control sections with ADT from 2,000 to 7,000

Control Section No.	No. of Lanes	Lane width, ft.	Length, mi.	Product of (Col.2 * Col.3 * Col.4)	Scenario 2 NPW of Overlay Cost/ 12-ft-lane-mile	Scenario 2 Total NPW of Overlay Cost of each Control Section, [(Col.5/12)*Col.6]
(Col.1)	(Col.2)	(Col.3)	(Col.4)	(Col.5)	(Col.6)	(Col.7), $
839-17	2	11	1.7	37.4	113,207	352,828
850-2	2	12	7.81	187.44	88,476	1,381,995
8-6	2	12	10.91	261.84	74,810	1,632,354
32-4	4	12	0.75	36	79,977	239,931
397-4	2	11	3.09	67.98	111,155	629,693
236-1	2	10	7.15	143	88,578	1,055,555
194-7	2	10	2.15	43	180,755	647,705
52-2	2	12	10.84	260.16	140,943	3,055,644
407-9	2	12	0.36	8.64	104,051	74,917
450-91*						
				1,045.46		9,070,622

(*) Data not available

Table 24
Dimensions and Scenario Two overlay costs for 13 control sections with ADT greater than 7,000

Control Section No.	No. of Lanes	Lane width, ft.	Length, mi.	Product of (Col.2 * Col.3 * Col.4)	Scenario 2 NPW of Overlay Cost/ 12-ft-lane-mile	Scenario 2 Total NPW of Overlay Cost of each Control Section, [(Col.5/12)*Col.6]
(Col.1)	(Col.2)	(Col.3)	(Col.4)	(Col.5)	(Col.6)	(Col.7), $
55-5	2	12	10.63	255.12	37,705	801,608
4-6	2	12	13.12	314.88	43,400	1,138,816
4-4	2	12	3.73	89.52	130,944	976,842
50-6	4	12	12.27	588.96	158,184	7,763,671
850-32	2	11	0.51	11.22	123,228	115,218
8-1	4	10	2.92	116.80	172,012	1,674,250
424-06	4	12	3.7	177.60	259,052	3,833,970
424-4	4	12	21.01	1,008.48	73,597	6,185,092
450-4	4	12	27.16	1,303.68	31,199	3,389,459
33-01	2	11	13.59	298.98	81,155	2,021,977
65-06*						
829-28*						
450-91	4	12	43.74	2,099.52		23,140,262
				6,264.76		51,041,165

(*) Data not available

The net present worth of overlay costs for all the three scenarios for the 20 year analysis period for each ADT group is summarized in Table 25.

Table 25
Net present worth of overlays for all control sections carrying sugarcane for all GVW/FHWA truck type combinations

ADT Group	NPW of Overlay Costs for study control sections carrying sugarcane for all GVW/FHWA truck type combinations, million $				
	Scenario 1 (80,000 lb.GVW)	Scenario 2 (100,000 lb.GVW)	Scenario 3 (120,000 lb.GVW)	Scenario 2a (100,000 lb.GVW, Triple axle)	Scenario 3a (120,000 lb.GVW, Triple axle)
(Col.1)	(Col.2)	(Col.3)	(Col.4)	(Col.5)	(Col.6)
ADT less than 2,000	8.25	9.26	10.27	7.49	8.19
ADT between 2,000-7,000	8.59	9.07	9.56	8.19	8.45
ADT greater than 7,000	50.27	51.04	51.72	50.32	50.67
TOTAL	**67.12**	**69.37**	**71.55**	**66.00**	**67.32**

Statewide Net Present Worth of Overlay Costs for All GVW/Truck Type Scenarios

Data for statewide control sections over which sugarcane was transported were tabulated in the same manner as in Table 9 to Table 21. However, summaries of the state wide control section dimensions are included in the Appendix for the other four GVW/truck type scenarios. Table 26 contains the statewide surface area of overlays by ADT group. Sugarcane was transported over 88 control sections with ADTs less than 2,000, 91 control sections with ADTs between 2,000 and 7,000, and 92 control sections with ADTs greater than 7,000 vehicles per day.

To generate the Scenario Two statewide costs of overlays for the 20 year performance period, a procedure was developed which is explained using data from Table 22. The sum of the total net present worth (NPW) of the study control sections (sum of column 7 in Table 22 i.e., 9,261,626) was divided by the sum of column 5 in Table 22 (1488.4) and multiplied by the value represented in row 1 and column 3 of Table 26 (11,589.9) for the 88 control sections with ADT less than 2,000 vehicles per day. To generate the Scenario Two statewide costs for the three ADT groups, the same procedure was followed using similar data from Table 23 and Table 24. The net present worth of overlays for all the three sets was added together to produce the total values shown in Table 27, column 3. The total row of Table 27, column 3 is the statewide Scenario Two net present worth cost of overlays for control sections carrying sugarcane during the 20 year analysis period.

Table 26
Summary of the product of number of lanes, lane width, and control section length for each ADT group for 271 control sections carrying sugarcane

ADT Group (Col.1)	No. of Control Sections (Col.2)	Product of no. of lanes X lane width (ft) X length (miles) for all Control Sections in each ADT group , (Col.3)
ADT less than 2,000	88	11,589.9
ADT between 2,000-7,000	91	15,362.14
ADT greater than 7,000	92	36,665.42
TOTAL	**271**	**63,617.46**

Table 27 contains the total state wide net present worth for overlay costs under each GVW scenario for the 20 year analysis period. The Scenario Two statewide cost of overlays for study control sections carrying sugarcane during the 20 year analysis period was calculated by multiplying and summing:

Statewide Scenario Two net present worth =
[(Table 26, Col. 3, Row 1) / (Table 22, Col. 5 Total)] * [Table 22, Col. 7 Total] +
[(Table 26, Col. 3, Row 2) / (Table 23, Col. 5 Total)] * [Table 23, Col. 7 Total] +
[(Table 26, Col. 3, Row 3) / (Table 24, Col. 5 Total)] * [Table 24, Col. 7 Total]

The sum of the above calculation is entered into the Table 27 total row as the statewide net present worth of overlay costs for Scenario Two. Similar calculations were performed to produce the statewide net present worth of overlay costs of all control sections carrying sugarcane during the 20 year analysis period for the other four GVW/truck type scenarios.

Table 27
statewide net present worth of overlays for all control sections carrying sugarcane for all GVW/FHWA truck type combinations

ADT Group	Statewide NPW of Overlay Costs for all control sections carrying sugarcane for all GVW/FHWA truck type combinations, Million $				
	Scenario 1 (80,000 lb.GVW)	Scenario 2 (100,000 lb.GVW)	Scenario 3 (120,000 lb.GVW)	Scenario 2a (100,000 lb.GVW, Triple axle)	Scenario 3a (120,000 lb.GVW, Triple axle)
(Col.1)	(Col.2)	(Col.3)	(Col.4)	(Col.5)	(Col.6)
ADT less than 2,000	64.27	72.12	79.97	58.30	63.77
ADT between 2,000-7,000	126.25	133.29	140.55	120.33	124.21
ADT greater than 7,000	294.23	298.72	302.68	294.52	296.57
TOTAL	484.75	504.13	523.20	473.15	484.55

[1]These data include only 31 of the 34 selected control sections, none from District 02.

Interpretation of Statewide Net Present Worth of Overlay Costs

The data in Table 27 are best interpreted by comparing the costs between the different GVW scenarios and FHWA vehicle type combinations. The current situation in Louisiana is Scenario Two (100,000 lb. GVW), using FHWA Type 9 vehicles. The current permit cost to increase GVW from 80,000 lb. to 100,000 lb. is $100/vehicle/year. A recent study by the DOTD permits office showed that 748 permits were sold for sugarcane trucks in the 2003 harvest season. The total state of Louisiana income paid by trucks hauling under these 748 permits in 2003 was $74,800; the overlay costs in Table 27 are in present dollars in 2006. The best way to compare the cost sequences is to convert these net present costs to annual costs for the 20 year analysis period using a 5 percent interest rate. The resulting annual cost for GVW and truck type combination is shown in Table 28.

Table 28
Statewide annual cost of overlays for all control sections carrying sugarcane for all GVW/FHWA truck type combinations

ADT Group	Statewide annual Overlay Costs for all control sections carrying sugarcane for all GVW/FHWA truck type combinations, Million $				
	Scenario 1 (80,000 lb.GVW) FHWA Type 9	Scenario 2 (100,000 lb.GVW) FHWA Type 9	Scenario 3 (120,000 lb.GVW) FHWA Type 9	Scenario 2a (100,000 lb.GVW, Triple axle) FHWA Type 10	Scenario 3a (120,000 lb.GVW, Triple axle) FHWA Type 10
TOTAL	**38.90**	**40.45**	**41.98**	**37.97**	**38.88**

These numbers were calculated by multiplying the NPW totals from Table 27 by 0.08024, the annual cost factor to convert present cost to an annual cost over 20 years at 5 percent interest per year.

The philosophy used in the 1997 Federal Cost Allocation Study was that each vehicle class should pay for the highway costs produced by the presence of those vehicles on the roads over which they travel *[7]*.

If this philosophy is applied to sugarcane trucks, all extra overlay costs on the 271 control sections induced by these vehicles should be borne by these vehicles. So under Scenario Two, sugarcane haulers using the FHWA Type 9 truck should be paying the difference between Scenario One and Scenario Two—1.475 million/year. (See Table 28.) As they are not, the state of Louisiana is paying the difference as a subsidy to the sugarcane industry. Another way to look at these numbers is to determine how much each permit should cost if the sugarcane truckers pay for the overlay costs occasioned by the heavier loads. The cost of a permit, if equity governs, will be ($1.55 million/year)/748 sugarcane permits issued or $2,072/year.

If the semi-trailer is converted from a tandem axle in the FHWA Type 9 vehicle to a triple axle in the FHWA Type 10 vehicle, the cost of a permit could be decreased from $2,072/permit/year to −$1,243/permit/year, [($37.97M - $38.90M) = $0.93M/year/748 trucks], meaning that the state could afford to offer each sugarcane transporter utilizing a FHWA Type 10 vehicle $1,243/year, as a tax subsidy to reduce pavement overlay costs. However, if the FHWA Type 9 vehicle is allowed on sugarcane trucks hauling 100,000 lb. GVW; the permit fee for a vehicle should increase from $100/year to $2,072/year.

As a result of hurricane devastation, there has been some discussion of increasing the GVW from 100,000 lb. to 120,000 lb., this GVW scenario for both the FHWA Type 9 and Type 10 vehicles was also included in the cost analysis. The annual overlay cost increases as the GVW increases from 100,000 lb. GVW to 120,000 lb. GVW utilizing the FHWA Type 9 trucks by, ($41.98M - $40.45M) $1.53 million or $2,045/truck/year. The total permit fee that sugarcane trucks should pay to carry 120,000 lb. GVW, for equity, would then be $2,072/truck/year plus $2,045/truck/year or #4,117/truck/year to pay for pavement costs incurred at the higher GVW level. One other significant factor should be noted—the bridge fatigue costs for the sugarcane trucks. As discussed later in this report, the bridge fatigue cost for FHWA Type 9 vehicles with 120,000 lb. GVW will exceed $5,400/truck/year; making the total cost per permit about $9,500/truck/year. Obviously, this level of permit fees is untenable for the sugarcane industry. The statewide NPW of overlay costs for each GVW scenario for all control sections carrying sugarcane is shown in Figure 3.

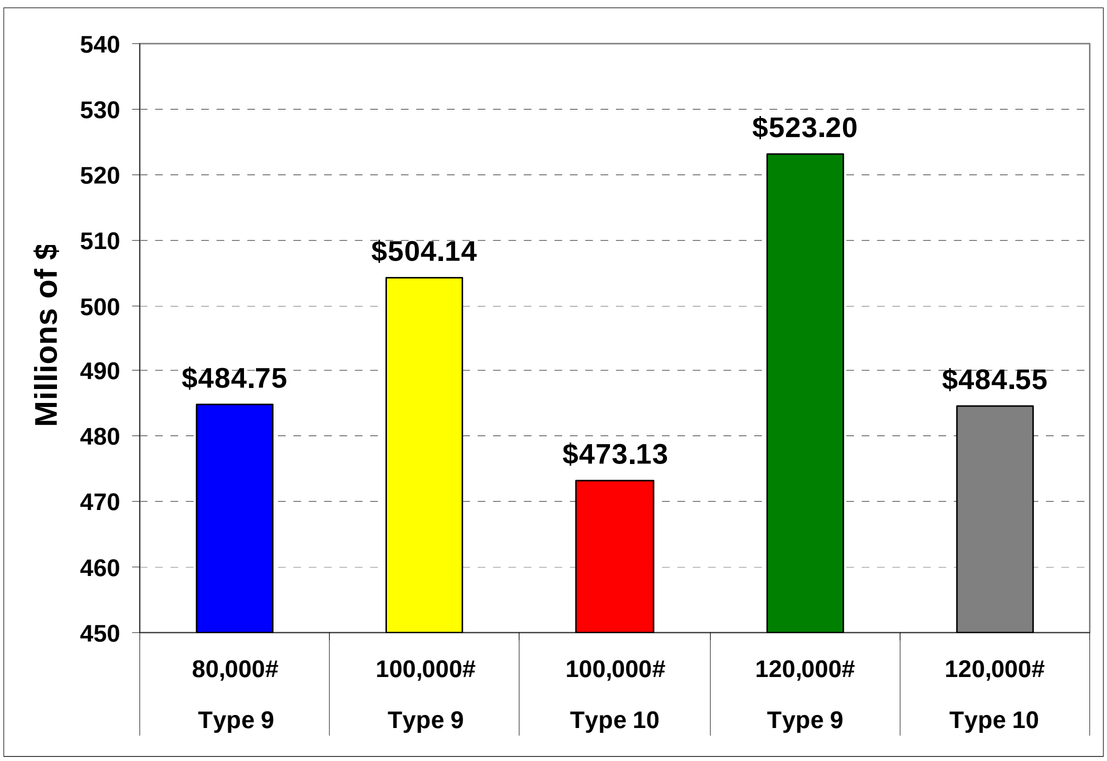


Figure 3

Statewide NPW of overlay costs for each GVW scenario for all control sections carrying sugarcane

If the GVW were increased from 100,000 lb. to 120,000 lb. and an FHWA Type 10 vehicle were used to haul the sugarcane, then the annual overlay cost to produce equity would decrease from $38.90 million/year for Scenario One to $38.88 million/year for Scenario

Three. Such again shows the savings in overlay costs associated with changing from a semi-trailer with a tandem axle to a semi-trailer with a triple axle. However, the problem of overstressing the bridges remains, and even with a triple axle it is a big hurdle to overcome.

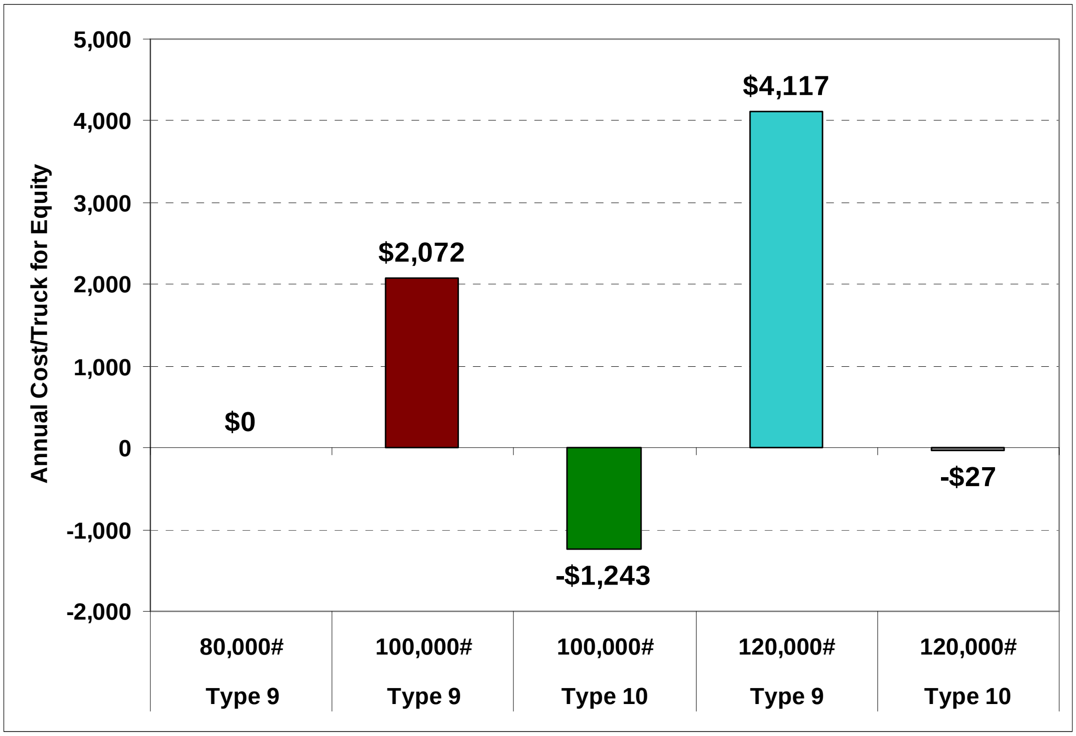


Figure 4

Statewide annual overlay costs per vehicle for all GVW and truck type combinations

Bridge Fatigue Costs

One other significant factor should be noted; the bridge fatigue costs should be included in this evaluation. The estimates are based on the following assumptions:

In 2002, the sugarcane production was estimated at 15 million tons.

In 2003, there were 748 permits for sugarcane trucks.

In 2003, there were 748 permits for sugarcane trucks.

The average weight of empty truck is 37,300 lb.

Each truck will cross one bridge per trip.

The sugarcane season starts on August 1 and ends on December 31, i.e., 153 days.

For trucks with 120,000 lb. GVW, each truck will be making about three trips per day—[(15M*2,000 lb./748 permits/(120,000-37,300) lb./153 days].

For trucks with 100,000 lb. GVW, each truck will be making about four trips per day—[(15M*2,000 lb./748 permits/(100,000-37,300) lb./153 days].

For Type 10 vehicles with 120,000 lb. GVW, the average cost for bridges as determined in at $11.75 per crossing, making the bridge fatigue cost at about $5,400/truck/year, ($11.75/trip/truck*3trips/day*153days/year) *[8]*. Clearly, the cost for Type 9 vehicles with 120,000 GVW will be higher.

For Type 10 vehicles with 100,000 lb. GVW, the average cost for bridges as determined in at $0.91 per crossing making the bridge fatigue cost at about $560/truck/year; ($0.91/trip/truck*4trips/day*153days/year) *[8]*.

For Type 9 vehicles with 100,000 lb. GVW, the average cost for bridges, as determined in at $5.75 per crossing, makes the bridge fatigue cost about $3,500/truck/year—($5.75/trip/truck*4trips/day*153days/year) *[4]*. Most of the bridges on the roads heavily traveled by sugarcane are simply supported; therefore the cost for a simply supported bridge was used in this case.

The statewide annual cost per vehicle for all GVW and truck type combinations is determined by adding the overlay cost to the bridge fatigue cost, as shown in Figure 5.

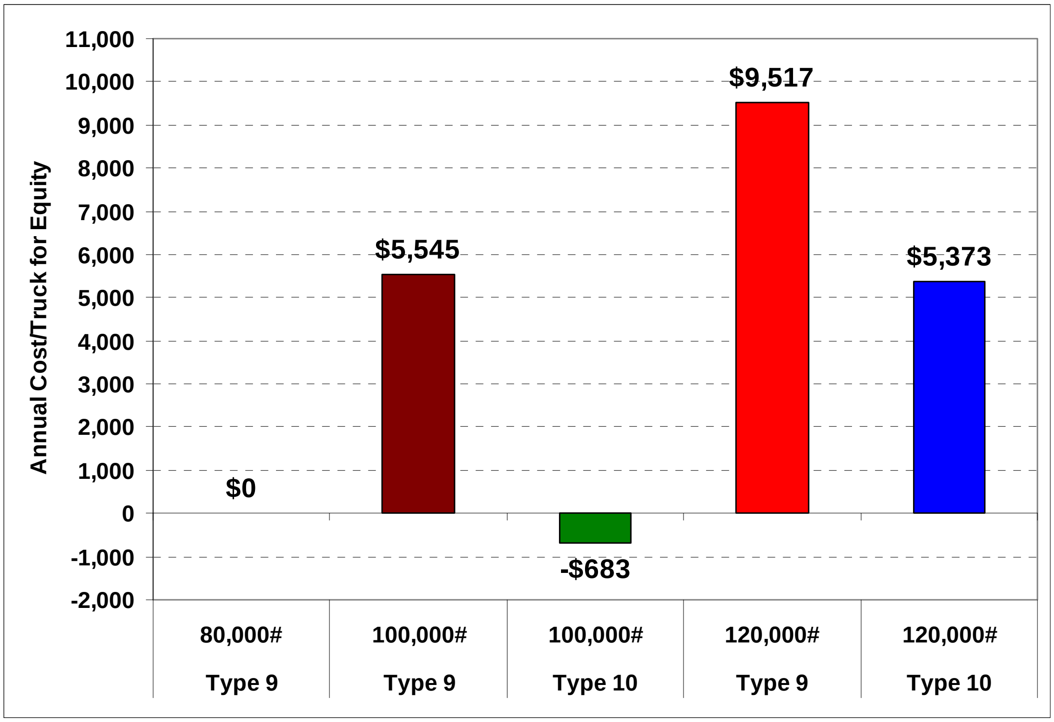


Figure 5
Statewide annual costs per vehicle for all GVW and truck type combinations

Trailer Axle Configurations

The GVW of a vehicle is not the prime determinant of a vehicle's impact on pavement behavior. Rather, pavements are stressed by loads on individual axles and axle groups directly in contact with the pavement. The GVW along with the number and types of axles and the spacing between the axles, is used to determine the axle load. Over time, the accumulated strains produced by axle loads deteriorate the pavement structure, eventually resulting in cracking and rutting of pavements. Pavements not routinely maintained experience accelerated cracking and rutting as a result of axle loads combined with the environmental effects such as moisture and temperature. To properly design a pavement the engineer must know the axle loading as well as the highway system. As the axle load increases, pavement deterioration increases quite rapidly.

A fourth power relationship between axle load and deterioration has been the rule of thumb since the AASHTO road test was conducted during the late 1950s. Such a relationship means that if an axle load is doubled from 10,000 lb. to 20,000 lb., then the impact of that increased load on pavement deterioration increases by a factor of 2^4 or 16. However, changing an axle type by adding one axle to make a tandem to produce a triple axle group permits a higher

GVW to be carried without increasing pavement damage. In this study, the benefit of changing the tandem axle on the semi trailer to a triple axle is shown. In other words, by changing the current FHWA Type 9 truck to a Type 10 truck, as shown in Figures 1 and 2, pavement rehabilitation costs can be reduced while hauling the same payload if a tridem axle is used instead of a tandem axle because pavement damage decreases as the number of tires supporting a load increases. A preliminary cost analysis regarding this axle modification is discussed below.

In a 1999 study, conducted by Dr. Salassi of the Louisiana State University Agriculture Center, costs were estimated for changing the trailer axle configurations of sugarcane trucks *[9]*. In this study, three options were investigated which represent alternatives to the current truck/trailer transport system that would reduce highway damage and/or reduce costs. These options are:

Adding an extra axle to truck/trailer

Use of lighter trucks and different trailer types

Mill delivery system or Bin transport system

In the following paragraphs, each option is discussed in detail and the costs incurred by each alternative are compared.

Adding an Extra Axle to Truck/Trailer

To study the costs involved in adding an extra axle to the truck/trailer, equivalent truck loads (ETL) were developed for different gross vehicle weight scenarios. These are generated by dividing the annual sugarcane harvest in tons by the payload per truck for all three scenarios. For a particular scenario, the ETLs for both the truck types are compared. The costs required for the additional truck loads and to add an extra axle are estimated. The sum of these two costs gives the total cost incurred to modify a FHWA Type 9 truck to FHWA Type 10 and this overall cost is compared with the pavement damage savings. In the following paragraphs, the method used to generate this overall cost and the assumptions made are discussed in detail.

The procedure involved the following factors:

2002 Louisiana sugarcane crop milled for sugar = 15 million tons.

Gross vehicle weight = 100,000 lb. (special permit)

Empty weight of the typical Sugarcane truck = 37,300 lb.

Pay load at 100,000 lb. =100,000-37,300 = 62,700 lb. (31.35 tons of cane/truck)

ETL = 15 million tons/31.3 tons per truck load = 479,233 truck loads

Similarly, ETLs were calculated for both the truck types and for all the three scenarios and are shown in Table 29.

Table 29
Calculation of equivalent truck loads for both truck types for all the three scenarios

Truck type	Equivalent Truck Load		
	Scenario One 80,000 lb. GVW	Scenario Two 100,000 lb. GVW	Scenario Three 120,000 lb. GVW
FHWA Type 9	697,670	479,233	361,445
FHWA Type 10	735,300	493,420	371,290
Increase in truck loads	37,630	14,187	9,845

From the above table, it is evident that the tare weight of the truck increases in the case of FHWA Type 10 truck as the weight of the empty truck increases. If a Type 9 truck is converted to a Type 10, then the tare weight of the Type 9 will increase by approximately 1,900 lb. The cost of adding this axle ranges from $4,500 to $7,500. Adding an extra axle on existing trailers, with axles properly balanced, will reduce the number of equivalent single axle loads required to carry the total sugarcane crop payload and this will reduce pavement overlay costs. Adding a third axle to the tractor was discussed with the sugarcane industry in 1999. Their thoughts were that it would be much less costly to modify the semi-trailer than to add a third axle to the tractor. However, for the Type 10 truck, the amount of sugarcane hauled per truck is decreased by approximately one ton since the tare weight increased by approximately one ton. The cost comparison between pavement damage costs and the costs incurred by changing the truck axle configurations and carrying additional truck loads is explained using the following example.

1. Average cost of adding an additional axle = $6,000.

   Number of trucks hauling sugarcane = 748

   Total cost incurred for adding axles = $6,000 x 748 = $4.5 million. (Assuming that all the trucks hauling sugarcane are of FHWA Type 9 and that all will convert in one year)

2. Additional FHWA Type 10 truck loads required for Scenario Two due to the extra tare weight = 14,187 (from Table 29)

   Assumed average distance traveled by a loaded truck with sugarcane = 50 miles. (Only used to give an order of magnitude cost)

   Average total cost per mile to operate a loaded truck = $1.8/mile *[10]*.

   Average annual cost for additional truck loads required by the 1,900 lb. increase in truck tare weight = 14,187 trips x 50 miles x $1.8/mile = $1.28 million/year.

   Therefore, the total cost incurred for changing the axle configurations from a tandem axle to a tridem, if all the trucks convert in the first year, is = $4.5 + $ 1.28 = $5.78 million.

   Note: $4.5 million for conversion from FHWA Type 9 trucks to Type 10

   $1.28 million annual additional costs for extra trips to carry payload

3. The pavement damage costs for Scenario Two GVW conditions between FHWA Type 9 and Type 10 trucks from Table 27 are:

   Annual pavement damage cost from FHWA Type 9 at 100,000 lb. – Annual pavement ..damage cost from FHWA type 10 at 100,000 lb. i.e., Pavement damage savings = $40.45 million/year – $37.97 million/year = $2.48 million/year

   Annually, about $1.2 million ($2.48 – $1.28 million) can be saved using a FHWA ..... Type 10 trucks instead of FHWA Type 9 trucks.

Use of Lighter Trailers

By using lighter weight trailers, the investment costs are significantly reduced, and the light weight of the trailer allows hauling more sugarcane per truckload (approximately 1-2 tons of sugarcane). The cost and weight of different trailer types are shown below:

Side dump trailer (22,000-24,000 lb. weight) and cost ($25,000-$30,000)

Rear dump trailer (17,000-19,000 lb. weight) and cost ($14,000-$16,000)

Rollover trailer (18,000-20,000 lb. weight) and cost ($16,000-$30,000)

For example, if the lighter trailer weight is 18,000 lb. and the lighter truck weight is 17,000 lb., then the total empty weight of the truck/trailer would be 35,000 lb. At this empty weight, the pay load at a 100,000 lb. weight limit would be:

Payload at 100,000 lb. = 100,000 lb. (GVW) – 35,000 lb. (empty truck/trailer weight) = 65,000 lb. (32.5 tons of cane).

Therefore, the payload per truck increases with the use of lighter trucks/trailers and hence reduces the cost of hauling sugarcane. The cost incurred by using lighter truck/trailers is given below:

ETL = 15 million tons/32.5 tons per truck load = 461,538 truck loads

Decrease in number of truck loads = 479,233−461,538 = 17,695 truck loads.

(479,233 is the number of truck loads required by FHWA Type 9 truck from Table 29)

Average annual savings by using the lighter trailers is

= 17,695 trips x 50 miles x $1.8/mile = $1.59 million/year

Pavement damage savings = $2.48 million/year (from above)

Therefore, total savings = $2.48million + $1.59 million = $4.07 million/year

The cost incurred for modifying the trailer = $20,000 x 748 = $14.96 million

($20,000 is only used as an average to calculate the total cost to modify all the trailers.)

Hence, it would require approximately four years ($4.07 million/year x 4 years = $16.28 million > $14.96 million) to recover the investment cost, and from then on, $4.07 million could be saved annually.

Mill Delivery System

Mill delivery system or "Rolloff" Bin Transport System improves harvest and transport efficiency. In this system, sugarcane would be loaded into standard bins in the field, and the bins would be loaded in trucks for transport to the sugar mills. Harvester operation is not dependent on truck availability, and loaded bins can be hauled to the mill day or night—whenever needed.

The key features of the Bin system are discussed below:

Trailer and bin weight is approximately 22,000 – 26,000 lb.

One bin or basket holds the same amount of sugarcane as one standard cane trailer. However, increased trailer weight may reduce maximum load by 1-2 tons of cane per truck load.

One truck/trailer can handle approximately 15 bins. So there is a significant reduction in total number of trucks and trailers required.

Trailer is self-dumping at the mill or can be used with a rear dump system.

Significant cost savings can be made in trailer tires and brakes as well as number of trucks and trailers required. In addition, there are possible cost savings at the mill related to handling and moving cane. The number of bins required would need to be determined for specific mill situations (logistics related to quantity of cane and distance hauled).

All the three options are feasible, but an appropriate decision must be made by the legislature, keeping in view the pavement damage costs, one time investment costs, number of trucks to be modified, etc. Switching to any one of these options would prove very beneficial to the sugarcane industry in the long term.

CONCLUSIONS

1. The GVW for FHWA Type 9 sugarcane trucks should be reduced from 100,000 lb. to 80,000 lb. or the permit fee increased from $100/truck/year to $5,545/truck/year. However, if the Legislature requires that the semi-trailer on the FHWA Type 9 truck be converted from a tandem axle to a triple axle, the permit fee could be reduced to $0/truck/year, and each truck could be given a $683/year tax incentive to pay for the conversion.

2. The GVW for FHWA Type 9 sugarcane trucks should not be increased from 100,000 lb. to 120,000 lb. If such a GVW increase should occur, the pavement overlay costs and bridge fatigue costs would increase from about $5,545/truck/year at 100,000 lb. GVW to over $9,517/truck/year at 120,000 lb. GVW. However, axle loads under the 120,000 lb. GVW would produce very severe overstressing of bridges *[4], [8]*. In these references, the researchers determined that bridge fatigue costs for a GVW of 120,000 lb. were estimated to be $5,400/truck/year. The magnitude of the damage for the 120,000 lb. GVW for a FHWA Type 9 truck makes the risk of bridge damage and even bridge failure too significant to ignore.

3. Allocate more highway funding for handling the extra damage caused by the increase of truck load limits.

RECOMMENDATIONS

1. Keeping the GVW for sugarcane trucks at 100,000 lb. and requiring that the axle configuration on the semi-trailer be changed from a tandem to a triple axle is recommended. If the axle configuration were changed, each sugarcane truck could be given a tax incentive of $683/year to assist with the conversion cost. Such a combination would reduce the damage to pavements to below the level produced by the FHWA Type 9 vehicle hauling freight at the legislated level of 80,000 lb. GVW.

2. Increasing the GVW from 100,000 lb. to 120,000 lb. is not recommended. Even if sugarcane trucks were required to convert from FHWA Type 9 to Type 10 vehicles, additional costs and the potential damage to bridges from overstressing would likely produce serious safety concerns for the bridges. The extra pavement and bridge costs far outweigh the potential savings in transportation costs for the trucks hauling sugarcane.

3. Future studies should evaluate an alternative transport system and develop an investment business plan for sugarcane harvest which will reduce highway damage and/or reduce costs. These options should include:

    Use of lighter trucks and different trailer types

    Mill delivery system or Bin transport system

4. The allocation of more highway funding for handling the extra damage caused by the increase of truck load limits is recommended.

ACRONYMS, ABBREVIATIONS, & SYMBOLS

A	annual cost, $
AASHTO	American Association of State Highway and Transportation Officials
ADT	average daily traffic, vehicles/day
a	a-value of a pavement material, the relative strength coefficient
B	the length of the axle group, in feet, used in bridge design
BC	binder course
D	thickness of a pavement layer, inches
DOTD	Department of Transportation and Development
ESALs	equivalent 18-kip single axle loads
FHWA	Federal Highway Administration
F_{RL}	remaining life factor
ft	foot/feet
GVW	gross vehicle weight
H_{OL}	Overlay thickness, inches
kip	1,000 lb.
LADOTD	Louisiana Department of Transportation and Development
lb.	pound(s)
LTRC	Louisiana Transportation Research Center
M	mean or average of all observations in a data set
N	number of axles in a group
NPW	net present worth, $
n	size of a sample
O.C.	overlay cost, $
P_i	initial present serviceability index
P_t	terminal present serviceability index
P	present worth, $
psf	pounds per square foot
R	reliability level, %
S_o	overall standard deviation for construction of pavements
SN	structural number
SN_{OL}	structural number of an overlay
SN_{xeff}	total effective SN of the existing pavement above the subgrade
$SN_{xeff\text{-}rp}$	effective structural capacity of all remaining pavement layers above the subgrade except for the existing PCC layer
W	overall gross vehicle weight, lb.
WC	wearing course
$Z_{alpha/2}$	value of standard normal deviate at an error level of alpha/2

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APPENDIX A

NOTE: Data for three control sections in District 02 is missing

Table A.1 Dimensions and Overlay Costs for All the 11 Control Sections with ADT Less Than 2,000 Veh/Day for Loads with a FHWA Type 9 Truck (Scenarios One, Two and Three)

Control Section No.	No. of Lanes	Lane width, ft.	Length, mi.	Product of (Col.2 * Col.3 * Col.4)	Scenario 1 NPW of Overlay Cost/ 12-ft-lane-mile	Scenario 1 Total NPW of Overlay Cost of each Control Section, [(Col.5/12)*Col.6]	Scenario 2 NPW of Overlay Cost/ 12-ft-lane-mile	Scenario 2 Total NPW of Overlay Cost of each Control Section, [(Col.5/12)*Col.8]	Scenario 3 NPW of Overlay Cost/ 12-ft-lane-mile	Scenario 3 Total NPW of Overlay Cost of each Control Section, [(Col.5/12)*Col.10]
(Col.1)	(Col.2)	(Col.3)	(Col.4)	(Col.5)	(Col.6)	(Col.7), $	(Col.8)	(Col.9), $	(Col.10)	(Col.11), $
849-8	2	11	2.77	60.94	52,985	269,075	70,734	359,210	82,762	420,293
233-1	2	10	9.43	188.6	69,896	1,098,532	79,090	1,243,031	85,323	1,340,993
393-7	2	10	7.47	149.4	82,211	1,023,527	88,534	1,102,248	95,900	1,193,955
824-6	2	10	11.56	307.32	76,048	1,947,589	84,764	2,170,806	94,013	2,407,672
	2	11	3.46							
804-21	2	9	1.6	28.8	0	0	0	0	35,368	84,883
219-8	2	12	4.07	97.68	42,112	342,791	61,840	503,377	83,747	681,700
219-30	2	9	1.15	170.46	83,188	1,181,685	89,275	1,268,151	96,432	1,369,816
	2	12	3.29							
	2	10	3.54							
402-3	2	11	4.66	102.52	57,192	488,610	75,644	646,251	82,429	704,218
207-3	2	12	0.32	174.28	73,729	1,070,790	76,532	1,111,499	80,538	1,169,680
	2	10	0.19							
	2	11	7.4							
823-14	2	10	6.44	128.8	51,491	552,670	52,624	564,830	54,197	581,714
805-9	2	10	3.98	79.6	41,923	278,089	44,053	292,218	47,512	315,162
				1488.4		8,253,358		9,261,621		10,270,086

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