A Study of the Impacts of Commercial Vehicles on the Strategic Intermodal System of Florida

Submitted to

The Florida Transportation Commission

By

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EXECUTIVE SUMMARY

Florida is one of the nation's fastest growing states, with its population increasing at a rate of almost a thousand new residents per day. It also has maintained one of the most vibrant economies in the world over the past three decades, with dynamic domestic commerce and an ever-expanding international trade industry. This long term consistent growth, however, has dramatically impacted Florida's transportation system, both structurally and functionally.

In 2003 the Legislature statutorily designated Florida's Strategic Intermodal System (SIS), a network of high priority transportation facilities that are critical to the state's economic vitality and quality of life. The SIS carries 68 percent of all commercial truck traffic and 54 percent of the total traffic on the State Highway System. The long term impacts of this high volume movement of people and freight on this top-priority system is, therefore, of significant interest to all citizens and businesses of the state.

Pavement sections on the SIS are resurfaced or reconstructed on a regular basis, primarily to remove the accumulated effects of damage caused by commercial trucks. The frequency of rehabilitation on the interstate portion of the SIS is fourteen years. Bridges are also affected. The physical impacts of truck loading lead to the question of relative fiscal responsibility of each of the types of vehicles that use the SIS.

The Florida Transportation Commission contracted with Highway Management Technologies, Inc., to gather reliable data that could be used to document the impacts of commercial trucks on the physical condition and efficient operation of the SIS. In addition, the study addressed the assessment of fiscal responsibility and the allocation of costs directly associated with the resulting impacts. Fiscal year 04/05 data was used to conduct these analyses.

This study first addressed the actual extent of physical impacts on the Florida SIS that are attributable to commercial truck traffic. This was done by analyzing data for the SIS contained in the Florida Department of Transportation's (FDOT's) Pavement Management System database. It was found that, while commercial vehicles make up approximately 9 percent of the traffic stream, they impose just less than 95 percent of the damage on the pavement.

The second phase of the study addressed two issues: (a) the average cost of damage, compared to average revenue generated by vehicle type; and (b) whether the current overweight fee and penalty structure, as established in Florida Statutes, is sufficient to cover the pro-rated cost of maintaining the SIS infrastructure in acceptable condition, under the ever-increasing level of commercial truck traffic. These two issues were approached by using a variety of software tools and databases within the Department as well as the Federal Highway Administration's (FHWA's) Highway Cost Allocation (HCA) software package. These resources were used to allocate SIS related costs to commercial trucks and passenger vehicles. These costs were used in conjunction with revenue data to compute a ratio of the average revenue generated by each vehicle type to the average allocated SIS costs for those same vehicle types.

The findings indicate that automobiles contribute significantly more than their costs, while commercial vehicles generally contribute less than their costs. The study calculated an equity ratio for each vehicle type, which is the ratio of the revenues paid by all vehicles within the vehicle type to the costs attributable to that vehicle type. The study concluded that in Fiscal Year 04/05 automobiles paid 133 percent more than their share of the SIS costs, buses paid 43 percent more, and light trucks paid 38 percent more. Of the commercial trucks, only single unit, two and three-axle trucks paid more (1 percent) than their allocated costs. The remaining commercial truck types paid between 30 and 62 percent of their allocated SIS costs through the revenues that are generated from them. This study concluded that revenue from commercial vehicles was short by $1.1 billion in FY 04/05 to cover their allocated cost of the damage to the SIS infrastructure. The study also concluded that the current penalty structure for overweight commercial vehicles is adequate for recovering the cost of damage to the SIS infrastructure subject to the current limitation that those vehicles more than 6,000 pounds overweight are identified and off-loaded.

INTRODUCTION

Florida's impressive rate of growth in both population and commercial activity requires that its highway system provide a high quality support infrastructure. From the standpoint of responsibility, Florida highways have had to be resurfaced at more frequent intervals because they are used by increasing numbers of commercial trucks than they would if only light vehicles were present. The greatest impact of this condition is seen in the Strategic Intermodal System (SIS), which carries 68 percent of all commercial truck traffic in Florida. This study has evaluated the impacts of commercial truck loadings on the physical condition and efficient operation of the SIS and other elements of the State highway infrastructure. The assessment of fiscal responsibility and allocation of costs was also addressed.

Pavement sections on the SIS are resurfaced or reconstructed on a regular basis, primarily to remove the accumulated effects of damage caused by commercial trucks. The frequency of rehabilitation on the interstate portion of the SIS is fourteen years. Bridges are also affected. The physical impacts of truck loading lead to the question of relative fiscal responsibility of each of the types of vehicles that use the SIS.

The first phase of this study was to determine the actual extent of physical impacts on the Florida Strategic Intermodal System (SIS) that are attributable to commercial truck traffic. The second phase included two parts: (a) to calculate the average cost of damage, compared to the average revenue generated by vehicle type; and (b) to assess whether the current fee and penalty structure, as established in Florida Statutes, is sufficient to cover the pro-rated cost of maintaining the SIS infrastructure in acceptable condition under the ever increasing level of commercial truck traffic.

These objectives have been met by performing a series of tasks using a variety of widely accepted analytical methods in conjunction with the best sources of readily available data. The selection of methods and data sources was made to ensure the most accurate and reliable results attainable while meeting the project time targets.

The first project phase was addressed by using the Pavement Management System created and maintained within the Pavement Management Section of the Florida Department of Transportation (FDOT). This resource was used to compute the average annual damage to the SIS pavement infrastructure by both commercial trucks and passenger vehicles. This value was compared to the usage by both commercial trucks and passenger vehicles to demonstrate their physical impacts on the SIS.

The first part of the second phase relied on analysis tools from the discipline known as Highway Cost Allocation (HCA). These include both Federal Highway Administration (FHWA) software specifically written for this purpose and other applicable FDOT software and databases. The FHWA HCA software package[1], published in 2000, is one of the products of its 1997 Federal Highway Cost Allocation Study. In addition to using the FHWA State HCA software, the software and databases developed by the Department's Financial Development Office and Pavement Management Section were used.

The second phase of the study addressing the adequacy of the fee and penalty structure for commercial trucks to cover their pro-rated cost of maintaining the SIS infrastructure in acceptable condition was addressed by analyzing the impacts of increasingly heavier overweight conditions.

The subsequent sections of this report present the study methodology, results, conclusions, and recommendations.

TECHNICAL APPROACH

This project required complex analyses of multiple sources of data from a variety of Florida and U.S. databases, encompassing several disciplines, over a very short period of time. The following discussion includes relevant background information and discussion.

The Strategic Intermodal System

The Strategic Intermodal System (SIS) was created in 2003 "to enhance Florida's economic competitiveness by focusing limited state resources on those transportation facilities that are critical to Florida's economy and quality of life." It is intended to include all of the principal transportation modes in an integrated network. The SIS includes approximately 3,500 miles of highway and carries 68 percent of all commercial truck traffic in Florida. Information about these highway sections is included in the Roadway Characteristics Inventory (RCI) and they are designated as components of the SIS in that database. Highway sections that are elements of the SIS are identified by a data item (feature) found in the Department's Roadway Characteristics Inventory (RCI) database.

Previous Relevant Studies

Considerable effort has gone into studying the effects caused by overweight trucks. One important example of these is the 1979 report "Excessive Truck Weight: An Expensive Burden We Can No Longer Support" by the United States General Accounting Office[2]. This document provides a thorough treatment of all costs attributable to overweight vehicles, including those impacting the physical infrastructure.

In 1999 the Office of Program Policy Analysis and Government Accountability (OPPAGA) of the Florida Legislature reviewed the Motor Carrier Compliance Program[3]. It found that carriers who deliberately overload their vehicles do not pay their fair share. In response to that report, FDOT staff analyzed the excess physical damage caused by overweight vehicles and computed the cost per mile that could be attributed to overloaded vehicles of varying degrees. The result was an estimated cost of $0.1265 per mile traveled for a 95,000 pound truck, escalating to $0.14 per mile for a 142,000 pound vehicle.

Another FDOT analysis found that for each one percent shift in trucks from 80,000 pounds to 95,000 pounds, pavement life on the non-Interstate system was reduced an average of 0.22 years.

FDOT Pavement Management Software

In addition to the FHWA State HCAS software, the software and databases developed by the FDOT's Pavement Management Section were used to assess the physical impacts of commercial vehicles on the SIS. The Pavement Management Section maintains databases that are derived from the principal sources of pavement related information for the Department. These include: the Roadway Characteristics Inventory (RCI); Construction

Quality Reporting (CQR); Pavement Core Reporting (PCR); Laboratory Information Management System (LIMS); and Pavement Condition Survey (PCS) databases.

FHWA State Highway Cost Allocation Software

Highway Cost Allocation Studies have been conducted for more than thirty years. Although Florida has never conducted a formal HCA Study as such, it contributed to the most recent (1997) national study done for the Federal Highway Administration (FHWA). Florida has conducted several internal evaluations related to the physical impacts of trucks on the pavement, as indicated in the preceding paragraphs.

In addition to a final report[4] and several supporting documents, the 1997 Federal Highway Cost Allocation (HCA) Study produced software that individual states can use to prepare highway cost allocation studies. The software is available on compact disk, entitled "State Highway Cost Allocation Study Tools – Final Version, August 2002."

The FHWA State HCA software provides two general analytical approaches for the states to use in allocating costs. The most current of these is the Minimum Pavement Thickness Method (Federal Method), which has generally replaced the older Incremental Method[1]. Both methods are important, however, since they handle pavement and bridge costs differently and allow comparison of these physical impacts from different perspectives. The FHWA State HCAS software incorporates both the Federal Method and the Incremental Method.

The FHWA State HCA software provides tools for populating Microsoft Excel spreadsheets designed to calculate equity ratios by vehicle type. An equity ratio is defined as the total revenue contributed by a vehicle of a certain type divided by the costs allocated to that same vehicle. The approach used is macroscopic in that the analysis is not performed section by section but for aggregate mileages. The FHWA State HCA software requires state-specific revenue and cost information. In this study these data were obtained from the Department's Office of Financial Development.

The product of the FHWA State HCA software is a table of equity ratios by vehicle type presented in a subsequent section of this report.

ANALYSES AND RESULTS

The following sections describe the analyses performed and results obtained. They are presented in the context of the specific goals of the study:

- Quantify the physical damage to the SIS infrastructure attributable to commercial truck traffic.
- Determine the average cost of damage to the SIS infrastructure compared to the average transportation related revenue collected by vehicle type.
- Determine the adequacy of the current fee and penalty structure for overweight commercial trucks to cover their pro-rated cost of maintaining the SIS infrastructure in acceptable condition.

Physical Damage Attributable to Commercial Truck Traffic

The primary resource used to determine the physical damage to the SIS attributable to commercial truck traffic was the Florida Department of Transportation's Pavement Management System (PMS). The Pavement Management Section maintains these analytical tools and databases. They are derived from the principal sources of pavement related and general inventory information supported within the Department. These databases include the Roadway Characteristics Inventory (RCI), Construction Quality Reporting (CQR), Pavement Core Reporting (PCR), Laboratory Information Management System (LIMS), and Pavement Condition Survey (PCS) databases.

In this task, the concept of "equivalent single axle load" was used to quantify the physical impacts of commercial trucks on the SIS in FY 04/05. A detailed explanation of equivalent single axle loads (ESALs), including illustrations, is provided in Appendix A. Briefly, an ESAL expresses the amount of damage that an 18,000 pound truck axle imposes on a pavement. The Pavement Management System includes the information necessary to compute the number of ESALs applied by commercial vehicles to every section of the SIS.

Use of the PMS databases to analyze the physical impacts on the SIS is enabled by the inclusion in the RCI database of Feature 147 "SISFACTP," the SIS Facility Type as well as traffic and pavement and bridge data. These entries allow the PMS databases to be used to determine, for each segment on the SIS, the actual and projected physical impacts by vehicle class. For this task, regular SIS sections (indicated by a value of "11" for the SIS code) were used. The sections were identified in the PMS databases and analyzed using the Department's SAS© software. A total of 1,944 SIS sections were selected from the PMS database.

The Department has determined that, on average, each commercial truck on Florida highways represents 1.0 ESALs. This study assumes that passenger vehicles have an average of 0.0005 ESALs. For this analysis, a measure useful for indicating the extent of "consumption" of pavement life was used – the ESAL-lane mile. An ESAL-lane mile is defined as a load of one ESAL traveling one mile. Using these values, analysis of the data shows that commercial trucks apply an average of more than 16.7 million

(16,727,706) ESAL-miles of loading to the SIS pavement every day of the year compared to just over 66.6 thousand (66,631) ESAL-miles for passenger cars.

As illustrated in Figure 1, this finding can be interpreted to mean that in FY 04/05 commercial trucks comprised 8.7 percent of the traffic stream on the SIS but imposed just less than 95 percent of the load related damage to the pavement.

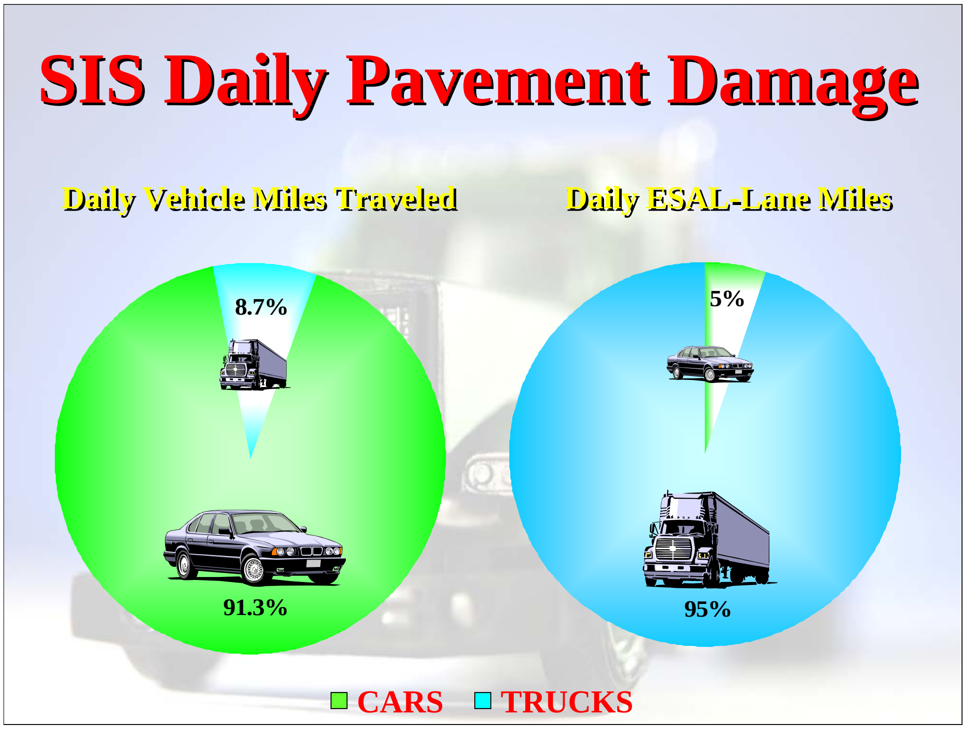

Figure 1. Physical Impacts of Commercial Vehicles

<u>Cost of Damage Compared to Transportation Revenue Collected</u>

The second goal of the study was addressed in two parts. The first was to calculate the average cost of damage to the SIS infrastructure, compared to the average transportation related revenue generated by vehicle type.

The Federal Highway Administration (FHWA) Highway Cost Allocation software was used to conduct the analyses for this portion of the study. The primary product of the FHWA HCA software is a set of "Equity Ratios". For each vehicle type, its SIS Equity Ratio is the quotient of its share of SIS highway related revenue collected in FY 04/05 divided by its share of SIS highway related costs[1]. An Equity Ratio greater than 1.0 indicates that a vehicle class is paying more than its fair share of highway costs. A value of less than 1.0 shows that a vehicle class is paying less than the costs that have been allocated to it.

The format for the FHWA HCA software is a series of spreadsheets grouped into expenditure data, revenue data, and analysis sections. Although the FHWA HCA software provides national default values that can be used as needed, the best and most accurate results are obtained when state-specific information is used. A great deal of the effort in this study was expended to acquire these data for Florida.

The initial activities were directed at identifying the sources and formats of data for use in the expenditure portion of the input to the FHWA HCA software. The general categories of data include annual expenditures for:

1. New Flexible Pavement Construction
2. New Rigid Pavement Construction
3. New Bridge Construction
4. Bridge Replacement
5. Bridge Repair
6. Special Bridge Projects
7. Grading and Drainage
8. General Construction (Residual Costs)
9. Transit and Rail
10. Truck-Specific Construction
11. Miscellaneous Maintenance
12. Wear-related Flexible Pavement Maintenance
13. Wear-related Rigid Pavement Maintenance

Each of the above items is further divided by highway system in the FHWA HCA software as follows:

1. Rural Interstate
2. Rural Other Principal Arterials
3. Rural Minor Arterials
4. Rural Major Collectors
5. Rural Minor Collectors
6. Rural Locals
7. Urban Interstate
8. Urban Other Freeways and Expressways
9. Urban Principal Arterials
10. Urban Minor Arterials
11. Urban Collectors
12. Urban Locals

In addition to allocating expenditures by highway system as indicated above, the FHWA HCA software also requests subdividing the data by:

1. Federal Aid Construction and Maintenance
2. Federal Aid Administration
3. State Level Construction and Maintenance
4. State Level Administration
5. State-Aid Construction and Maintenance
6. State-Aid Administration

Florida Department of Transportation staff was contacted in each of the following offices for the indicated data types:

1. Transportation Statistics – Roadway Characteristics Inventory (RCI), Highway Performance Monitoring System (HPMS) information, and traffic data.
2. Policy Planning – SIS inquiries
3. Systems Planning – SIS data
4. Maintenance – Maintenance data
5. Planning – Highway Capacity information.
6. Pavement Management and Design – Pavement Management data
7. Financial Development – Departmental Financial data
8. FHWA Office of Policy Planning – FHWA HCA software inquiries

The information and data acquired from these and other sources were reviewed and analyzed to determine the best ways to fit the available Florida data within the input requirements of the FHWA HCA software. Apparent conflicts were identified so that they could be resolved or neutralized. Data structure decisions were formulated as appropriate.

The acquisition, processing, and analysis of these data to derive the information required by the HCA software was a significant undertaking. There were several reasons for this situation. First, as indicated in the list shown above, the required data were residing in a wide variety of locations. The necessary data items had to be identified from the HCA software documentation and then located within the Department.

Second, when the data were located, they were often not available in a form that would allow direct entry into the HCA spreadsheets. This is because the data are acquired, stored, and maintained for specific purposes that did not necessarily meld cleanly with the HCA software.

Once the data were prepared in a manner compatible with the HCA input requirements, the HCA software was run, producing the set of Equity Ratios shown in Table 1.

Table 1. Equity Ratios for the SIS for FY 04/05.

Vehicle Type	FHWA HCA Florida
Auto	2.33
Bus	1.43
LT	1.38
SU-2 & 3	1.01
SU-4	0.59
TT-3 & 4	0.62
TT-5	0.39

TT-6	0.30
DBL-5	0.31
DBL-6	0.48
DBL-7+	0.36

Note: The vehicle type codes in Table 1 indicate the following vehicle configurations:

Auto	Automobiles
Bus	Buses
LT	Light Trucks with two axles and four tires
SU-2	Single Unit Trucks with two axles
SU-3	Single Unit Truck with three axels
SU-4+	Single Unit Trucks with four or more axles
TT-3&4	Tractor with Semi trailer with three or four axles
TT-5	Tractor with Semi trailer with five axels
TT-6+	Tractor with Semi trailer with six or more axles
DBL-5	Tractor with two trailers and five axles
DBL-6	Tractor with two trailers and six axles
DBL-7+	Tractor with two trailers and seven or more axles

Table 1 indicates that in FY 04/05 automobiles paid much more in taxes and fees than their attributable cost responsibility for the SIS. Buses and light trucks were also net contributors, as were two and three-axle single unit trucks. All other truck types paid less than their cost responsibility.

Specifically, the findings indicate that automobiles paid more than twice their share of the SIS costs, buses paid 43 percent more, and light trucks paid 38 percent more. Of the commercial trucks, only single unit, two and three-axle trucks paid more (1 percent) than their allocated costs. The remaining commercial truck types paid between 30 and 62 percent of their allocated SIS costs through the revenues that were generated from them. (This study did not include the positive effects of the movement of goods on the overall economy.)

The HCA software also provided per mile costs to the SIS by vehicle type. These are shown in Table 2.

Table 2. Per Mile Costs to the SIS by Vehicle Type

Vehicle Type	Daily ESAL Miles	Daily VMT	HCA Per Mile Cost ($)
Auto	66,631	133,262,167	0.0170
Bus	117,925	242,879	0.1012
LT	656,322	2,017,410	0.0286
SU-2&3	704,060	852,308	0.1528
SU-4+	204,491	97,579	0.2893
TT-3&4	916,677	921,625	0.2414
TT-5	12,998,087	10,547,570	0.4257
TT-6+	134,139	107,656	0.5633
DBL-5	651,151	365,653	0.5350
DBL-6	153,366	123,002	0.3528
DBL-7+	124,857	55,310	0.4865

Using the equity ratio data from Table 1, we were able to calculate the surplus/deficit by vehicle type based on the transportation related revenue produced compared to the attributable cost of damage to the SIS for FY 04/05 as shown in Table 3.

Table 3. Equity Ratios and Revenue Shortfall by Vehicle Type

Vehicle Type	Equity Ratio	HCAS Cost per Mile (cents)	Revenue (millions)	Cost (millions)	Difference (millions)
Auto	2.33	1.70¢	$1,925.7	$827.9	$1,097.8
Bus	1.43	10.12¢	$12.9	$9.0	$3.9
LT	1.38	2.86¢	$29.2	$21.1	$8.1
SU- 2 & 3	1.01	15.28¢	$47.9	$47.5	$0.4
SU- 4+	0.59	28.93¢	$6.1	$10.3	-$4.2
TT- 3&4	0.62	24.14¢	$50.3	$81.2	-$30.9
TT- 5	0.39	42.57¢	$644.6	$1,639.1	-$994.5
TT- 6+	0.30	56.33¢	$6.7	$22.1	-$15.4
DBL- 5	0.31	53.50¢	$22.3	$71.4	-$49.1
DBL- 6	0.48	35.28¢	$7.6	$15.8	-$8.2
DBL- 7+	0.36	48.65¢	$3.6	$9.8	-$6.2

Based on this analysis, the total transportation related revenue shortfall as compared to their attributable cost of damage to the SIS for commercial vehicles in FY 04/05 is a little over $1.1 billion per year (the sum of SU-2 & 3 through DBL-7+).

Adequacy of Overweight Fee and Penalty Structure

Part two of the second phase of this study was to address the adequacy of the current overweight fee and penalty structure for commercial vehicles to cover their pro-rated cost of maintaining the SIS infrastructure in acceptable condition. It is apparent from the analysis in the previous section of this study that commercial vehicles are paying less in registration fees and fuel taxes than the amount of their cost responsibility for maintaining the SIS in acceptable condition.

The overweight fee and penalty structure in Florida, as defined in s. 316.545 Florida Statutes, was examined for reasonableness with respect to the findings of this study. Analyses conducted during thus study indicate that the direct monetary cost of slight overloads (less than 6,000 pounds overweight) is less damage to the SIS infrastructure than the fine currently imposed. The average cost to resurface a mile of pavement on the SIS is approximately $160,000. The amount of pavement loading that is expected before the next resurfacing is five million ESALs. The ratio of cost to loads is therefore 3.2 cents per ESAL mile.

For example, a truck that has a tandem axle that is overloaded by 4,000 pounds in Florida pays a fine of $200 (five cents per pound overweight). The additional damage that the overloaded tandem applies to the pavement is 2.72 cents per mile. The truck would have to travel more than 7,000 miles at that weight to cause physical damage equal to the $200 fine.

Therefore, the current penalty structure is adequate for recovering the costs to the SIS caused by overweight commercial vehicles subject to the current limitation that vehicles more than 6,000 pounds overweight are identified and off-loaded. However, this only applies to those vehicles that are caught. There are clearly other vehicles that are not caught and, therefore, pay no fine while they impose damage to the system. This study did not address the deterrent effects of the fine structure.

CONCLUSIONS

This study produced the following findings:

- While commercial trucks comprise 8.7 percent of the traffic stream on the Strategic Intermodal System in FY 04/05, they caused just less than 95 percent of the load related damage to the pavement.

- In FY 04/05, automobiles paid more than twice their share of the allocated cost of maintaining the SIS in acceptable condition, buses paid 43 percent more, and light trucks paid 38 percent more. Of the commercial vehicles, only single unit, two and three-axle trucks paid more (1 percent) than their allocated cost. The remaining commercial vehicle types paid between 30 and 62 percent of their allocated SIS costs in comparison to the revenues that were generated from them. Commercial vehicles would have to generate an additional $1.1 billion in transportation related revenue to cover the cost of damage they caused to the SIS. (This study did not include the positive effects of the movement of goods on the overall economy).

- The current penalty structure is adequate for recovering the costs of damage to the SIS caused by overweight vehicles subject to the current limitation that vehicles more 6,000 pounds overweight are identified and off-loaded.

REFERENCES

1. "Guidelines for Conducting a State Highway Cost Allocation Study Using the State HCAS Tool." Federal Highway Administration Office of Transportation Policy Studies. May 2000.

2. "Excessive Truck Weight: An Expensive Burden We Can No Longer Support" United States General Accounting Office, 1979.

3. "Justification Review – Motor Carrier Compliance Program, Florida Department of Transportation, Report 98-86, June 1999." Office of Program Policy Analysis and Government Accountability, Florida Legislature.

4. "1997 Federal Highway Cost Allocation Study Final Report" U.S. Department of Transportation Federal Highway Administration, May 2000.

5. Federal Highway Administration. Bureau of Transportation Statistics.

6. Pavement Guide. Washington Department of Transportation.

Appendix A

Equivalent Single Axle Loads

Engineers have developed the concept of Equivalent Single Axle Loads to allow the expression of the expected damage due to any loaded axle weight in terms of the expected damage from a single standard – a commercial truck axle with four tires, loaded with 18,000 pounds. The use of ESALs has been common in the design of pavements in the United States for many years.

Since cost responsibility is associated with the damage a vehicle is expected to cause, Figures 1 and 2[5] illustrate the importance of increasing axle weight in allocating cost responsibility. In the figures, the term "kip" is used for a thousand pounds. A tandem axle is a pair of axles that are no more than eight feet apart.

A nominal axle weight for a passenger vehicle is 2,000 pounds, which does almost no harm to the pavement or to bridges. Commercial trucks (especially those over the legal weight) do significantly greater damage to pavements than even legally loaded trucks.

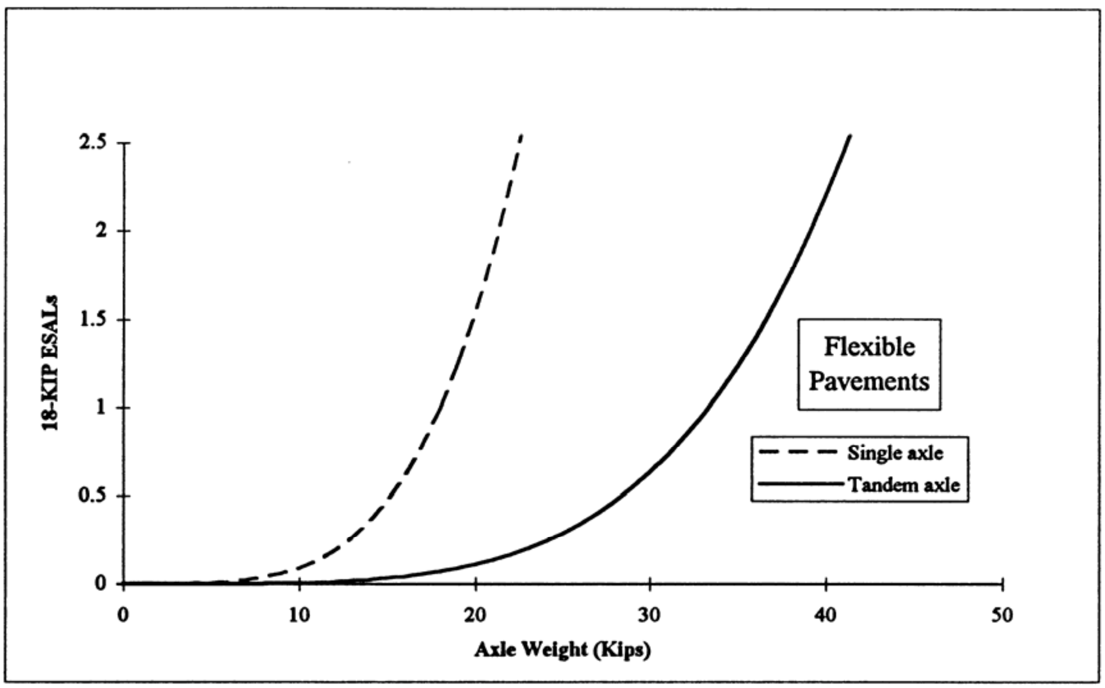

Figure 1. Relationship between axle weights and pavement damage for flexible pavements[5].

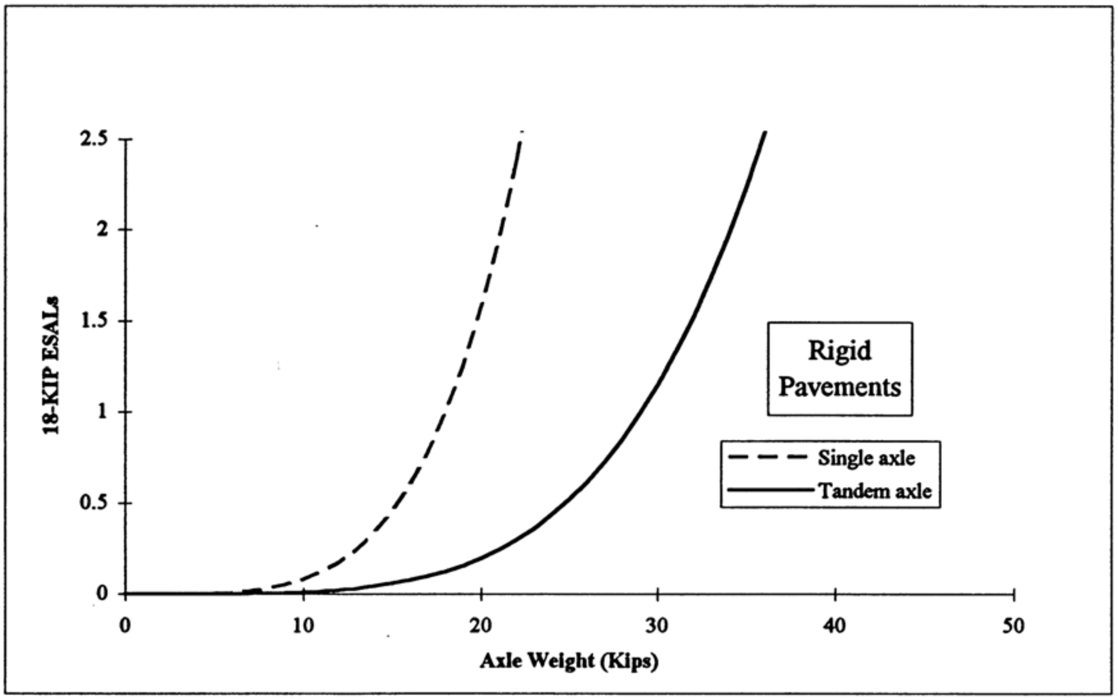

Figure 2. Relationship between axle weights and pavement damage for rigid pavements[5].

Examples of some common axle configurations are shown in Figure 3.

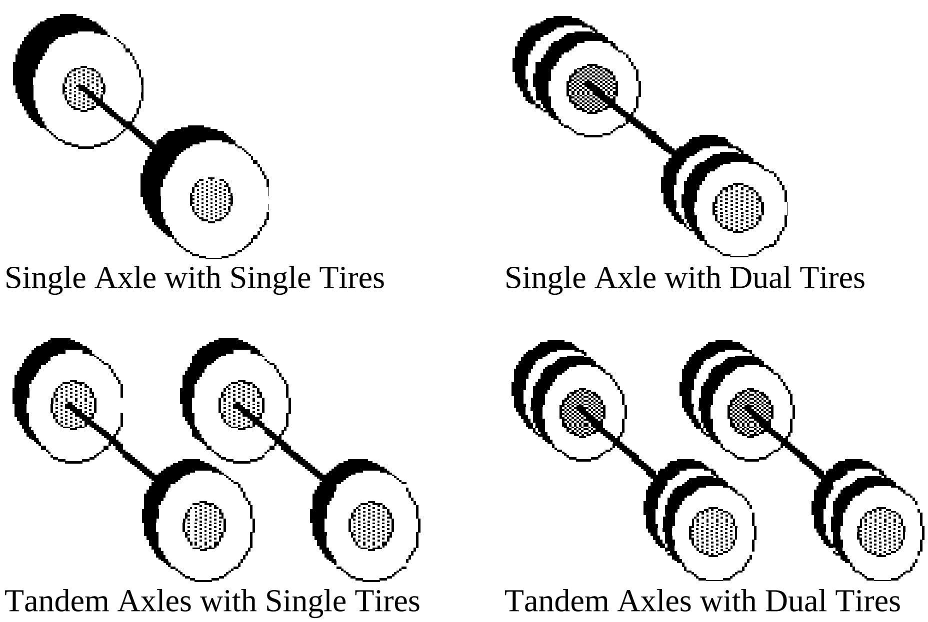

Figure 3. AASHTO Axle Configurations[6]

The ESAL value indicates the amount of pavement damage a specific axle or axle group will cause relative to a standard axle. This standard is a single axle with four tires and

18,000 pound load. The relationship between ESALs and single or tandem axle loads was shown in Figures 1 and 2.

A rule of thumb for computing the number of ESALs for any single axle is to determine the ratio of the weight of the unknown axle to 18,000 pounds and raise that ratio to the fourth power. The computation for a 30,000 pound single axle is illustrated here [6]:

$$\left(\frac{30{,}000 \ lb}{18{,}000 \ lb}\right)^4 = 7.7$$

Some typical values for ESALs are shown in Table 2[6].

Table 2. Typical ESAL Values[6]

Axle Type (lbs)	Axle Load		Load Equivalency Factor (from AASHTO, 1993)	
	(kN)	(lbs)	Flexible	Rigid Table 2. Typical ESAL values[6].
Single axle	8.9 44.5 62.3 80.0 89.0 133.4	2,000 10,000 14,000 18,000 20,000 30,000	0.0003 0.118 0.399 1.000 1.4 7.9	0.0002 0.082 0.341 1.000 1.57 8.28
Tandem axle	8.9 44.5 62.3 80.0 89.0 133.4 151.2 177.9 222.4	2,000 10,000 14,000 18,000 20,000 30,000 34,000 40,000 50,000	0.0001 0.011 0.042 0.109 0.162 0.703 1.11 2.06 5.03	0.0001 0.013 0.048 0.133 0.206 1.14 1.92 3.74 9.07

It is worth noting that more than three thousand 2,000 pound axles (typical of a passenger car) are required to produce the same amount of pavement damage to an asphalt pavement as one 18,000 pound truck axle.