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WEIGHT ANALYSIS OF TRUCKS ENTERING THE UNITED STATES THROUGH THE PORT OF LAREDO, TEXAS

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INTRODUCTION AND BACKGROUND

In 1994, total U.S.-Mexico trade touched $100 million, making Mexico one of the United States' leading trading partners. Within this trade pattern, the economic linkages between Texas and Mexico are profound. According to the U.S. Department of Commerce, Texas ranks first among the 50 states in exports to Mexico. Almost 27 percent of U.S. exports to Mexico crossing the Texas border originate outside the state and since 1987, Texas has captured half of the total U.S. export growth in products bound for Mexico.

In December, 1994, the Mexican currency devalued significantly with a predictable impact on trade. First, U.S. exports to continental Mexico were substantially affected, but not those products being exported into the maquila industries. Since many Mexican imports were now substantially less expensive, a stimulus was given to Mexican exports to the U.S. Previously, in terms of trade patterns, more trade was moving south than north, and the peso devaluation has corrected this at a number of ports.

Currently, U.S. trucks are not allowed to operate in Mexico and this has stimulated the rise of a number of partnerships between U.S. and Mexican trucking companies (Ref 1). These partnerships have had a profound impact on patterns of trade and have also given rise to arrangements such as drayage, which have been viewed by others as unnecessary impediments that raise costs and cause inefficiencies. On December 18, 1995, as part of the North American Free Trade Agreement (NAFTA) legislation, Mexican and U.S. trucking entities will be able to operate along the contiguous border states of both countries. In other words, trucks from Mexico will be able to take loads anywhere within Texas rather than partnering with a U.S. company at gateways such as Laredo, El Paso, Reynosa or Brownsville.

Research in Mexico has identified a substantial problem with overloaded vehicles of all types. Not only are Mexican limits higher than those currently operating within the U.S., but lack of enforcement results in them being totally ignored by the majority of truckers. This has resulted in problems within the Mexican trucking industry and has led to accelerated pavement damage along its highway system. The Texas Department of Transportation (TxDOT), cognizant of the December 18 opportunity for Mexican trucks to enter its state, was concerned about the NAFTA impacts on its highway infrastructure. As part of the TxDOT research program, a study was awarded to the Center for Transportation Research at The University of Texas at Austin to look into these impacts, and these have ranged from policy impacts to truck weight analysis (Ref 2). As part of the weight analysis, the study team installed a weigh-in-motion system at the Port of Laredo, the most important port of entry for continental trade patterns (Ref 3). Lessons learned at that site were to be applied to other important border crossings, notably El Paso.

This paper reports on the selection, installation and operation of the weigh-in-motion site at the Laredo port of entry and presents preliminary data from this site.

WEIGH-IN-MOTION SITE SELECTION AND CONFIGURATION

An earlier study (Ref 4) identified that virtually all loaded commercial truck traffic passed over a single bridge to be subsequently processed through an adjacent U.S. Customs yard. Once processed, the motor carriers were allowed to continue their journey within the commercial zone on designated truck routes. Selection of the weigh-in-motion (WIM) site was made with the intent of capturing the axle loadings of all trucks processed through this port-of-entry prior to their dispersal on Laredo streets downstream from the customs yard.

Negotiations were made with City of Laredo officials to develop a 4.3m by 61m (14 ft by 200 ft) segment of straight pavement, situated just 125m (407 ft) from the customs yard exit gate, into a WIM site. The selected site had the benefit of consisting of only a single outbound lane (total pavement width was just 8.8m (29 ft)); the total length of straight pavement was more than 122m (400 ft) with no intersections except for an entrance to a city-owned parking lot (Fig 1). The parking lot was outfitted with several luminaries, one of which would ultimately provide the power source for the WIM processor. The existing pavement was an asphalt concrete structure more than 10 years old. Although it showed no significant signs of distress, concern regarding eventual rutting of the weigh-site approaches by channeled truck traffic led to the subsequent proposal that the City replace this segment of the outbound lane with 0.30m (12 inch) continuously reinforced concrete pavement (CRCP). While telephone access was not immediately available to allow remote downloading of data, the City was able to provide this service within five weeks of the initial system on-site calibration.

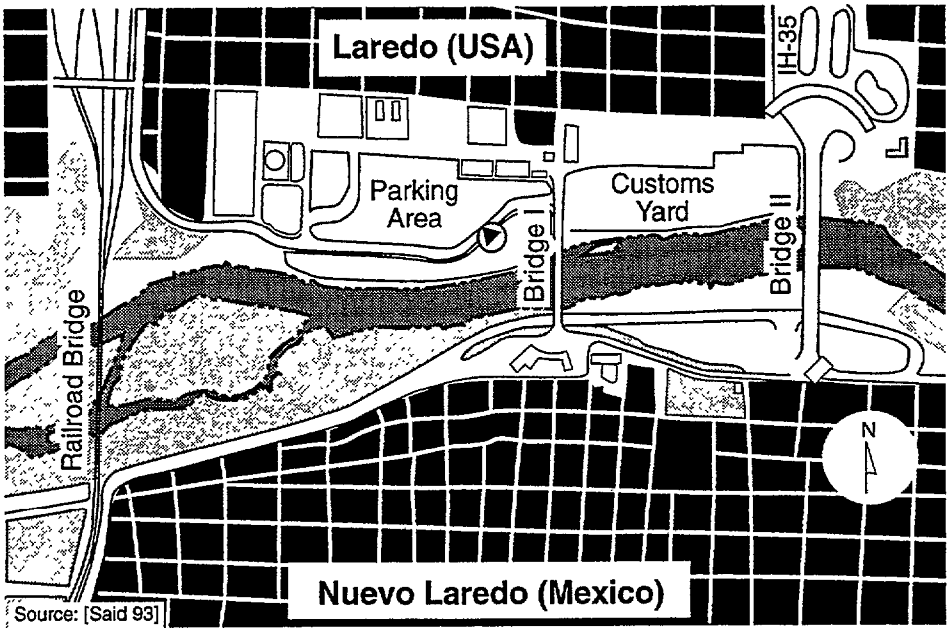

Figure 1 Location of the 1319 Study WIM site at Laredo

The weigh-in-motion system chosen for the Laredo site was a PAT (Pietzsch Automatisierungstechnik) Equipment Corporation's DAW 100 system. The system incorporates bending plate transducers (one placed in each wheel path), in which resistance strain gages are bonded directly to the bottom surface of transverse grooves in a flexible steel plate. When the transducers are dynamically "loaded" by a passing vehicle, the resultant signal is interpreted by a processor to produce an estimate of the vehicle's static wheel and axle loads. Initial vehicle detection is accomplished using a standard 1.8m (6 ft) square inductive loop, which when "activated" initiates a new vehicle record. A staggered weigh pad (transducer) pattern was used to allow calculation of vehicle speed, based on the known 1.8m (6 ft) offset (Fig 2). The dynamics of the vehicle departure from the customs yard, proceeding from a complete stop, imply that the traffic will probably be accelerating when crossing the weigh pads (transducers). Since this condition has the potential of affecting the accuracy of the axle-load record produced, the algorithm used to process impulse signals from the weigh pads determines the speed of each axle and calculates axle spacing by multiplying the average speed of two adjacent axles by the time interval between these axles arriving at one of the weigh pads. A constant acceleration is assumed over this short time interval. Truck speeds generally ranged between 24 and 48 kph (15 and 30 mph) over the transducers.

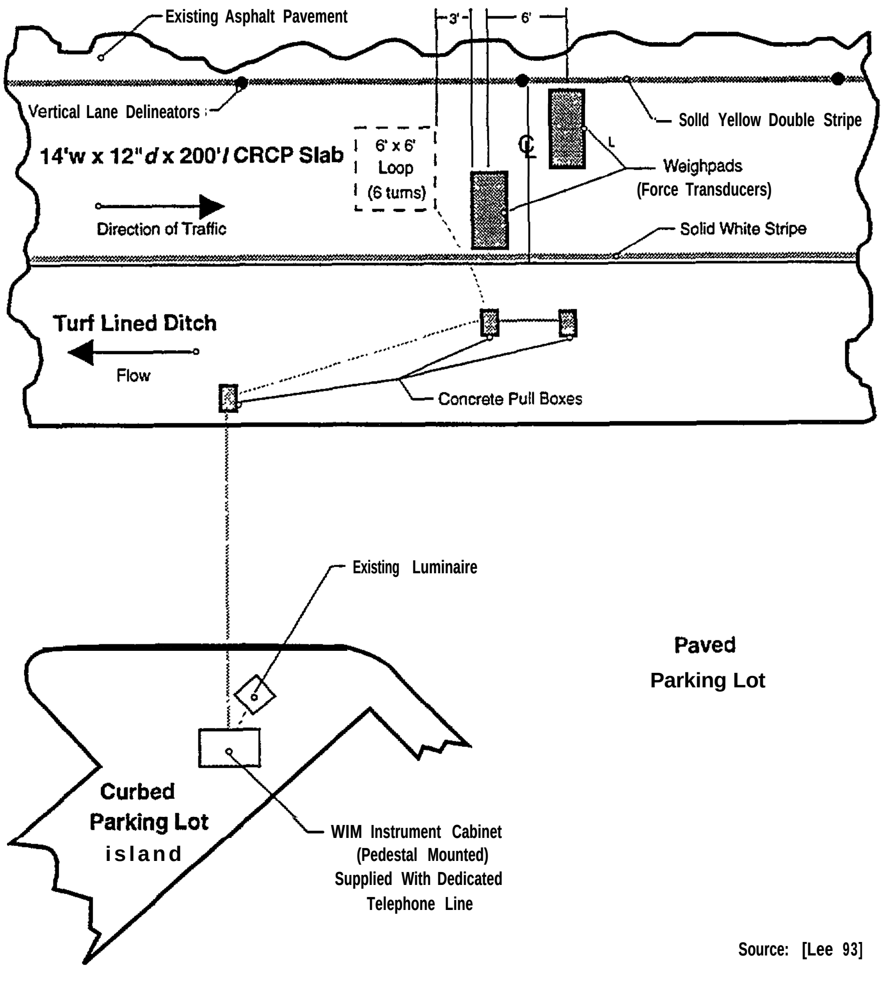

Figure 2 Project 1319 WIM *configuration at Laredo*

System Calibration

Initial system calibration was accomplished using a three-axle, baffled tank truck, with known static axle loads and spacings[1] Calibration proved to be the most time-consuming aspect of the commissioning process. Over 100 passes were made before the magnitude and repeatability of the responses were considered sufficiently close for final tuning. This final tuning was accomplished in the last six runs with results somewhat less consistent than anticipated, considering the typically low site speeds under controlled operating conditions. Values for the gross-vehicle weight were within six percent of the static gross-vehicle weight; front axle loads were within 11 percent of the static axle load. Individual rear axle loads, when compared against their respective static loads, were within the l0-12 percent range. When considered as a tandem set, differences in axle-group load were within seven percent of the set's static load.

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1 The calibration truck used was an FHWA Type "6" three-axle, single unit truck. Ideally, a variety of truck types should be used as specified in ASTM E1318, Section 7.5. However, because of traffic control difficulties, this was impractical.

A follow-up calibration session was conducted in early December 1993 using a four-axle tractor-flatbed combination (FHWA Type "8") hauling a backhoe. This exercise required only very minor correction factor adjustments to those installed during the October exercise. An analysis of these vehicle records shows that the values for the gross-vehicle weight ranged within about four percent of the static weight; steering-axle results were within eight percent of the static load, and the trailer-tandem load was within six percent of the static load.

LAREDO WIM DATA SUMMARIES

A number of issues and assumptions had to be first resolved prior to evaluation of the collected data in a concise manner. Although the WIM. site had been properly chosen from the strategic standpoint, a major site operational shortcoming was not resolved for several months. Additionally, a system software parameter was not set to a value appropriate for the relatively slow-moving traffic characteristic of the site and new routines had to be written and installed. Decisions were also necessary regarding categorizing the predominant truck classes and assumptions made regarding empty truck weight thresholds once the class categories were established. Finally, a pavement type had to be assumed in order to calculate relative damage factors using the original AASHO damage relationship formulas.

Resolving Site And System Shortcomings

Proper lane-tracking of trucks exiting the customs yard proved to be one of the most difficult issues affecting the collection of representative data. Observations made during site visits dating back to the initial calibration date indicated that many truck drivers practiced lane straddling, or even drove their trucks completely within the on-coming lane boundaries. Some of the improper lane tracking was caused by other motor carriers parking for short periods of time on the shoulder, while at other times it appeared that drivers were attempting to cut the curve preceding the weigh site to improve their acceleration out of the customs yard. Initially, the solution was thought to lie in the application of double-yellow centerline stripes and "no parking" signs along the shoulder. However, once these were applied, it was apparent that additional channeling measures were necessary as the striping and signs were largely ignored. This conclusion was confirmed by a six-hour physical and video surveillance of the site. A workable solution lay in the application of vertical centerline delineators for an interval beginning 100 ft prior to the weigh site, and continuing just past the transducers. These delineators had to be flexible enough to preclude damage to trucks which accidentally strayed into the centerline. Once the City of Laredo applied these, the number of vehicle records processed on an average weekday increased from about 900 to nearly 1400, or by about 55 percent.

The second major shortcoming involved the correction of presence indication parameters within the PAT processor. While calibrating a similar WIM system near the Zaragosa Bridge in El Paso, a PAT technician discovered that certain default parameters were inappropriate for the slower-moving combination vehicles which typified the traffic at both the El Paso and Laredo sites. Default settings would cause the presence signal to terminate between the tractor and trailer of combination trucks when moving at speed less than about 15 mph. As a result, two records would often be generated for combination trucks instead of a single correct record. Proper axle loadings were generated, but it was difficult to positively categorize the vehicles involved and the errant parameters were adjusted by telemetry.

Analysis Time Frame and Tools

The combination of corrections just cited was successful in reducing the number of error files generated from 20 percent to less than 5 percent of the daily total. Because it was difficult to state with any degree of confidence how representative the recorded loads were of the entire population, and what types of loads were typically associated with a given type of truck configuration, only records which were generated following both corrections were used in these analyses. The closing period for data collection was mid-July 1994, and this paper covers data collected over a period of approximately six weeks.

Data processing was conducted on a microcomputer (IBM compatible), using two software applications. The first application, developed in-house at The University of Texas at Austin[2], translated binary encoded records retrieved from the on-site DAW 100 processor into ASCII (text) format. Once the files were translated, a series of Microsoft EXCEL@ macros were developed to sort records by truck class and load-status, calculate ESALs, group load data for histogram presentation, and produce various summaries. The initial sort macro also extracted records containing various specified irregularities which made them inappropriate for further analysis as standard truck records.

Truck Population Composition

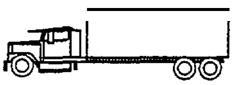
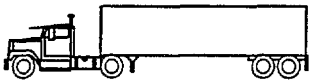
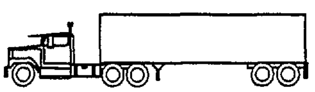
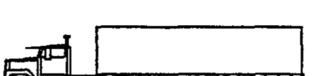
As a preliminary sorting procedure, the raw database was split into records by axle count. Trucks crossing into Laredo generally fall into five axle-count categories (numbering two through six), with a small percentage (less than 0.5 percent) of combinations above six axles. Additionally, combinations entailing more than one trailer were found to appear quite infrequently. These last two categories are not included in the summaries which follow.

2 This programming was accomplished by Liren Huang, Research Assistant, The University of Texas at Austin, Department of CivilEngineering.

A percentage of motor carriers operating within the border commercial zones are involved in the back-haul of empty trucks and trailers. Further dividing the database into categories of empty trucks, and those with at least a partial load, allowed for a closer look at data records belonging to the loaded trucks which are responsible for the overwhelming proportion of highway damage. Empty weight thresholds were chosen to delimit load status within each predominant truck class. Loaded trucks accounted for approximately 80 percent of the total daily count; their weekday distribution can be seen in Table 1.

Table 1 Daily Distribution of Loaded Trucks*

Table 5.2 Daily Distribution of Loaded Trucks*

Axle Count	Predominant Configuration	Average Daily Count	Percent of Total Count	Average Daily ESAL's	Percent of Total ESAL's	ESAL Factor
2		57 (12)	3.8 (2.7)	12 (6)	1.1 (2.0)	.21 (.50)
3		58 (15)	3.9 (3.3)	22 (6)	2.0 (3.1)	.38 (-40)
4		324 (107)	21.5 (23.4)	277 (110)	25.6 (36.1)	.85 (1.03)
5		732 (222)	48.5 (48.6)	655 (175)	60.6 (57.8)	.89 (.79)
6		28 (1)	1.8 (0.3)	102 (1)	9.4 (0.4)	3.64 (1.W
	Total	1199 (357)	79.5 (78.3)	1068 (29)	98.7 (98.3)	

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Truck Loading Profiles: Assessment of Compliance with U.S. Legal Limits

U.S. load limits on Interstate highways for single and tandem axles of 89 and 151kN (20 and 34 kips) respectively, and gross-vehicle weight of 356kN (80 kips) were used in these analyses as reference points. In addition, a limit of 53.4kN (12 kips) was used for the steering axle as this value corresponds roughly with the maximum allowed when considering load per inch of tire tread width limits stated in Texas law. Also, a limit of 187kN (42 kips) was used as the maximum permissible load on a tridem axle group through direct application of the federal bridge formula, assuming a 2.4 m (8 ft) interval between the first and third axles (Ref 5).

Next, axle loads and gross-vehicle weights from the Laredo truck files were converted into percentages of the allowable legal limit, and histograms were produced for each axle group or gross-vehicle weight using bin increments of 10 percent. Steering axles for all truck classes were analyzed together, while the remaining axle groups and gross-vehicle weight were analyzed separately for each vehicle class. Summaries were then generated in two forms: aggregate profiles showing percentages of trucks (by class) observed during the analysis period relative to their steering axles' load (as a percentage of the allowable legal limit), and aggregate profiles showing the remaining axle groups and gross-vehicle weight, grouped by vehicle (axle) class. Figure 3 is an example of the latter for five-axle trucks; total quantity of vehicles sampled are shown in parenthesis beneath the applicable axle group load or gross-vehicle weight. These profiles enable detection of significant load violation trends at a glance. Supplemental aggregate loading profiles of selected axle groups or gross-vehicle weights were then run, showing the load distribution in terms of actual loads, along with the cumulative percentage of axles/vehicles exceeding any given load category. Figure 4 is an example of this type of summary for semi-trailer tridem axles belonging to six-axle class trucks.

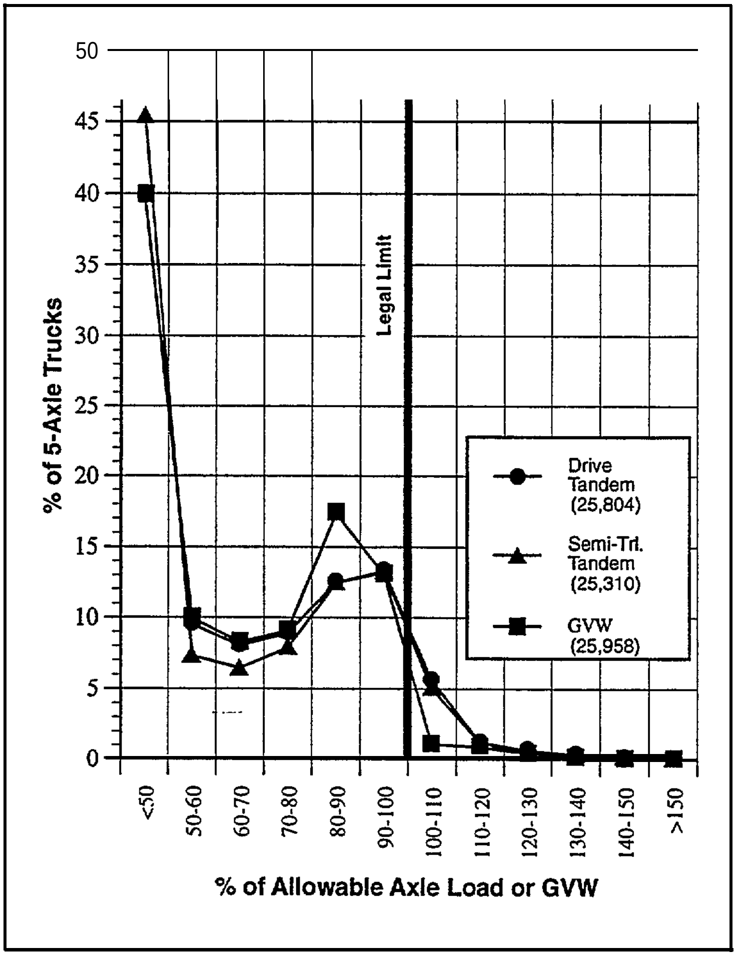

Figure 3 Five-axle truck loads: Weekday aggregate profile, 6 June - 15 July 1994

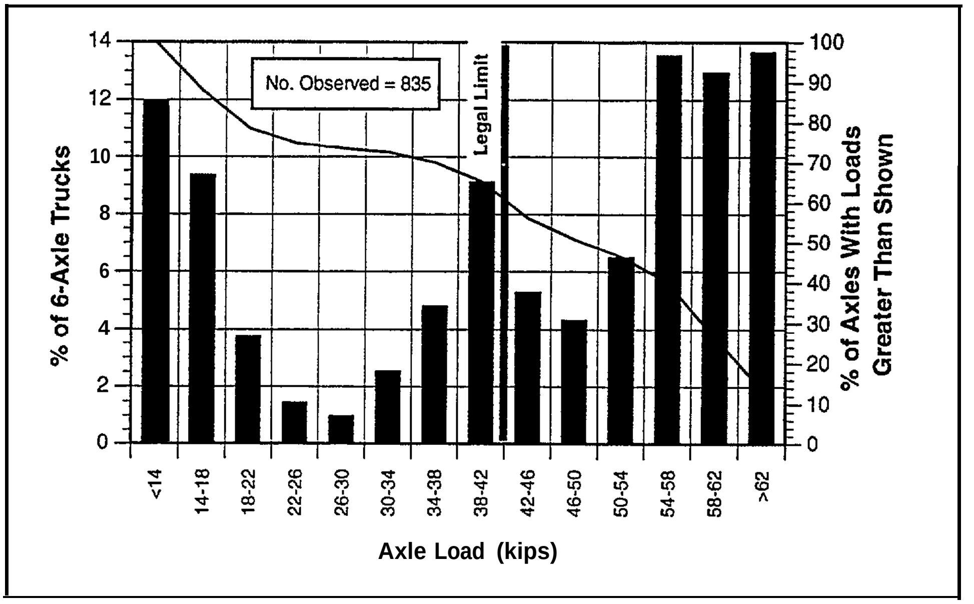

Figure 4 Axle loads (semi-trailer tridem), 6-axle trucks: weekday aggregate profile, 6 June - I5 July I994

The findings supported by these summaries are perhaps not what were expected, considering the conclusions of a 199 1 truck weight survey conducted in continental Mexico (Ref 6), and considering the lack of load monitoring and enforcement taking place on the border at the present time. For example, the Mendoza study indicated that nearly 30 percent of the 18-wheeled (five-axle) tractor-trailer combinations exceeded Mexican legal weight standards on average by 18 percent, and over 40 percent of the six-axle combinations pulling semi-trailers equipped with tridem axles were overweight on average by 28 percent. When it is recalled that a fully-loaded Mexican truck operating under “legal” conditions has axle loads 10 to 17 percent heavier than a legally loaded U.S. truck, it becomes apparent that these overloaded vehicles can cause very significant pavement damage. Analyses conducted in this study indicate that Mexican motor carriers passing through the U.S. Customs yard in Laredo are largely in compliance with U.S. load limits. The single exception was the six-axle class, which were on the whole significantly overloaded.

Readily apparent from the loading profiles generated in this study is the fact that modal loads (axle and gross-vehicle weight) for all classes of truck are generally less than one-half of the legal limit, with the exception of loads on steering axles. Steering axle loads rarely exceed the informal maximum of 53.4kN (12 kips). Those which do exceed this limit do so by relatively small amounts. The greatest offender was the six-axle class; the study showed that less than five percent of their steering axles were overloaded, the bulk of these exceeded the limit by less than 10 percent.

With the two-axle class, less than two percent of the drive-axle loads or gross-vehicle weights exceeded U.S. legal limits. These same load parameters for seventy to 80 percent of trucks in this class are below 50 percent of the allowable. This condition may be a reflection of loads which tend to “cube-out” in these smaller trucks which are primarily used for local delivery at the border.

An analysis of the data collected over the study period indicated that there are two principal axle configurations in the three-axle truck class. The single unit variety constitutes approximately 83 percent of the total three-axle population; the remainder consist of tractor-semi-trailer combinations. The later configuration in general shows little over-loading tendency. Within the three-axle single unit configuration, the tandem-axle groups show some tendency for being overweight, with about four percent of these axle groups more than 10 percent above the legal limit. Modal loading for this axle group was in the 44.5 - 62.3kN (10 -14 kips) range.

The most common configuration of four-axle trucks (95 percent of this class) is the two-axle tractor pulling a tandem-axled semi-trailer. The drive (single) axle on the tractor is particularly suspect for overloading since the tandem-axled semi-trailers are ordinarily pulled by three-axle tractors on the long haul. Drayage companies, however, often use older two-axle tractors unfit for long-hauls to shuttle these semi-trailers back and forth across the border over relatively short distances. Approximately 10 percent of the single drive axles on four-axle trucks exceed legal limits by at least 10 percent, with from one to two percent exceeding allowable limits by more than 50 percent. Modal loading for this axle group was in the 35.6 - 44.5kN (8 - 10 kips) range.

Five-axle tractor-semi-trailer combinations are the dominant vehicle conducting transborder hauling at this port-of-entry. They constitute roughly 97 percent of all five-axle trucks and 60 percent of all trucks with respect to all classes combined. One might suspect that a significant percentage of these trucks are overweight, but this is not the case at the Laredo port-of-entry. Less than two percent exceeded the gross-vehicle weight limit by more than 10 percent. Less than three percent of drive-tandems and semi-trailer tandems exceeded load limits by more than 10 percent (Fig 3). Loading of five-axle trucks appeared to be bi-modal, representing groups at the empty and nearly full extremes.

As a group, six-axle tractor-semi-trailer combinations are the only class which is consistently grossly overweight. Their dubious notoriety is somewhat mitigated by the fact that they constitute only two percent of the observed truck population. Over the period of analysis, drive tandems, semi-trailer tridems (Fig 4), and gross-vehicle weights associated with 45 - 50 percent of these vehicles were more than 10 percent above the legal limit. Between 10 and 15 percent of the observations in these load categories exceeded limits by more than 50 percent.

Relative Damage and ESAL Factors

The assessment of relative damage used in this study employed the concept of the equivalent single axle load (ESAL) and damage relationships developed at the AASHO Road Test conducted near Ottawa, Illinois, from 1958 to 1960. The original AASHO pavement performance equations are used in this study (with the exception of the extrapolation allowing for assessment of damage caused by tridem axle groups) for simplicity and generalization not requiring considerations of varying roadway resilient module or reliability for varying levels of traffic used in design of pavements for a specific location[3]. Because ESALs are dependent on pavement type, thicknesses or structural number, and terminal serviceability parameters, some assumptions were necessary prior to an assessment of damage due to observed truck traffic. For purposes of this study, analysis focused strictly on flexible pavements with a structural number of "5" and terminal serviceability of "2.5." These assumptions were made with the view that asphalt concrete pavements are the dominant type and these parameters are fairly typical of high-type pavements constituting the majority of the long-haul network in Texas.

Equivalent single axle loads were assessed for each type of axle group for each basic class of truck. All ESALs produced by trucks within each distinctive class were summed, then divided by the truck count within that class. This produces an "ESAL factor" summary statistic, the average number of ESALs per truck by class, which equates to average relative damage. Preliminary separation of truck records into empty and loaded categories gives an appreciation for the relative damage caused by trucks carrying at least a partial load against that caused by empty trucks, and the relative damage of one category of trucks against another. Returning to Table 1, relative damage statistics are given for each class of truck for those vehicles with at least a partial load. Even though trucks which are at least partially loaded constitute about 80 percent of the total truck population, they generate almost 99 percent of the damage. During weekdays, loaded five-axle trucks comprise just under 50 percent of the entire population and contribute slightly more than 60 percent of the total damage. Because of their extreme overloading, six-axle vehicles . contribute over nine percent of the damage although they constitute slightly less than two percent of the total population.

Weekly variations in weekday ESAL factors for the analysis period are shown in Figure 5. While the average loading of most truck classes appears to be rather consistent, the loading **of** six-axle trucks tends to be high variable.

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3 Inclusion of these factors are considered significant modifications incorporated in the 1986 AASHTO Guide affecting pavement design and performance relationships [HHZ 94, AASHTO 93].

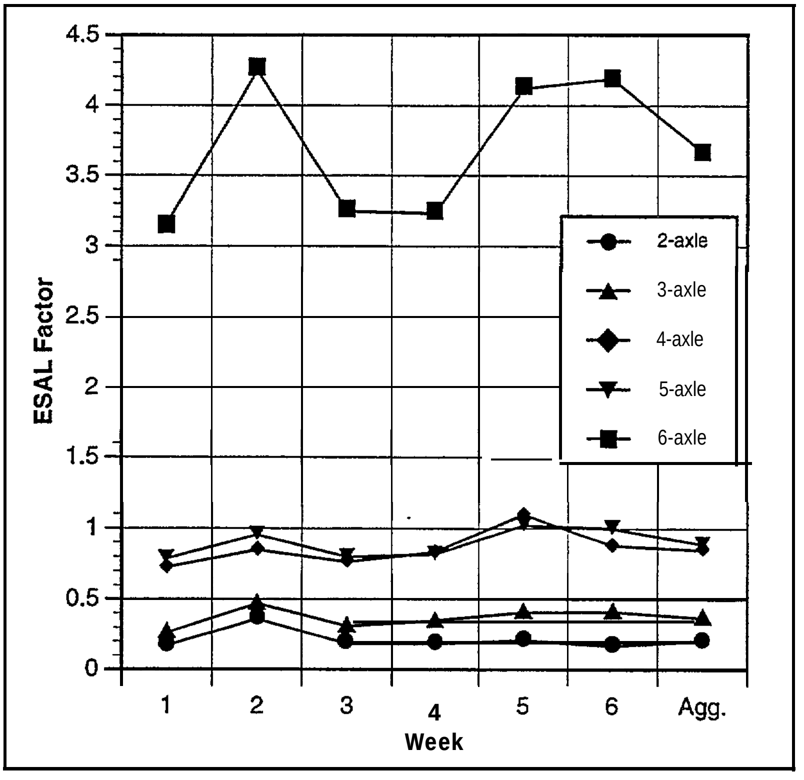


Figure 5 Weekly variations in weekday ESAL factors

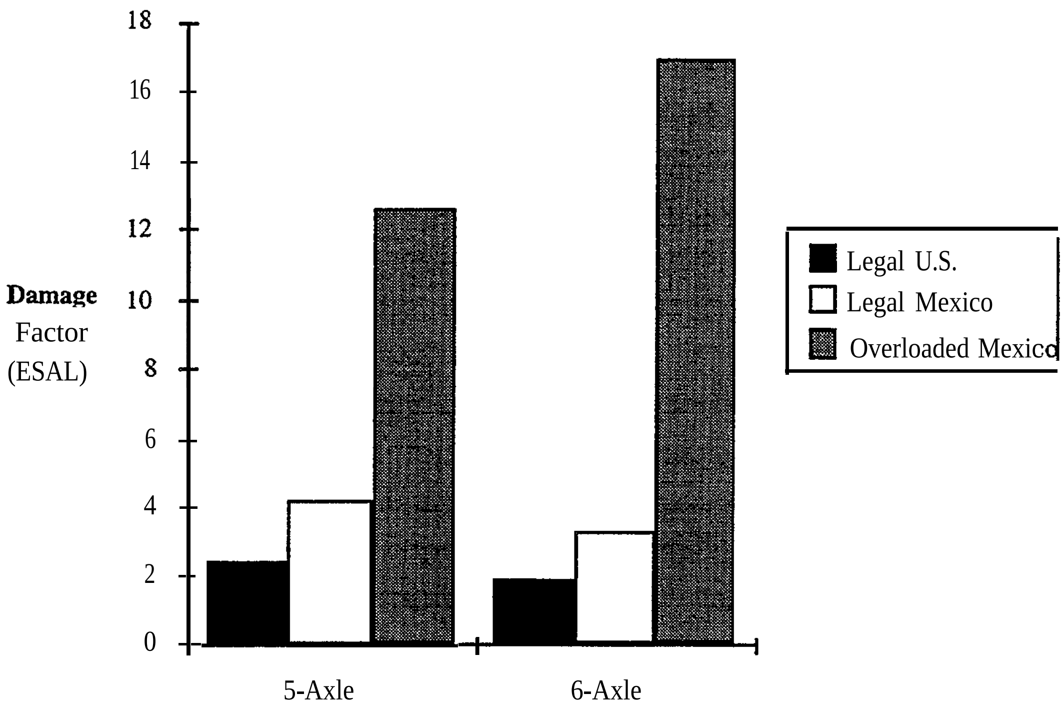
A comparison of ESAL factors derived from the Laredo site during the analysis period against a two-day inventory of over 6,500 truck records collected by a four-lane WIM system located on IH-35 south of San Antonio[4] provides insight into relative damage between corresponding truck classes operating in the respective areas. All truck classes representative of the Laredo site have higher ESAL factors than corresponding truck classes operating at the IH-35 site, except for the two-axle group which was 22 percent lower. ESAL factors for three- and four-axle trucks operating at the Laredo site averaged 46 percent and 85 percent higher respectively. Little difference exists between respective five-axle populations, the dominant truck class at both sites, with Laredo **ESAL** factors averaging just seven percent higher. The typical six-axle truck from the Laredo site would cause approximately four and one-half times the damage to a selected pavement as a six-axle truck typical of the III-35 site.

Comparisons with Mexico

As previously noted, staff at the Mexican Institute of Transportation have carried out substantial work into the problems of overloaded Mexican trucks (Ref 6). One of the principal products was a 1991 truck weight survey conducted in continental Mexico at nine sites, covering a

4 Records used were from the Lytle WIM site located 5.3 miles south of Loop 1604 for the 48-hour period 7-8 March 1994.

96-hour period and incorporating the weighing of approximately 120,000 vehicles, or one-third of Mexico's truck fleet. The results of this study demonstrated the extent of truck overloading in Mexico. As an example, the IMT study indicated that nearly 30 percent of the 18-wheel, five-axle tractor-trailer combinations exceeded Mexican legal weight standards on average by almost 20 percent, and that over 40 percent of the six-axle combinations pulling semi-trailers equipped with tridem axles were overweight by an average of almost 30 percent. When it is recalled that a fully-loaded Mexican truck operating under legal conditions has axle loads in the range of 10 to 17 percent heavier than legally loaded vehicles, it becomes apparent that such vehicles can cause substantially significant increases in pavement damage. Figure 6 shows pavement damage from the overloaded vehicles for both five-axle and six-axle combinations and impact on the damage of Mexican overloaded vehicles can be clearly shown.



Source: IMT, 1992

Figure 6 Pavement damage from truck overloads

A clear concern is the implication of this for entry into Texas after December 18. TxDOT officials cannot afford to allow the entry of such loaded vehicles into the state, running over a variety of highways, some totally inadequately designed for such heavy loads. The preliminary data from the weigh-in-motion device shows that only the six-axle tridem combinations are currently entering the U.S. in an overloaded state and not only are their numbers relatively few, but they do not currently go beyond the commercial zone specified for border trade. Typically, such vehicles go to consolidator and shipping points where they are reconfigured into loads that meet current Texas and U.S. standards. The vehicle then returns to Mexico for further work. If the current patterns of border truck movements were to hold after December 18, then there may not be the wave of heavy vehicles entering the state that was previously indicated from the Mexican research. However, under NAFTA, substantial changes can be made and it is possible for consolidation to take place in any city along the trade corridors. Currently over one rnillion truckloads move on I-35 through the state of Texas, so it might be possible for consolidators to move to Dallas, and then for heavy loads to move along that route unless strict enforcement has taken place.

SUMMARY

The weigh-in-motion site at Laredo has been successfully modified to accurately read loaded vehicles traveling at slow speeds out of the Customs inspection yards. Preliminary data show that the typical vehicle used in U.S.-Mexico trade, the 18-wheeler semi-trailer, is not currently entering the U.S. in an overloaded state. And though the six-axle articulated vehicle is substantially overloaded, almost all are broken down within a few kilometers of the border into legal loads for onward delivery in Texas and to adjoining states.

Research under another LBJ School study (Ref 7) has shown that interviews with truckers emphasize the importance of partnerships responsible for most of the current trade movements. U.S. shippers and truckers and transportation companies instruct their Mexican partners to load to current U.S. standards with respect to all shipments passing beyond the commercial zone around the ports of entry. Furthermore, this research has shown that truckers to not want to operate overloaded vehicles for reasons of the damage caused to their vehicles and associated costs and the driving down of rates within the industry that overloading frequently produces.

One of the difficulties that truckers and transportation companies face with respect to choices after December 18 is that no clear set of rules currently exists so that truckers cannot plan effectively for changes to the current system. However, it can be said that if partnerships weaken, there will be new incentives to overload vehicles, especially where there is no clear guidance and a lack of enforcement. The key need at this stage is the development of a coherent policy associated with truck loading together with a clear statement of rules and an effective policy of enforcing these for reasons of industrial and intermodal competitiveness, the protection of infrastructure, and safety issues relevant to other highway users.

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ANALYSIS OF THE TRUCK INVENTORY AND USE SURVEY FROM THE TRUCK SIZE AND WEIGHT PERSPECTIVE FOR TRUCKS WITH FIVE-AXLES OR MORE

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Authors: Alan Clayton, et al.
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The primary objectives of the U.S. Department of Transportation's Comprehensive Truck Size and Weight (TS&W) Study are to:

- assess the potential economic, safety, and environmental impacts of changing existing TS&W limits; and
- identify opportunities to increase the efficiency of freight transportation while preserving safety and highway infrastructure.

Reports which have been completed for the TS&W Study, to date, include the following:

(1) Synthesis of Truck Size and Weight Studies and Issues
(2) Analysis of the Truck Inventory and Use Survey from the Truck Size and Weight Perspective for Trucks with Five-Axles or More

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Executive Summary

This report, as part of the U.S. Department of Transportation (DOT) Comprehensive Truck Size and Weight (TS&W) Study, provides factual information about and analysis of the U.S. freight hauling truck fleet, and is based on the Truck Inventory and Use Survey (TIUS) data bases from 1992 and 1987. The Bureau of the Census collects truck data every five years with 1992 being the latest data available. The TIUS can be used to help understand the U.S. truck fleet make-up, size, uses, location, and type of commodities hauled at the national and regional levels. This information will be used to present a picture of the U.S. truck fleet and its uses as well as to evaluate the potential national/regional TS&W policy options.

The TIUS provides data on the physical and operational characteristics of the U.S. truck fleet. The survey contains a sample of privately- and commercially-owned trucks. The survey also covers trucks used for personal transportation and freight hauling. The survey sample is drawn from each state's registration records. For example, in 1992, the sample size was over 150,000 trucks which reflected a population of over 60 million commercially- and privately-owned trucks in the U.S.

Since this report supports the U.S. DOT TS&W Study, larger trucks hauling freight are the focus of the analysis. Specifically, trucks with 5-axles or more that contain three types of truck-trailer combinations were analyzed:

- straight truck with one trailer
- truck tractor with semitrailer
- truck tractor with two or more trailing units.

This Executive Summary provides highlights of these analyses of the TIUS data, however, it is not a summary of the entire report. First, some cautions are provided about the use of the TIUS data analyses. Second, information is provided about how the data are organized in the analyses with reference to the portions of the main report that are relevant to each topic area. Third, a brief set of highlights, based on the more detailed analyses and findings contained in the body of this report, provide a snapshot of the 1992 U.S. commercial truck fleet.

Cautionary Note

There are a number of cautionary notes in reviewing this analysis of the TIUS (see Section 1.4 for more detail), including:

- Data reported in the TIUS is based on State registration data and the potential for registration-bias exists.

- Survey and population estimates are by registration state and care needs to be taken in conducting analysis at the state level. For example, triples are reported in Minnesota where the use of such vehicles is not permitted. This may be due to ownership in one state and use in another state.

Vehicle Categorization

In this report, the trucks from the TIUS data base were categorized into vehicle configuration classes, vehicle groups, and state of registration. The vehicle configuration class identifies the way the truck is most often operated or used. Each truck was classified based on three factors:

(1) Vehicle type: straight truck not pulling trailer, straight truck pulling trailer, tractor pulling trailer, tractor pulling two or more trailers
(2) Number of axles on truck or tractor
(3) Number of axles on each trailer.

Based on this categorization, the data were analyzed using five major vehicle configurations (truck, truck + trailer, tractor-semitrailer, tractor + doubles, and tractor + triples) and 3 1 subclasses (see Section 2.1 for detailed descriptions).

Vehicle Groups

In this report, the TIUS data for trucks with 5-axles or more were analyzed by dividing the data into eight vehicle groups, as follows (see Figure 2.2-l in Section 2.2 for descriptions):

- Truck + trailer with 5-axles (2+3 and 3+2)
- Truck + trailer with 6-axles or more (3+3, 4+2, 4+3)
- 3-S2 tractor-semitrailer
- Tractor-semitrailer with tridem axles (2-S3, 3-S3, 4-S3)
- Other tractor-semitrailer (4-S 1, 4-S2)
- STAA tractor + double trailers (2-S l-2)
- Tractor + double trailer combinations with 6-axles or more (all doubles except STAA as defined above).
- Tractor + triple trailers.

Traffic Regions And States

The report organizes the TIUS truck data into five regions (North Central, North East, South Atlantic, South Gulf, and West) and for each of the 50 states and Washington, D.C. as shown in Figure ES-l (see Section 2.3 of the report).

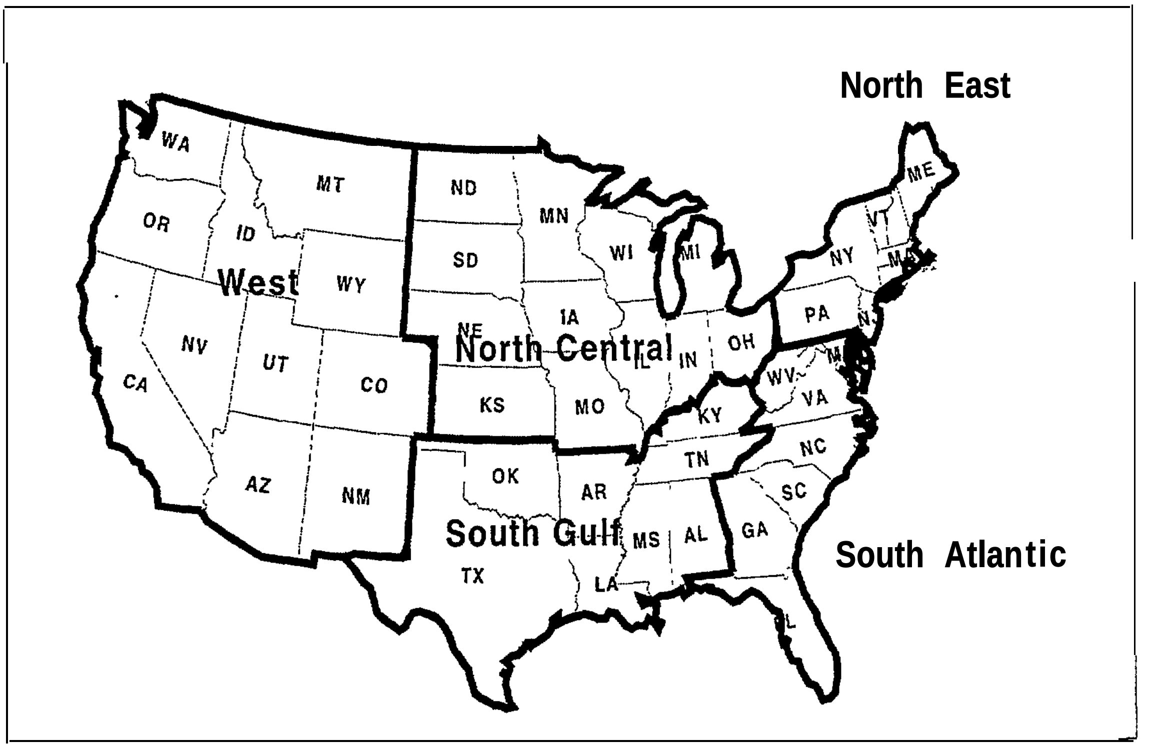

Figure ES-l. Five Regions For Analysis

Body Types

In this report, the TIUS data for trucks with 5-axles or more were analyzed by 11 major body types, as follows (see Section 4.0 for more details):

- Platform (which consists of low boys and basic platform types)
- Van (which includes multi-stop, basic enclosed, drop frame, insulated non-refrigerated, insulated refrigerated, and open top types)
- Auto transport
- Dump truck
- Grain bodies
- Garbage truck
- Livestock truck
- Pole, logging truck
- Tank truck, dry bulk

- Tank truck, liquids or gas
- Other (includes platforms with devices permanently mounted, beverage truck, utility truck, winch or crane truck, wrecker, service truck, yard tractor, oil field truck, concrete mixer, and other).

Commodities Hauled

For the above-mentioned vehicle groups and body types, the TIUS database was also analyzed by principal commodity types (see Section 6.0). There were 29 commodity types ranging from raw materials to manufactured goods.

Highlights of the U.S. Commercial Truck Fleet

The TlUS data provide a comprehensive factual base of U.S. commercial freight hauling trucks. The focus of this report is a selected subset of the U.S. truck fleet, trucks with 5-axles or more, that will most likely be influenced by Federal TS&W regulations and provides data/analysis of fleet size, location, vehicle configuration, body type, principal commodity products hauled, and vehicle operating statistics. Table ES-l provides only a snapshot of the 5-axles or more truck fleet in 1992 and some changes since 1987.

TABLE ES-1
1992 U.S. COMMERCIAL FREIGHT TRUCK FLEET HIGHLIGHTS
(Trucks with 5-axles or more, unless noted otherwise)

Truck Population

✔ 4.1 million total commercial trucks in 1992, a 4% increase from 1987.[1]

✔ Total U.S. commercial truck fleet distribution:[1]
- 68% straight trucks
- 4% straight trucks pulling trailer(s)
- 26% tractor-semitrailer
- 1% tractor with 2 or more trailers.

✔ 976,000 trucks with 5-axles or more (of most interest to truck size and weight analysis) in 1992, a 22% increase from 1987.

1 The data reflect the total commercial truck fleet including trucks with 5-axles or more, but excludes personal trucks.

TABLE ES-1
1992 U.S. COMMERCIAL FREIGHT TRUCK FLEET HIGHLIGHTS
(Trucks with 5-axles or more, unless noted otherwise)

✔ 3-S2 (3-axle tractor with 2-axle semitrailer) trucks
- Most common freight hauling truck
- 19% of total truck fleet[1]
- 78% of trucks with 5-axles or more
- 21% growth in number of trucks between 1987/1992.

✔ Truck + trailers [straight trucks pulling a trailer(s)]
- 4% of total truck fleet[1]
- 7% of trucks with 5-axles or more, little change from 1987.

✔ Tractor-semitrailers with tridem axles (2-S3, 3-S3, 4-S3)
- 2% of total truck fleet[1]
- 7% of trucks with 5-axles or more
- 20% growth in the number of trucks between 1987/1992.

✔ STAA (2-axle tractor with 2-28' trailing units) trucks
- Less than 1% of total truck fleet[1]
- Only 3% of trucks with 5-axles or more, little change from 1987.

✔ Double (2 or 3-axle tractor with 2 trailing units with 3+ axles) trucks
- Less than 1% of total truck fleet[1]
- 2% of trucks with 5-axles or more.

✔ Triple (2 or 3-axle tractor with 3-28' trailing units) trucks
- Less than 1% of total truck fleet[1]
- Less than 1% of trucks with 5-axles or more.

Regional Differences

✔ West Region had 53% increase in trucks with 5-axles or more versus the national average of a 22% increase between 1987/1992.

✔ North Central Region contains the largest number of trucks with 5-axles or more with 38%, while the other four regions have about 15% each.

[1]The data reflect the <u>total</u> commercial truck fleet including trucks with 5-axles or more, but excludes personal trucks.

TABLE ES-1
1992 U.S. COMMERCIAL FREIGHT TRUCK FLEET HIGHLIGHTS
(Trucks with 5-axles or more, unless noted otherwise)

✔ Illinois, California, Texas, Pennsylvania, and Ohio account for 36% of trucks with 5-axles or more.

Trailer Types

✔ 3-S2 Van is the preferred freight hauling truck configuration accounting for 40% of all trucks with 5-axles or more.

✔ Van is the preferred trailer body type, used for 45% of all trucks with 5-axles or more—a 31% growth in the number of trailers with this body type was experienced between 1987 and 1992.

✔ Platform is second preferred trailer type with 22% of all trailers, but no growth from 1987.

✔ Van and Platform trailers comprise about 67% of all body types used to haul freight.

Commodities Hauled

✔ Top 7 carried commodities are: Processed Foods, Mixed Cargo, Building Material, Farm Products, Paper Products, Primary Metal, and Chemicals, respectively [as measured by total fleet vehicle miles of travel (VMT)].

✔ STAA vehicles (2-S1-2) predominately carry Mixed Cargo products (as measured by VMT).

✔ Tridem axle semitrailers predominately carry Building products and Machinery products (as measured by VMT).

Trailer Width

✔ 102" trailer width gaining favor in all major trailer body types (e.g., 65% of 3-S2 Basic Enclosed Vans use 102").

✔ 96" trailer width still preferred with several trailer body types on 3-S2s (platform, grain, liquid tank, and dry tank).

TABLE ES-1
1992 U.S. COMMERCIAL FREIGHT
TRUCK FLEET HIGHLIGHTS
(Trucks with 5-axles or more, unless noted otherwise)

Trailer Lengths

- ✔ 3-S2 Basic Enclosed Van increased use of 53 foot trailer from about 17% in 1987 to 29% in 1992.[2]
- ✔ 3-S2 Reefer Van increased use of 53 foot trailer from about 27% in 1987 to 36% in 1992.[2]
- ✔ 3-S2 Liquid Tank, Dry Tank and Dump have little or no use of 53 foot trailers (less than 7%).[2]

Truck Weights

- ✔ Average tare weight increased about 1,000 to 2,000 lbs., for trucks with 5-axles or more between 1987/1992 (e.g., 3-S2 Basic Enclosed Vans increased from 29,300 to 30,500 lbs.).
- ✔ Average payload weight decreased, about 1,000 to 3,000 lbs., for trucks with 5-axles or more between 1987/1992 (e.g., 3-S2 Basic Enclosed Vans decreased from 37,500 to 36,200 lbs.).

Truck VMT

- ✔ Average annual VMT increased, 5 to 6 percent, for trucks with 5-axles or more between 1987/1992 (e.g., 3-S2 Basic Enclosed Vans VMT increased from 76,300 to 79,700).

[2]An overall vehicle (tractor-semitrailer) length of 65 feet or more was used as a measure of the use of 53 foot trailers for tractor-semitrailer combinations.

Source: 1992 and 1987 TIUS data base.

LIGHT TRUCK CLASSIFICATION
DIFFERENTIATING LIGHT TRUCK TRAVEL ESTIMATES FROM PASSENGER CAR TRAVEL ESTIMATES IN THE THIRTEEN-CATEGORY VEHICLE CLASSIFICATION SCHEME

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Albuquerque, New Mexico

May 5-9, 1996

ABSTRACT

The Federal Highway Administration (FHWA), Traffic Monitoring Guide (TMG) recommends classifying vehicles into thirteen categories. Among these categories are "passenger cars" and "other two-axle, four-tire single unit vehicles." Passenger cars include all sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers. Other two-axle, four-tire single unit vehicles are all two-axle, four-tire vehicles other than passenger cars. Included in this classification are light trucks; such as pickup trucks, panel trucks, vans, and other vehicles like sport/utility vehicles and campers. Passenger cars are referred to as "class two vehicles" and other two-axle, four-tire single unit vehicles are called "class three vehicles" in the thirteen-category classification scheme.

There is an inherent difficulty in distinguishing between these two vehicle categories. Vehicle classification is primarily accomplished through the use of automatic vehicle classifiers (AVCs). While there are many variations, AVCs typically use axle spacing and/or vehicle length to classify vehicles. These machines cannot tell the difference between some models of passenger cars and some types of other two-axle, four-tire single unit vehicles.

This paper discusses the procedures used by the FHWA to segregate travel estimates for these vehicle types at the national level. The model uses the combined vehicle miles of travel (VMT) for passenger cars and other two-axle, four-tire single unit vehicles. It then employs other sources, such as the Truck Inventory and Use Survey (TIUS), and vehicle registration data to extract other two-axle, four-tire single unit vehicle travel from the combined VMT. The result is a vehicle distribution based on travel that more closely resembles actual VMT. The travel distribution also corresponds to estimates from other sources for these two vehicle types. This procedure is directly applicable to State use.

INTRODUCTION

The objective of this paper is to explain the procedures used by the FHWA to segregate **travel** estimates for light trucks and passenger cars at the national level and how these procedures can be applied at the State level. Current practice in traffic data collection of vehicle classification information consists of thirteen vehicle types. These vehicle types were determined in consultation with the States and based on several vehicle classification studies. Descriptions of the vehicle classifications are provided in Appendix A. Use of automatic vehicle classifiers (AVCs) to collect vehicle classification data has become a de-facto standard. The typical data collection configuration consists of an AVC receiving signals from inductance loop detectors or loop detectors coupled with piezo cable. The AVC collects the data in categories or "bins" based on the thirteen vehicle classes. Ideally, States perform these tasks based on guidelines detailed in the *Traffic Monitoring Guide* (TMG).' The TMG is a companion document to the *Highway Performance Monitoring System* (HPMS) *Field Manual.*[2] States submit vehicle classification information annually through the HPMS program. The HPMS Field Manual also requests each State to submit site-specific vehicle classification data records in electronic format. This is referred to as the "Card 4" or "C card" data, reference made to old computer cards. With the advent of microcomputers and user-friendly mainframe systems, these vehicle classification data are now easier to collect and analyze.

The thirteen vehicle classes present some technical difficulties. The procedure used in the preponderance of AVC equipment places data into thirteen bins based on vehicle length and/or axle spacing. The most popular algorithm used to perform this procedure is based on vehicle classification "scheme F" developed through FHWA-sponsored research.[3] Class two vehicles (passenger cars) and class three vehicle (other two-axle, four-tire vehicles) exhibit similar length and axle spacing characteristics. Passenger cars are sedans, coupes, and station wagons manufactured primarily for carrying passengers while other two axle four tire vehicles include pickups, vans, and sport/utility vehicles. AVC equipment often cannot distinguish between these two vehicle classes. A recent study, sponsored by the FHWA, Office of Highway Information Management, has confirmed this conclusion. The study, conducted by the Georgia Department of Transportation, and authored by the Georgia Tech Research Institute of the Georgia Institute of Technology, sampled thousands of vehicles using various AVC configurations! The tests showed that the equipment correctly classified vehicle types within an accuracy range of 64% to 79% when class two vehicles are separate from class three vehicles. Combining class two and class three vehicles yields an accuracy range of 79% to 96%.

Increased focus on minivans and sport/utility vehicles has prompted the need for more accurate travel estimates for class three vehicles. The thirteen vehicle classification scheme was developed well before the advent of small pickups, minivans, and sport/utility vehicles. Travel usage and characteristics of class three vehicles has also changed significantly since the origin of the thirteen-class scheme. Initially, class three vehicles consisted of full-size pickup and panel trucks. A large proportion of these vehicles were used in commercial activity. Now, however, most of these vehicles are used as personal passenger vehicles. Thus, the usage tends to resemble that of passenger cars (class two vehicles), rather than single-unit trucks (classes five through seven). This represents a major shift in the characteristics of the class three vehicle.

JUSTIFICATION

States are directed to submit vehicle classification data annually through HPMS Templates 6 and.7 (Appendix B). Template 6 is a matrix describing the proportion of vehicle types for each roadway functional classification. Note that these data are presented as distributions and not as VMT or average annual daily traffic (AADT). Template 7 describes the temporal aspects of the data in Template 6. States report which hours of day, days of week, and months of year data were collected on the top portion of Template 7. The bottom portion shows how specific vehicle configurations are normally classified. Information from Template 7 is used to adjust vehicle distribution to account for missing elements.

Annual VMT estimates for each of twelve roadway functional classifications are also submitted by each State through the HPMS program. The VMT is reconciled with the adjusted Template 6 data for each State to give VMT by vehicle type and roadway functional classification for each State. These estimated VMT figures are summed to produce a national total. The resulting VMT estimates for each vehicle type are then normalized to the total annual VMT estimates by roadway functional classification. The resulting distributions may be slightly revised at this point in order to be reconciled with national fuel usage and fuel economy data. The result is the FHWA estimate of VMT by vehicle type.

It became apparent that this FHWA approach to estimating light trucks was probably undercounting class three vehicles. A 1995 National Highway Traffic Safety Administration (NHTSA) report supports this conjecture.[5] Using R. L. Polk and Company registration data, the NHTSA report shows a 1% differential between FHWA and Polk light truck registration data in 1975. The differential has steadily grown to 9% by 1992. During this time, FHWA consistently reports a lower number of light truck (class three) registrations. than Polk. Conversely, FHWA shows class two (passenger car) registrations to be 9% higher than the Polk figures in 1992.

Due to the findings of the Georgia accuracy study and, to coordinate more closely with the National Highway Traffic Safety Administration (NHTSA) definition of other two-axle four-tire vehicles, the FHWA included an additional step when processing the 1994 HPMS vehicle classification data- The additional step uses the Georgia accuracy report findings that suggest that combining class two and class three vehicle yield greater accuracy. State-submitted class two and class three data are summed to provide a composite national VMT control total. Travel for the various vehicle types that comprise the class three vehicle category are then extracted individually based on average annual miles traveled per vehicle (AAMPV), and the number of vehicles registered.

PROCEDURE

AAMPV for the pickup truck, minivan, full-size van, and utility vehicle types are reported in the Bureau of Census 1992 *Truck Inventory and* Use Survey (TIUS).[6] The TIUS is a survey conducted every five years by the U. S. Department of Commerce, Bureau of the Census. The TIUS consists of a sample of more than 150,000 trucks to measure the universe of -over 60 million trucks. Expansion factors are provided in the TIUS for each of five stratifications. The expansion factors weight the sample data to provide an estimate of the universe data.

The AAMPV are calculated and projected to the current year then multiplied by the projected number of each vehicle type registered as reported by the TIUS. The product yields VMT for each of the light truck vehicle types (i.e., pickup trucks, minivans, full-size van, and utility vehicles). Individual vehicle type VMTs are then summed to provide total VMT for class three vehicles. Total class three VMT is then divided by total class three registrations to give AAMPV for the vehicle group-

The class three AAMPV must then be reconciled with the number of vehicles registered as reported annually by the States and shown in the light truck categories in Table MV-9 of *Highway Statistics*.’. Vehicle class three VMT is derived by multiplying the FHWA-determined number of class three vehicles by the class three AAMPV estimate. Class two VMT is then produced by subtracting class three VMT fi-om the control total VMT.

This procedure balances several data elements to derive the missing component. This is based on the relationship between VMT, AAMPV, and the number of registered vehicles. These three functions are dependent upon each another as illustrated in Figure 1.

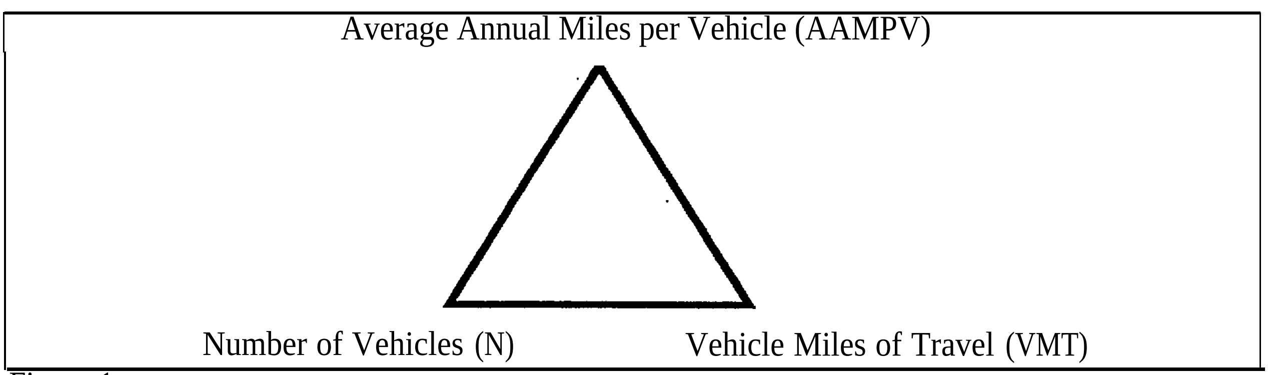

Figure 1

The functional relationships are as follows:

$$N=VMT/AAMPV$$

$$AAMPV=VMT/N$$

$$VMT=N*AAMPV$$

Since class two VMT as determined by AVC equipment cannot distinguish between some class two **and** class three vehicle types, VMT becomes the least stable of the three functions for these two vehicle groups individually. This provides justification for use of the VMT = N * AAMPV formula as shown, thereby using data elements with the greatest integrity This procedure is applicable only to the class two and class three categories.

The same process can be applied on an individual State level. This procedure is intended to supplement, rather than replace the current thirteen vehicle classification guidelines. It is critical for a State to have collected sufficient data to provide a stable control total for the summed classes two and three. Analysts must have confidence in the control total in order to apply this estimation procedure. In addition, the most recent TIUS data must be available to the analyst.

The body types used in the TIUS are similar to those defined as other two-axle four-tire vehicles in the Traffic Monitoring Guide. TIUS pickups include full size and small pickup trucks. Minivans are small vans. Panel or Vans, are two-axle four-tire van-type vehicles other than minivans. Utility vehicles are analogous to sport/utility, or “jeep-like” vehicles. The TIUS station wagon category includes two-axle four-tire station wagons on a truck chassis. An example of the TIUS station wagon is a Chevrolet Suburban. These vehicle types encompass the majority of two-axle four-tire vehicles in vehicle class three. Therefore, they provide a good representation of average annual miles per vehicle for vehicle class three.

Figure 2 shows the number of each type of vehicle in the TIUS sample for New Mexico. It is evident that a majority of light trucks are pickups. The weighted mileage for the 388,960 pickups in the expanded TIUS sample is 4,475 million miles in 1992. Dividing annual miles by number of pickups yields average annual miles per pickup of 11,505 miles in 1992. The weighted sum of annual miles in the total light truck sample is 6,456 million. Dividing the total annual light truck miles by the weighted number of vehicles in the sample yields an average annual miles per vehicle of 11,673. This method accounts for the weighting of vehicles by summing the number and total mileage components separately.

New Mexico TIUS 1992 - Body Types	Weighted Number of Vehicles	Weighted Sum of Annual Miles	Average Annual Miles per Vehicle
Pickup	**388,960**	4,474,866,811	11,505
Minivan	42,525	617,264,704	14,5 15
Panel or Van	34,319	306,425,618	8,929
Utility	63,983	801,949,815	12,534
Station Wagon	23.324	255.735.165	10.964
	553,111	6,456,242,113	11,673

‘igure 2

There are still some “unknowns” in this process. For example, class three vehicles not included in the TIUS descriptions listed in Figure 2 are not considered. One can assume that the travel characteristics of other class three vehicles resembles that of the vehicle types listed. Also, the light truck category is overwhelmingly composed of pickups, vans, and sport/utility vehicles. The relatively small proportion of other vehicle types will not substantially alter the composite average annual miles per vehicle figure for all light trucks.

The 1992 Table MV-9 in *Highway Statistics* lists 452,340 light truck registrations for New Mexico which differs from the TIUS estimate of 553,111. The discrepancy is caused by differences in definitions of light trucks, factoring, and differences in data collection and processing methods. There are differences in the definitions of class three vehicle data collected by AVCs and Table MV-9 light truck registrations as well. Class three vehicle data collected by AVCs are keyed to vehicle length and/or axle spacing, whereas, the Table MV-9 light truck registrations are (generally) keyed to vehicle weights of 10,000 pounds or less. As suggested earlier, the best available source of data should be used at every step of the process. With this in mind, multiplying total light truck registrations from the FHWA by the estimated class three AAMPV from the TIUS will give light truck VMT as follows:

$$VMT_1 = R_1 * AAMPV_1$$

where: VMT = vehicle miles traveled
1 = light trucks
R = number of vehicles registered
AAMPV = average annual miles per vehicle

yielding 5,280 million light truck VMT in New Mexico as follows:

$$5,280,164,820 = 452,340 * 11,673.$$

Total VMT for all vehicles in New Mexico was reported as 18,452 million for 1992 as listed in Table VM-2 of Highway *Statistics*. If our calculation of 5,280 million VMT for light trucks is correct, then class three vehicles account for 29% of VMT. This is significantly larger than the 1993 and 1994 proportions from the New Mexico HPMS Template 6 data. These show 18% and 20% light trucks respectively. This is one of several indicators that suggest that AVC equipment undercounts class three vehicles. If this is so, how can we verify that we are now on the right track?

The next step should be a reasonableness check. Is a light truck AAMPV of 11,673 realistic? Is our estimate of 29% light truck VMT reasonable? A comparison with the national distribution provides a benchmark. Table VM- 1 in the *Highway Statistics* publication provides the composite total for all States. Figure 3 shows the proportion of travel attributed to different vehicle categories. Listings are given for 1993 and 1994.1993 is the first year for which VM-1 data are available in the new format.

Year	Passenger Cars	**Motor-Cycles**	**Buses**	**Other 2-Axle 4-Tire Vehicles**	**Single-Unit** 2-Axle **6-Tire or More Trucks**	**Combin-ation Trucks**	**All Motor Vehicles**
1994	1,585,618	10,251	6,416	587,284	61,350	109,065	2.359984
	67.19%	0.43%	0.27%	24.89%	2.60%	4.62%	100.00%
993	1,547,366	. 9,906	6,126	573,398	56,78 1	103,123	2,296700
	67.37%	0.43%	0.27%	24.97%	2.47%	4.49%	100.00%

The New Mexico estimate of 29% light trucks is reasonable compared with the rounded national estimate of 25%. One can assume that the relatively large, rural State of New Mexico is likely to have a higher proportion of light trucks than the national average. Also, note the small changes in vehicle distribution from one year to the next. This reduces apprehension about comparing vehicle distributions from different years. Large fluctuations in distribution from year to year are a cause for concern.

METRICATION

VMT appeared in metric format *in Highway Statistics* for the first time in the 1994 edition. Metrication resulted in revisions to the terminology. Vehicle-Miles of Travel (VMT) became Vehicle Distance Traveled (VDT). Using this syntax, VDT is followed by the units (miles or kilometers). 1994 data were submitted in U.S. units. Therefore, a soft conversion was done to provide metric equivalent units. The SI standard was used, resulting in a ratio of 1.609 344 kilometers per mile.

Most of the data used in this report is from 1992. As metric tables are not available prior to 1993 and elements of this research require direct comparison of VMT and AAMPV, U.S. units are-used throughout this report. Also, due to the technical nature of this study, it was determined that presenting information using dual units would hinder readability.

SUMMARY

The problem of converting vehicle classification class two and class three data collected with AVCs to VMT estimates can be improved by utilizing additional resources. Using any two of the relevant factor triad of, AAMPV, VMT, and number of vehicles registered, the third factor can be derived. In the event where AAMPV, VMT, and registration data are all present, the two factors deemed most accurate are used to derive the third factor. Given these relationships, the FHWA aggregates class two and class three VMT to provide a control total. Individual vehicle type AAMPV estimates and registration estimates are extracted from the TIUS database. A composite AAMPV is then derived for all class three vehicles using the TIUS data. This AAMPV is then multiplied by the FHWA estimated number of class three vehicles to produce total VMT for class three vehicles. The class three total VMT are subtracted from the control total VMT for classes two and three to give class two VMT.

An identical procedure can be used at the State level. The TIUS reports on vehicle classification data for each State providing a source for AAMPV. Vehicle registration data is submitted annually by State to the FHWA, therefore, registration data is available for each State. The estimating process for a State to derive class two and class three VMT then becomes the same as the national estimating process.

The analyst is advised to investigate other relevant resources. The goal of data integrity must be addressed at every step toward truth-in-data. In each case, a determination of the best data source must be made. Comparisons of different data sources coupled with common sense should be used to decide which is the best available data. Some States have an extensive vehicle classification program. If data retrieved from the AVCs for classes two and three is very accurate, then it should be used "as is." However, research has shown that AVCs are not sufficiently accurate to distinguish between class two and class three vehicles. Suppliers of AVC equipment continue to work toward improving accuracy. Eventually, AVCs may be able to correctly segregate class two and class three vehicles. Until then, there is no "one size fits all" solution to the light truck classification dilemma. The methodology presented here should be used as one more tool in a well-stocked tool box.

APPENDIX A

FHWA Vehicle Classification Definitions

1. **Motorcycles** (Optional) - All two-or three-wheeled motorized Vehicles. Typical vehicles in this category have saddle type seats and are steered by handle bars rather than wheels. This category includes motorcycles, motor scooters, mopeds, motor-powered bicycles, and three-wheeled motorcycles. This vehicle type may be reported at the option of the State.

2. **Passenger Cars** - All sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers and including those passenger cars pulling recreational or other light trailers.

3. **Other Two-Axle, Four-Tire Single Unit Vehicles - All two-axle, four-tire, vehicles** other than passenger cars. Included in this classification are pickups, panels, vans, and other vehicles such as campers, motor homes, ambulances, hearses, carryalls, and minibuses. Other two-axle, four-tire single unit vehicles pulling recreational or other light trailers are included in this classification. Because automatic vehicle classifiers have difficulty distinguishing class three from class two, these two classes may be combined into class two.

4. **Buses** - All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses (including school buses) functioning as passenger-carrying vehicles. Modified buses should be considered to be a truck and be appropriately classified.

5. **Two-Axle, Six-Tire, Single unit Trucks** - All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., having two axles and dual rear wheels.

6. **Three-Axle Single Unit Trucks -** All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., having three axles.

7. **Four or More Axle Single Unit Trucks** - All vehicles on a single frame with four or more axles.

8. **Four or Less Axle Single Trailer Trucks** - All vehicles with four or less axles consisting of two units, one of which is a tractor or straight truck power unit.

9. **Five-Axle Single Trailer Trucks -** All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit.

10. **Six or More Axle Single Trailer Trucks -** All vehicles with six or more axles consisting of two units, one of which is a tractor or straight truck power unit.

11. **Five or Less Axle Multi-Trailer Trucks** - Al1 vehicles with five or less axles consisting of three or more units, one of which is a tractor or straight truck power unit.

12. **Six-Axle Multi-Trailer Trucks -** All six-axle vehicles consisting of three or more units, one of which is a tractor or straight truck power unit.

13. **Seven or More Axle Multi-Trailer Trucks** - All vehicles with seven or more axles consisting of three or more units, one of which is a tractor or straight truck power unit.

Source: *1995 Traffic Monitoring Guide*

TEMPLATE - 6
TRAVEL ACTIVITY BY VEHICLE TYPE TEMPLATE

PART I

[ ]	[ ]	[ ]	[ ]
(STATE)	(STATE FIPS CODE)	(DATA YEAR)	(DATE)

PERCENT OF TRAVEL

FUNCTIONAL SYSTEM	MOTORCYCLES (OPTIONAL)	PASSENGER CARS	LIGHT TRUCKS OTHER (2 AXLE, 4 TIRE)	BUSES	SINGLE-UNIT TRUCKS 2 AXLE, 6 TIRE	SINGLE-UNIT TRUCKS 3 AXLE	SINGLE-UNIT TRUCKS 4 AXLE OR MORE	SINGLE-TRAILER TRUCKS 4 AXLE OR LESS	SINGLE-TRAILER TRUCKS 5 AXLE	SINGLE-TRAILER TRUCKS 6 AXLE OR MORE	MULTI-TRAILER TRUCKS 5 AXLE OR LESS	MULTI-TRAILER TRUCKS 6 AXLE	MULTI-TRAILER TRUCKS 7 AXLE OR MORE	TOTAL
RURAL														
INTERSTATE	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[P]
OTHER PRINCIPAL ARTERIAL	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[P]
MINOR ARTERIAL	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[P]
MAJOR COLLECTOR	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[P]
MINOR COLLECTOR	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[P]
LOCAL	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[P]
URBAN														
INTERSTATE	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[P]
OTHER FREEWAYS & EXPRESSWAYS	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[P]
OTHER PRINCIPAL ARTERIAL	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[P]
MINOR ARTERIAL	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[P]
COLLECTOR	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[P]
LOCAL	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[P]

TEMPLATE - 7
TRAVEL ACTIVITY BY VEHICLE TYPE
(Supplemental Data)

[:]	[:]	[P]	[P]
STATE	STATE FIPS CODE	DATA YEAR	DATE

1 VEHICLE CLASSIFICATION DATA ON TEMPLATE 6 ARE REPRESENTATIVE OF DATA NORMALLY COLLECTED DURING THE HOURS OF:
(ENTER RESPONSE IN THE [:] CELL)

HOUR	AM/PM		HOUR	AM/PM
[:]	[:]	TO	[:]	[:]

ALL HOURS OF DAY
[:]
(ENTER "X" IF ALL HOURS OF DAY)

2. VEHICLE CLASSIFICATION DATA ON TEMPLATE 6 ARE REPRESENTATIVE OF DATA NORMALLY COLLECTED ON THE FOLLOWING DAYS DURING THE FOLLOWING MONTHS:
(MARK) WITH AN "X"

ALL DAYS	[:]	ALL MONTH	[:]
SUNDAY	[:]	JANUARY	[:]
MONDAY	[:]	FEBRUARY	[:]
TUESDAY	[:]	MARCH	[:]
WEDNESDAY	[:]	APRIL	[:]
THURSDAY	[:]	MAY	[:]
FRIDAY	[:]	JUNE	[:]
SATURDAY	[:]	JULY	[:]
		AUGUST	[:]
		SEPTEMBER	[:]
		OCTOBER	[:]
		NOVEMBER	[:]
		DECEMBER	[:]

3. INDICATE BELOW WHERE EACH OF THE SPECIFIC VEHICLE TYPES, LISTED IN THE LEFT COLUMN, ARE INCLUDED ON TEMPLATE 6.

SPECIFIC VEHICLE TYPE	PREFERABLE VEHICLE TYPE	REPORTED VEHICLE TYPE IS CONTAINED IN THE FOLLOWING CATEGORY ON TEMPLATE 6. (BEGIN TYPING RESPONSES IN THE [:] CELLS BELOW)
2-AXLE, 4-TIRE TRUCK WITHOUT A TRAILER	3	[:] [:] [:]
2-AXLE, 4-TIRE TRUCK WITH A TRAILER	3	[:] [:] [:]
2-AXLE, 6-TIRE PICKUP TRUCKS WITHOUT A TRAILER	5	[:] [:] [:]
2-AXLE, 6-TIRE PICKUP TRUCKS WITH A TRAIL	8-10 AS APPROPRIATE	[:] [:] [:]
OTHER SINGLE-UNIT TRUCKS WITH SEMI-TRAILER	8-13 AS APPROPRIATE	[:] [:] [:]
OTHER SINGLE-UNIT TRUCKS WITH FULL-TRAILER	8-13 AS APPROPRIATE	[:] [:] [:]

4. COMMENTS:
(TYPE ON LINE BEGINNING IN THE CELL WITH THE [:] SYMBOL)
[:]
[:]
[:]
[:]
[:]
[:]
[:]
[:]

NOTES

1. *Traffic Monitoring Guide*, Third Edition, February, 1995, U.S. Government Publication Number FHWA-PL-95-031, Contact U.S. Department of Transportation. Federal Highway Administration for more information: (202) 366-O 180.

3. *Highway Performance Monitoring System Field Manual*, August 1993, OMB Number 2 125-0028, Contact U.S. Department of Transportation, Federal Highway Administration for more information: (202) 366-0180.

3. *Field Evaluation of FHWA Vehicle Classification Categories*, January 1985, Research Contract Number DTFH-7 1-80-54-ME-O 1, contact Maine- Department of Transportation for more information: P.O. Box 1208, Bangor, Maine 0440 1.

4. *Accuracy of Traffic Monitoring Equipment*, June 1995, Technical Report GTRI Project A-929 1, contact GDOT, Office of Materials and Research for more information: 15 Kennedy Drive, Forrest Park, GA 30050.

5. *Registered Passenger Cars and Light Trucks*, February 1995, Technical Report Number DOT HS 808 235, contact National Technical Information Service, Springfield, VA 22 16 1.

6. *1992 Truck Inventory and* Use Survey, U.S. Government Publication Number TC92-T-52, Contact U.S. Department of Commerce, Bureau of the Census for more information: (301) 457-2797.

7. *Highway Statistics*, Annual, Technical Report Number FHWA-PL-95-042, contact U.S. Department of Transportation, Federal Highway Administration for more information: (202) . 366-0180.