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16. Abstract

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The extent to which national statistics about trucks are utilized by state agencies is also described. These data base include: (1) HPMS, (2) TWS, (3) FARS, (4) BMCS accident file, (5) NASS, and (6) TIUS.

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A state-of-the-art paper with an annotated bibliography is contained in the report.

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FINAL REPORT

HEAVY TRUCK DATA IN VIRGINIA: COLLECTION, USES, AND NEEDS

by

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Graduate Research Assistant

and

Lester A. Hoel
Faculty Research Scientist

(The opinions, findings, and conclusions expressed in this report are those of the authors and not necessarily those of the sponsoring agencies.)

Virginia Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the Virginia Department of Transportation and the University of Virginia)

In Cooperation with the U.S. Department of Transportation
Federal Highway Administration

Charlottesville, Virginia

March 1988
VTRC 88-R10

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ABSTRACT

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INTRODUCTION

Truck transportation is a vital element in the nation's economy because most goods in urban and suburban areas are transported by over-the-road vehicles, and interstate truck travel is an important component of the state's regional distribution network. The growth in truck transportation has been continuous. Preliminary estimates furnished by Transportation Policy Associates indicate that in 1986 trucks accounted for 40.3 percent of all freight tonnage carried (compared with 25.9 percent for rail). In Virginia the growing need for new highways is reflected in the importance of moving goods with greater efficiency and economy. As the state's highway system continues to improve, further economic benefits will be realized that derive from new developments in truck technology and services.

As truck travel grows in magnitude (at an expected rate of 2 to 4 percent annually) the effect of heavy trucks on the state's highway system will become of increasing concern. Although heavy trucks, defined as vehicles with gross vehicle weight greater than 10,000 pounds, comprise only about 11 percent of all registered trucks (and trucks comprise about 30 percent of all vehicles), heavy trucks represent over 10 percent of all vehicle miles of travel in a typical Virginia traffic stream. Accordingly, the influence of heavy trucks on the highway system far exceeds their numbers. Trucks are a factor in highway design, safety, and planning because their size, weight, and geometric characteristics may influence or govern engineering and safety considerations.

In order to assure that the highway system will adequately accommodate the increased movement of goods by heavy truck, it is imperative that decisions concerning the management of the system be based on complete and sound information. Basic areas on which data about truck transportation are required fall into three categories: (1) the trucking industry and its relationship to the statewide economy; (2) the efficiency, productivity, and effect on highway design of truck transportation as affected by vehicle size and weight; and (3) the impact of truck transportation on highway safety. Several studies have identified the importance of understanding and defining the data base for truck transportation. For example, the Transportation Research Board in its report on twin trailer trucks recommended that the U.S. Department of Transportation should work with state agencies to improve the quality and consistency of state-collected data.

PURPOSE AND SCOPE

The purpose of this report is to describe the process of data collection for heavy trucks by Virginia agencies, the uses of heavy truck data, and data needs. The report describes the collection and uses of heavy truck data of the following categories: (1) classification counts, (2) accidents, (3) off-tracking, (4) passenger car equivalents (PCE), (5) equivalent axle load (EAL), (6) speed, and (7) size and weight. The report also describes the extent to which national statistics about trucks are utilized by state agencies. These data bases include: (1) Highway Performance Monitoring System (HPMS), (2) Truck Weight Study (TWS), (3) Fatal Accident Reporting System (FARS), (4) Bureau of Motor Carrier Safety Accident File (BMCS), (5) National Accident Sampling System (NASS), and (6) Truck Inventory and Use Survey (TIUS).

The report describes data collection and use for each of the twelve divisions within the Virginia Department of Transportation (VDOT), including: (1) Bridge, (2) Construction, (3) Environmental Quality, (4) Location and Design, (5) Maintenance, (6) Materials, (7) Rail and Public Transportation, (8) Right of Way, (9) Secondary Roads, (10) Traffic Engineering, (11) Transportation Planning, and (12) Urban. Heavy truck data use and collection responsibilities are also reported for other state agencies including: (1) Department of Emergency Services, (2) Department of Motor Vehicles (DMV), (3) State Corporation Commission, (4) Department of State Police, and (5) Department of Waste Management.

This study is confined to direct examination of data gathering and its use within Virginia, and no attempt was made to determine how this type of data is collected and used in other states, nor the extent to which data gathering procedures conform to Federal guidelines. In the original conception of the project it was anticipated that a total evaluation of truck data gathering procedures would be possible. However, based on results of our surveys which indicated general satisfaction with present data gathering procedures, and limitations in resources and information about experiences in other states, this element is not included. Nevertheless, in order to understand the problem from a national perspective, a review of the literature was conducted using the Transportation Research Board's (TRB) Highway Research Information Service. Three bibliographic searches were conducted, the first titled "Characteristics of Truck and Freight Transportation" with 225 citations, the second "Truck Classification and Counting" with 254 citations, and the third "Truck Weighing" containing 148 listings. These records were analyzed, categorized, and reviewed. A state-of-the-art paper was prepared with an annotated bibliography. The report is contained in the appendix and was available to the divisions and agencies during the time of this study.

METHODOLOGY

A review was conducted to determine the current sources of truck travel data in the state and to examine the types of data on truck travel characteristics that are currently collected in Virginia. Also considered were the organizational arrangements for truck data collection within the VDOT and the current responsibilities for the acquisition and tabulation of data.

The study also examined how truck data are used and the nature and extent of data needs within the state. An examination was conducted of truck studies that have been undertaken by the VDOT and their data requirements. Various departmental activities in design, operations, maintenance, safety, and planning were reviewed to identify the extent to which information about truck travel is required and how truck data are applied in the VDOT's work program.

Each organizational unit or agency within Virginia was asked to furnish information about its heavy truck data program. A questionnaire was developed (see Appendix C) that requested the following information:

* status of the organizational unit with regard to heavy truck data needs
* data collection activities
* use of heavy truck data
* inter-division/agency exchanges of heavy truck data
* utilization of national statistics
* heavy truck data needs not met by existing sources.

The questionnaire was mailed to division or agency heads on March 11, 1987. Replies that indicated the nature and extent of its involvement in this area were received by each of the 17 organizational units. Subsequent to review and analysis of the results, several units or agencies were identified as having substantial involvement in some aspect of heavy truck data acquisition or use. These agencies included:

* VDOT
  (1) Transportation Planning Division
  (2) Traffic Engineering Division
  (3) Maintenance Division
  (4) Materials Division
* DMV
  (1) Driver Services Administration
  (2) Vehicle Services Administration
  (3) Transportation Safety Administration
* Department of State Police.

Follow-up interviews were conducted with key individuals from each of the four divisions in the VDOT and with representatives from the DMV and the Department of State Police. The interviews were designed to expand or clarify the responses to the questionnaire and to permit each agency to furnish additional details concerning its involvement in heavy truck activities. The meetings were recorded on tape, and the results were later included with the earlier questionnaire responses. Follow-up telephone calls were made where further clarification was desired.

In addition to information about data gathering activities, we were supplied with reports, survey forms, and other relevant documentation.

COLLECTION AND USE OF HEAVY TRUCK DATA BY DIVISIONS AND AGENCIES

Department of Transportation

Bridge Division

This division is a user of traffic count data. The Traffic Engineering Division provides Average Daily Truck Traffic(ADTT) and the percentage of all traffic for those road sections with ADTT of 1,500 or more. According to section 10.3.2 of AASHTO specification for Load Cycles, steel bridges carrying one direction ADTT of more than 2,500 vehicles should be designed as case I structures. The ADTT is used in determining the fatigue category for both reconstruction or new facility designs of steel structures.

Construction Division

This division does not collect or use any heavy truck data. Nevertheless, the Traffic Engineering Division furnishes copies of all accident reports involving construction projects regardless of the type of vehicles involved. These reports are utilized to prevent similar accidents if possible and to correct any deficiency if found and not already corrected.

Location and Design Division

This division is a user of heavy truck counts and off-tracking data. It does not collect truck data, but acquires truck off-tracking information for its own and other agencies' use. The percentage of truck traffic directly affects the designs of truck climbing lanes and truck escape ramps, location and number of toll booths, and the redesign of truck weigh stations. Off-tracking information is applied to facilities wherever heavy trucks are of concern because of their large size and heavy weight.

Maintenance Division

This division collects heavy truck weight and classification data for use strictly by other agencies.

A truck weight study is completed every two years. About twenty stations are set up to gather gross weight, axle loadings, axle spacings, and commodities carried. Data are gathered in June, July, and August. Each station is operated for eight hours from 6 a.m. to 2 p.m. for weighing, with classification counts taken yearly for a duration of 24 hours. Thirteen categories of vehicles are classified. The field data are coded and submitted to FHWA on magnetic tape (see Fig. 1 and Fig. 2).

The division also operates 14 permanent weigh stations and 10 mobile weighing units, which help the State Police in enforcement. Monthly reports are made summarizing the number of vehicles weighed and number of summonses issued. Liquidated damages and fines (as well as court costs) for overweight violations are also assessed. Records of trucks that are overweight are kept on Truck Weight Report forms (TW-14-A) for one year and saved on tapes for five years (see Fig. 3).

To monitor the trend of bypassing weigh stations, the division conducts a Permanent Scales Bypass Route Survey for 11 of the 14 permanent scales for 2 days each year. The results address the reasons that are given by truck drivers for being on the surveyed routes. A copy of this report is furnished to the State Police.

The division is empowered to issue special hauling permits for the operation of a vehicle with a size or weight in excess of legal limits. Applications for single-trip and blanket permits are processed by this division. Information about the size and weight of the vehicle and the route is required in the application. At this writing, this information is not computerized. Although an annual report summarizing numbers of permits issued and fees collected is made, it is not accessible in a format stratefied by other elements.

Materials Division

This division is a user of heavy truck data collected by others. Items of concern are traffic counts, classification, EAL, and weight. There is a lack of heavy truck data for the division's needs.

Data Analysis and Use

EAL: For flexible pavement design for a highway project, this division requests 18-kip EAL information from the Traffic Engineering Division.

TRUCK WEIGHT STUDY

STATION NO. ____________ DIRECTION ____________ LOCATION ____________ DATE ____________

HOURS	CARS	MOTOR-CYCLES	PICKUPS, VANS & OTHER 2 AX 4 TIRE	BUSES	SINGLE UNIT TRUCKS			SINGLE TRAILER TRUCKS			MULTI-TRAILER TRUCKS			TOTALS
					2Axle 6 Tire	3 Axle	4 Axle or more	4 Axle or less	5 Axle	6 Axle or more	5 Axle or less	6 Axle	7 Axle or more	
6-7 A.M.														
7-8														
8-9														
9-10														
10-11														
11-12														
12-1 P.M.														
1-2														
2-3														
3-4														
4-5														
5-6														
6-7														
7-8														
8-9														
9-10														
10-11														
11-12														
12-1 A.M.														
1-2														
2-3														
3-4														
4-5														
5-6														
TOTAL														

SIGNED ____________ RECORDER, DAY COUNT

SIGNED ____________ RECORDER, NIGHT COUNT

Figure 1

T&S 230

TRUCK WEIGHT STUDY

STATION ________ HOUR ________ DIRECTION OF TRAVEL ________________

TYPE OF VEH.	BODY TYPE	STATE OF REG.	GROSS REG. WEIGHT	MODEL YEAR	OPER	FUEL	LOAD	COMMODITY	WEIGHT BY AXLES					GROSS WEIGHT	AXLE SPACING				WHEEL BASE
									A	B	C	D	E		A-B	B-C	C-D	D-E	

TYPE OF VEHICLE

11-PICKUP
12-OTHER 4 TIRED
13-2-DT
14-3A-SU
21-2-S1
22-2-S2
23-3-S1
24-3-S2

OPERATION

1-PRIVATE
2-FOR HIRE ICC
3-OTHER FOR HIRE

LOAD

0-EMPTY
1-LOADED WITH A PRODUCT
2-NON-COMMODITY (UTILITY OR MOUNTED EQUIPMENT, ETC.)

FUEL

1-GASOLINE
2-DIESEL
3-PROPANE
4-OTHER

Figure 2

FORM
TW-14-A
REV. 11-1-84

Commonwealth of Virginia

DEPARTMENT OF HIGHWAYS AND TRANSPORTATION

Truck Weight Report

1
1

Summons Number 2 — 11

Weighing Station No. 12 - 13

Mobile Unit No. 14 - 15

Route 16 — 19 Location City or County 20 — 22

23V1500 2-85

Weights		Axles	Time & Date		Axle Spacings FT. IN.	Weight Limits
23	27		Date of Violation	Time	69 — 72	Axle:
28	32		Date Released	Time	73 — 76	Tandem:
33	37		Year 58 - 59	Month 60 - 61	77 — 80	Group:
38	42		Day/Night 62	Day of Month 63 - 64	81 — 84	Gross:
43	47		Day of Week 65	Hour 66 - 67	85 — 88	Type Scales 93
48	52				89 — 92	
53	57		Weather	68	Wheel Base	Direction 94

← Gross Weight

Violation: Lic. 95 Axle 96 Tandem 97 Gross 98 Group 99

Truck Type of Vehicle: 100 — 102

State of Vehicle Registration 103 — 105

Truck/Tractor License No. 106 — 113

Class of Operation
Private 114
For Hire 115
Leased 116

License Wt. 117 — 122

Trailer License No. 123 — 128

2
1 Owner:
12 — 40

Address

Driver:
41 — 69

Permit 70 Permit Type: 71 — 73 Permit No. 74 — 82 No. Pass. 83 -84 Escorted 85

Commodity Carried 86 — 89 Officer ______ No. ______

Leased to: ______ Date of Trial ______

Address: ______ Interviewer ______

Origin: ______ Destination ______ Weigh Party Chief ______

REMARKS: ______

Figure 3

Classification Counts: When a weight study is not done, a simplified pavement design is accomplished by converting heavy truck counts to EAL using a graph developed by the Research Council. The Traffic Engineeering Division's "Average Daily Traffic Volumes On Interstate, Arterial and Primary Roads" provides the necessary heavy truck counts for this procedure.

Weight: Heavy truck weight data are sampled at road sections for monitoring purposes in order to adjust the required maintenance period, which is applied at the design stage.

Needs

This division needs more complete axle count and weight data for rigid pavement design and evaluation purposes because the present design procedure for concrete pavement is the PCA (Portland Cement Association) method. The PCA method requires the weight of each axle but accumulated by equivalent 18-kip loads. The information required to determine accumulated numbers are the ADT, ADTT (in both directions), and the axle load distribution of truck traffic. Only trucks with six tires or more are included in the design.

The traffic data from secondary roads are unsatisfactory because they provide only the number of axles without a complete weight profile. It is hoped that weigh-in-motion equipment might fulfill these functions in the future.

The impact of tire pressure on pavement is not clear. Studies in other states reveal increasing concern with this subject since tire quality has been improved by manufacturing technology so that significantly higher tire pressures are now possible.

Rail and Public Transportation Division

This division does not collect or use heavy truck data. However, on a site-specific and as-needed basis, truck rates, volumes, and commodity types are used in analyzing rail abandonments. Truck rates and volumes may be requested from the Traffic Engineering Division, but commodity type information is difficult to obtain.

For use in the grade crossing assessment program, this division would like to obtain the volumes of hazardous materials shipments throughout the state and updated truck operating characteristics such as lengths of vehicles, time involved in clearing a crossing, etc.

Traffic Engineering Division

This division is actively involved in the collection and use of heavy truck data. It collects classification counts, accident statistics, and speed data and calculates EAL's. It uses classification counts, accident, off-tracking, speed, size, and weight information. The division indicates that there is a lack of heavy truck data for its needs.

Data Collection Activities

Classification Counts: The traffic count program includes information about all classes of vehicles on Virginia's highways. Heavy trucks are included in the interstate, arterial and primary traffic counts program. Vehicle classifications are Virginia passenger car, out-of-state passenger car, 2-axle 4-tire truck, 2-axle 6-tire truck, 3-axle or greater, tractor-trailer, and bus. The traffic count program was a manual operation with a statewide counting network composed of 1,345 sites of which the majority operated four times a year (73 sites operated nine times a year and 324 sites two times). The duration of each operation was 12 hours. There were also 56 permanent stations that generated machine counts without classification data for 24 hours a day, 7 days a week. As of January 1, 1988, the manual traffic count program was discontinued.

Truck classification data are collected on urban streets and secondary routes on a scheduled basis for the HPMS program. A 12-hour vehicle classification count is done manually. At the present time, this division does not have the capability to collect classification counts automatically. Classification counts are summarized by vehicle type and by hour. Seven categories are used: (1) in-state cars, (2) out-of-state cars, (3) 2-axle 4-tire trucks, (4) 2-axle 6-tire trucks, (5) 3-axle trucks, (6) trailer trucks, and (7) buses.

Counts are also made on an as-needed basis. The counting period extends for about 40 weeks per year. Heavy truck classification counts are provided to the following divisions: Location and Design, Environmental, and Materials.

Accidents: This division administers the accident records that are forwarded by the DMV. The annual publication "Summary of Accident Data" does not specify the type of vehicle. However, the 1986 edition includes two summary tables illustrating rate and accident frequency for straight trucks, tractor-trailers, and twin trailers on interstate and primary highways. Beginning in 1985, additional information on length, width, number of axles, and type of trucks is being provided in the Police Accident Report, FR300P (see Fig. 4). Although this is not a routine procedure, a summary of truck accidents can be generated for each truck category and stratified by type of accident. The accident file processed by the DMV is sent to this division every day and is supplemented with the road inventory data, which include road type, lane width, shoulder width, mileage post, and traffic information.

Speed: Speed data are collected by radar equipment and automated detectors on an as-needed basis. Speed data are summarized as peak and off-peak, percentage under speed limit, percentage over speed limit, and number at the 85th percentile. Only in special studies are truck speeds identified; for example, to evaluate the need for a truck climbing lane. There are 36 speed monitoring locations that are used for the Virginia Monitoring Plan as required by the federal government.

EAL: About 10 times a year, this division furnishes the Materials Division with EAL values for specific projects. The AASHTO design procedure is used. Equivalent 18-kip axle loads are provided in tabular form, and actual highway load volumes are then converted by a formula.

Origin-Destination (OD) Surveys: Truck OD surveys are undertaken on an as-needed basis by stopping trucks and inquring about the trip. License surveys are not used because the licenses can be difficult to read. Also, if a truck has multi-licenses, it is a problem to decide which one to read. The most recent truck OD study was completed in Northern Virginia for use in the truck restriction study of the I-495 beltway.

Data Analysis and Use

Classification Counts: The major result of the traffic counting program is the publication of the report "Average Daily Traffic Volumes on Interstate, Arterial and Primary Routes." Copies are supplied to federal, state, and local governments. Approximately 1,200 copies are printed each year. The data are also used to prepare traffic flow maps that graphically portray the relative daily volumes section by section of each route. Although not routinely done, it would be possible to produce traffic flow data separately for heavy trucks. The percentage of truck traffic is one of the criteria used by this division in truck restriction studies.

COMMONWEALTH OF VIRGINIA - DEPARTMENT OF MOTOR VEHICLES DMV COPY

POLICE ACCIDENT REPORT

PAGE _____ OF _____ PAGES FR 300P (REV 9/84)

ACCIDENT DATE Month Day Year | DAY OF WEEK | TIME AM PM | COUNTY OF ACCIDENT | MILE POST NUMBER | RAILROAD CROSSING ID NO. IF WITHIN 150 FEET

1 CITY OR TOWN OF | LANDMARKS AT SCENE | NUMBER OF VEHICLES | OFFICIAL USE ONLY 17

ROUTE NO. OR STREET NAME AT SCENE 18

AT INTERSECTION WITH OR MILES FEET N S E W OF ROUTE NUMBER OR STREET NAME

2 VEHICLE NO. 1 | VEHICLE NO. 2 (OR PEDESTRIAN)

DRIVER'S NAME (LAST, FIRST, MIDDLE) | OCCUPATION | DRIVER'S NAME (LAST, FIRST, MIDDLE) | OCCUPATION

3 ADDRESS (STREET & NO.) | YEARS OF DRIVING EXPERIENCE | ADDRESS (STREET & NO.) | YEARS OF DRIVING EXPERIENCE 19

CITY | STATE | ZIP CODE | CITY | STATE | ZIP CODE 20

4 DATE OF BIRTH Month Day Year | SEX | DRIVER'S LICENSE NUMBER | STATE | DATE OF BIRTH Month Day Year | SEX | DRIVER'S LICENSE NUMBER | STATE 21

VEHICLE OWNER'S NAME (LAST, FIRST, MIDDLE) | VEHICLE OWNER'S NAME (LAST, FIRST, MIDDLE) 22

5 ADDRESS (STREET & NO.) | ADDRESS (STREET & NO.) 23

CITY | STATE | ZIP CODE | CITY | STATE | ZIP CODE

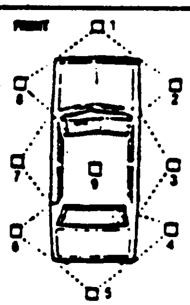
MAKE & TYPE OF VEHICLE (SHOW MOPED, MOTORCYCLE, AMBULANCE, ETC.) | YEAR | REPAIR COST | MAKE & TYPE OF VEHICLE (SHOW MOPED, MOTORCYCLE, AMBULANCE, ETC.) | YEAR | REPAIR COST 24

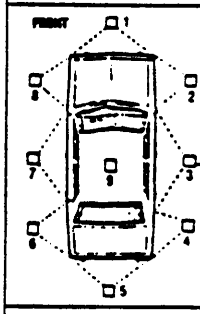
6 LICENSE PLATE NUMBER | STATE | NAME OF INSURANCE CO. (NOT AGENT) | LICENSE PLATE NUMBER | STATE | NAME OF INSURANCE CO. (NOT AGENT) 25

DAMAGE TO PROPERTY OTHER THAN VEHICLES | OBJECT STRUCK (TREE, FENCE, ETC.) | OWNER'S NAME (LAST, FIRST, MIDDLE) | ADDRESS | REPAIR COST 26

7 VEHICLE NO. 1 DAMAGE CHECK POINTS OF IMPACT | ACCIDENT DIAGRAM | VEHICLE NO. 2 DAMAGE CHECK POINTS OF IMPACT 27

8





28 29 30 31 32 33

INDICATE NORTH BY ARROW

SPEED: BEFORE ACCIDENT | LIMIT | MAXIMUM SAFE

SPEED: BEFORE ACCIDENT | LIMIT | MAXIMUM SAFE

VEHICLE NO. 1 DAMAGES: 1 UNKNOWN | 2 NO DAMAGE | OVERTURNED 3 | MOTOR 4 | UNDERCARRIAGE 5 | TOTALED 6 | BY FIRE 7 | OTHER 8

VEHICLE NO. 2 DAMAGES: 1 UNKNOWN | 2 NO DAMAGE | OVERTURNED 3 | MOTOR 4 | UNDERCARRIAGE 5 | TOTALED 6 | BY FIRE 7 | OTHER 8 34

ACCIDENT DESCRIPTION 35

36

37

OFFENSES CHARGED DRIVER:

ALL INJURED	9	10	11	12	13	14	15	16	NAMES OF INJURED - IF DECEASED, INCLUDE DATE OF DEATH
A									
B									
C									
D									
E									

TROOPER/OFFICER'S NAME | BADGE/CODE NUMBER | DEPARTMENT NAME AND CODE NUMBER | REVIEWING OFFICER | DATE REPORT FILED

Figure 4

Classification counts on interstate and primary routes for HPMS are provided by this division. A typical page from the report is shown in Table 1.

In special studies, truck classification counts are an indicator of the level of noise and safety. Classification data are also used in capacity analysis and the HPMS reporting requirement.

Some jurisdictions perceive that they can increase their opportunity of funding by transferring secondary roads to primary ones. Table 2 shows nine factors of which the majority should be met in order to change a secondary road to a primary one. Truck classification collected by this division and stratified by truck type, including tractor-trailers and buses, is a part of the evaluation process.

Table 2 Criteria for Recommending the Transfer of Secondary Roads to the Primary System

1. The road constitutes a link of an interstate or intrastate highway.

2. The road serves a place of great historical or scenic interest.

3. The road connects county seats.

4. The road has a minimum traffic volume of 750 vehicles per day.

5. The road carries a minimum of 7 percent foreign vehicles.

6. The road carries a minimum of 20 percent light and medium trucks.

7. The road carries a minimum of 2 percent tractor-trailers and buses.

8. Twenty percent of the traffic on the road is on trips of 25 miles or more in length.

9. Five percent of the traffic on the road is on trips of 100 miles or more in length.

Accidents: One of the criteria for making a special study of a hazardous location is the occurrence of more than two

INTERSTATE, ARTERIAL AND PRIMARY TRAFFIC TABULATIONS

ROUTE NUMBER	FROM	TO	AVERAGE DAILY TRAFFIC							
			VIRGINIA PASSENGER CARS	OUT OF STATE PASSENGER CARS	SINGLE UNIT TRUCKS			TRAILER TRUCKS	BUSES	TOTAL VEHICLES
					2 AXLE 4 TIRES	2 AXLE 6 TIRES	3 AXLE 6 10 TIRES			
75	TENNESSEE STATE LINE	RT 670 GREEN SPRINGS	440	55	270	60	15	2	3	945
75	RT 670 GREEN SPRINGS	SCL ABINGDON	2,350	60	1,150	110	20	7	3	3,700
I-77	NORTH CAROLINA STATE LINE	RT 148 NORTH OF FANCY GAP	930	6,200	850	440	90	2,850	60	11,420
I-77	RT 148 NORTH OF FANCY GAP	RT 58 WEST OF HILLSVILLE	1,800	5,900	1,250	460	50	3,100	60	12,620
I-77	RT 58 WEST OF HILLSVILLE	RT 69	2,700	6,100	1,750	360	70	3,250	85	14,315
I-77	RT 69	RT 81 E OF FORT CHISWELL	3,100	6,100	1,800	530	55	3,200	25	14,810
I-77	RT 81 N OF WYTHEVILLE	RT 717	3,900	5,600	1,850	410	50	1,500	25	13,335
I-77	RT 717	RT 52 WEST OF BLAND	2,650	5,800	2,000	370	50	1,450	20	12,340
I-77	RT 52 WEST OF BLAND	RT 666	1,650	5,600	1,600	370	50	1,700	25	10,995
I-77	RT 666	RT 606	1,800	5,700	1,650	380	55	1,700	25	11,310
I-77	RT 606	RT 52-61 ROCKY GAP	2,300	5,900	2,100	430	95	1,650	45	12,520
I-77	RT 52-61 ROCKY GAP	RT 52 & 598	2,300	5,800	2,100	410	80	1,500	25	12,215
I-77	RT 52 & 598	WEST VIRGINIA STATE LINE	2,700	5,700	2,000	400	85	1,500	25	12,410
78	APPALACHIA	RT 686 NEAR ANDOVER	2,650	200	1,250	250	130	50	10	4,540
78	RT 686 NEAR ANDOVER	RT 600 NEAR STONEGA	2,250	180	1,100	240	120	55	5	3,950
79	RT 55 WEST OF LINDEN	RT 66	2,200	750	1,350	140	50	110	10	4,610
80	KENTUCKY STATE LINE	RT 768 BREAKS P O	1,100	530	420	10	2	2	1	2,065

Table 1

fatal accidents at that location within a three-year period. Sometimes, problems are also identified by the media. By examining the truck accident history, this division also identifies hazardous locations that may require a runaway truck escape ramp. Input data and requirements are provided to the Location and Design Division for actual design application. The analysis of accident data is used in order to fulfill the requirements of the Surface Transportation Assistance Act of 1982 (STAA) that requires the safe accommodation of heavy trucks on Virginia highways. As of March 1987, Virginia has some 1,903 miles of highways for use by the longer and wider vehicles on the designated and access systems. Truck accident history is applied directly in a truck restriction study to assess the safeness of trucks on the routes of concern.

Off-tracking: Off-tracking data are provided by the Location and Design Division where off-tracking information for different truck types is maintained. These data are used to examine whether the roadway geometry is adequate and to consider the ability of a road section to accommodate safely large trucks for STAA route approval. Data are also used in revising minimum standards of entrances to state highways. These standards regulate the construction of entrances and exits to and from commercial and industrial establishments, and they are used by city or county authorities to establish their ordinances.

Speed: In special studies, speed is often an important factor required to determine whether there is a relationship between speed and the severity of accidents, weather, etc. Of special concern regarding heavy trucks is their capacity for acceleration on ascending sections of a highway. Separate truck climbing lanes may be required where traffic is impeded by slower moving trucks, which results in capacity decreases.

Size and Weight: Heavy truck size and configuration data are furnished by the Maintenance Division. Truck size information is used in preparing background requests for the legislature. State Police and the Truck Weighing Unit within the Maintenance Division provide heavy truck weight data. These data have been used for assessing the routing of longer and wider loads, which is now permitted by the Surface Transportation Assistance Act of 1982.

In calculating EAL for pavement designs completed by the Materials Division, this division uses standard tabulated factors to convert traffic counts to equivalent 18-kip loads. If actual weight data are required for a specific section of roadway, the truck weight data are furnished by the Maintenance Division.

OD Survey: The results of OD surveys can determine how many truck trips are to be rerouted and the possible alternative routes. These surveys are conducted when restrictions to truck traffic are under consideration or the potential needs for new truck facilities are to be determined.

Needs

The data need of highest priority relates to the truck accident reporting system. Additional data are required that provide size and configuration information as well as operational defects, driver condition, and histories. Data on types of cargos carried and ownership information are also needed. These additional items will furnish the division with an opportunity to assess countermeasures and develop realistic and cost-effective safety operations. This type of information is now included in a State Police report form being field tested beginning January 1987. Details about this accident data form are described under the sections concerning the Department of State Police.

Transportation Planning Division

This division develops passenger car equivalents (PCE). It uses heavy truck accident and PCE data. The division reports that the heavy truck data presently available are sufficient for its needs.

Data Collection Activities

PCE: The division does not determine PCE values by truck type but does input truck classification data to computer programs that generate PCE values. The results are used for capacity analysis studies. PCE determinations are done routinely, and the results of capacity analyses are provided to the Location and Design, Environmental, and Traffic Engineering Divisions.

Data Analysis and Use

Accidents: Accident information furnished by the Traffic Engineering Division is used in reporting truck safety levels at specific planning sites. Accident rates of heavy trucks as well as all vehicles are also used to prioritize road improvement projects at the statewide planning level.

PCE: Passenger car equivalents, adopted from the Highway Capacity Manual, together with classification counts are used in capacity analysis. Computer programs are available for calculating these conversions. The PCE values generated are used in determining the level of service for planning purposes.

Department of Emergency Services

The Department of Emergency Services does not collect heavy truck data. It uses heavy truck count and accident information in the hazardous material response program. Both are indicators of potential locations of hazardous materials spills or leaks. The count and accident data are obtained from the VDOT (Traffic Engineering Division) and the State Police.

Department of Motor Vehicles

The DMV is involved in collecting and using heavy truck accident, size, and weight data. Heavy truck data presently available are sufficient for this department's needs.

Data Collection Activities

Accident: When a truck involved in an accident has six or more tires, the reporting police officer provides length, width, and number of axles in addition to other data on an accident report (FR300P). Only a reportable accident is filed; it is defined as an accident occurring on public property involving death, personal injury, or total combined property damage of $500 ($750 effective July 1, 1988) or more. Accident reports are sent to the Centralized Accident Processing Center. After the central accident process, a monthly summary is sent to the State Police on a tape. The VDOT (Traffic Engineering Division) has access to this accident file, and it may add other necessary information for its own use.

The Crash Investigation Team has responsibility for determining the circumstances and probable causes of traffic crashes. The team is a multi-disciplined group consisting of a highway engineer, a state trooper, and a psychologist, with advisory assistance when needed from medical people, mechanics, or other personnel. The team investigates contributing factors prior to the crash, details of the crash, and data of interest on post-crash developments.

Size, Configuration, and Weight: Truck size, configuration, and weight data are collected by the Vehicle Services Section for registration purposes. Information is furnished at the time of registration. Truck owners may register either yearly or quarterly. Vehicles that are registered quarterly are primarily farm vehicles, produce carriers, and seasonal transport vehicles. After the data are entered into the computer master file, they are available at any time.

Data Analysis and Use

Accidents: Accident records are incorporated into the annual "Virginia Traffic Crash Facts" and the Crash Investigation Team's daily crash report. The former is a comprehensive annual report that produces a profile of accidents stratified by factors reported on accident form FR300P. Trucks in this report are categorized as straight trucks, tractor-trailers, or tractor-twin trailers. The team report is an in-house document, which updates statewide accident statistics.

Size, Configuration, and Weight: Truck configuration and weight data are used in budget and fiscal areas for revenue assessments. The information contained in the master file in the DMV is also used to respond to legislative requests, such as providing the number of trucks within a certain weight group or the number of certain types of trucks.

Other: The DMV provides a list of license numbers to each weigh station indicating the identity of vehicles that have been suspended for any reason.

Off-tracking, speed, and other relevant evidence that may be available are recorded for selected accidents for which in-depth investigations are conducted by the Crash Investigation Team. Information is shared with federal, state, and local governments. The team also makes conclusions and recommendations. Between July 1984 and June 1987, the team released 70 investigative reports. Twenty five crashes were investigated by the team in 1986, of which only five involved trucks.

State Corporation Commission

The Motor Carrier Division of the State Corporation Commission (SCC) registers heavy trucks with more than two axles and all tractors for the purposes of economic regulation of motor carriers and the collection of Motor Fuel Road Use Taxes. This registration is separate from that of the DMV. A flat rate of ten dollars is levied on each vehicle used to transport property. The Motor Carrier Division sends bills to the vehicle owners to collect this fuel tax, which is based on the actual mileage traveled and fuel used in the state. The SCC's 30 personnel and the State Police enforce this law. They can either operate in a weigh station or work independently. Summonses are issued to drivers of vehicles without proper registration. The SCC also has a staff of 18 people who audit for compliance of the Motor Fuel Road Tax requirement. All records of heavy trucks and tractors in Virginia are entered into the SCC proof-of-operation system to assist in compliance.

Department of State Police

The Motor Carrier Safety Division of the State Police is a heavy truck data user. Data used are classification counts, accidents, speed, size, and weight. It collects heavy truck accident data primarily for its own use. There is a lack of heavy truck data for this division's needs.

Data Collection Activity

Accidents: All troopers file the Police Accident Report (FR300P) on every reportable crash. When a heavy commercial vehicle is involved in a reportable crash, the officer files a statistical indicator form (see Fig. 5) in which information on carrier and trip, driver and passenger, vehicle, cargo, and the accident is recorded. The FR300P covers only length, width, and number of axles. The statistical indicator form, adopted in January 1987, is the first complete information source of heavy truck accidents in Virginia.

All information in the statistical indicator form has been entered into a computer. As of May 1987, 1,602 reports were filed.

Inspection History: The Motor Carrier Safety Division carries out a safety inspection program for heavy commercial vehicles. The State Police checks heavy commercial vehicles at truck weigh stations or at safe roadside locations and keeps records on a history sheet, form SP-233, which requires the owner to correct the defects indicated on the form and to respond to the State Police within 30 days (see Fig. 6 and Fig. 7). The police officers may issue summonses on defective

TEMPORARY REPORT - DEPARTMENT OF STATE POLICE

ACCIDENT DATE | ACCIDENT LOCATION ☐ County ☐ City ☐ Town of

CARRIER AND TRIP INFORMATION

NAME OF CARRIER (Corporate business name under whose authority vehicle is operated)

CARRIER ADDRESS | CITY | STATE | ZIP CODE

TYPE OF OPERATION ☐ Private ☐ Common Carrier ☐ Contract Carrier ☐ Exempt. Comd. ☐ Household Goods ☐ Passenger ☐ Rental ☐ Other

PERMITS ☐ ICC Docket ☐ MC VA. Stamp ____ ☐ SCC Decal ____ ☐ VDH & T ____ ☐ EPA ID # ____ ☐ Health Dept. ID # ____ ☐

TYPE OF TRIP ☐ Over the Road ☐ Local Pickup/Delivery ☐ Charter or Special ☐ Regular Route ☐ City ☐ Other ____ Origin | Destination

DRIVER AND PASSENGER INFORMATION

NAME OF DRIVER | Social Security/Operators Number

Years Employed By Carrier ____ | Actual Hours Driven Since Last 8 off ____ | Est. Hours Driven Since Last 8 off ____

DRIVER ☐ Normal ☐ Asleep ☐ Sick | ☐ Drinking ☐ Drugs ☐ Medical Waiver ☐ Other ____ | Medical Examiner's Certificate ☐ Yes - Exp. Date ____ NO ☐

DRIVER QUALIFICATION

TRAINING ☐ YES - Explain ____ NO ☐

FATALITIES ☐ Driver ☐ Co-Driver ☐ Carrier Personnel ☐ Passengers ☐ Others ____ | INJURIES ☐ Driver ☐ Co-Driver ☐ Carrier Personnel ☐ Passengers ☐ Others ____ | SEAT BELTS Driver ☐ PASS. ☐ Installed ☐ IN ☐ USE

VEHICLE INFORMATION

VEHICLE TYPE	Yr.	No. Axles	MAKE	VIN. NO.	Comp. No.	TYPE OF BODY Van	Flat	Tank	Car Carrier	Other
Truck										
Tractor										
Semi-Trailer										
Full Trailer										
Full Trailer(s)										
Bus										
Other										

Length (Feet) / / | Width (In) | Height | Empty Wt. | Cargo Wt. | Gross Wt. | Fuel Type ☐ Gasoline | Diesel ☐ LPG

MECHANICAL DEFECT ☐ Not Applicable ☐ Other ☐ Engine ☐ Transmission ☐ Driveline ☐ Coupling ☐ Suspension ☐ Fuel System | BUS INFORMATION Seating Capacity ____ Total Passengers ____

CARGO INFORMATION

CARGO TYPE ☐ Gen. Freight ☐ Motor Veh's. ☐ Explosives ☐ Gases/Bulk ☐ Solids/Bulk ☐ Liquids/Bulk ☐ Mobile Home ☐ Driveaway/Towaway ☐ Farm Products ☐ Ref. Foods ☐ Logs/Poles/Lumber ☐ Household Goods/Furniture Fixtures ☐ Metal: Coils/Sheets/Rods/Plates/Etc. ☐ Heavy Machinery/Other Large Objects ☐ Empty ☐ Other ____

PLACARDS ☐ YES ☐ NO | HAZARDOUS MATERIAL CLASS

ACCIDENT INFORMATION

NON COLLISION ☐ Ran Off Road ☐ Jackknife ☐ Overturn ☐ Units Separated ☐ Loss/Spill Cargo ☐ Cargo Shift ☐ Other ____ ☐ Fire

TOTAL NUMBER LANES ____ | TYPE OF HIGHWAY ☐ Interstate ☐ Divided ☐ Undivided

ACCIDENT RESULTS ☐ Explosion ☐ Fire ☐ Spillage/Non-Hazardous ☐ Spillage/Hazardous Mat'l ☐ Other ____

INVESTIGATING TROOPER/OFFICER	Badge Code No.	Department Name	Reviewing Officer	Date Filed

Figure 5

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S.P. 233 11-1-86

VIRGINIA STATE POLICE MOTOR CARRIER SAFETY CHECK

NO. 18838

CARRIER

NAME OF MOTOR CARRIER OPERATING AUTHORITY	
STREET ADDRESS	
CITY/STATE/ZIP CODE	MC.SCC I.D. NO
TIME STARTED / DATE / LOCATION OF INSPECTION	TYPE OF OPERATION

DRIVER	SHIPPING PAPER
LAST NAME / FIRST NAME / MI	IF EMPTY/LAST LOAD
STREET ADDRESS	ORIGIN / DESTINATION
CITY/STATE/ZIP CODE	NAME OF SHIPPER
DOB / OL-CL- NUMBER/STATE	DATE / NUMBER OF DOCUMENT
POWER UNIT-STICKER NUMBER EXPIRATION DATE	COMMODITY
TRAILER-DECAL NUMBER EXPIRATION DATE	HAZARDOUS MATERIAL CLASS

VEHICLE	MAKE	YEAR	ID NUMBER	COMPANY NUMBER	BODY TYPE		SLEEPER YES / NO	TAG NUMBER/STATE
POWER UNIT								
TRAILER								
TRAILER								

DEPT USE	SECTION	FINDING AND REMARKS	OUT OF SVC.

NOTE TO MOTOR CARRIER IF VEHICLE HAS BEEN PLACED "OUT OF SERVICE"

BRAKE ADJUSTMENT

	AXLE 1	AXLE 2	AXLE 3	AXLE 4	AXLE 5	AXLE 6	AXLE 7
RIGHT							
FRONT							
LEFT							
CHAMBER SIZE							

PURSUANT TO AUTHORITY CONTAINED IN THE 1950 CODE OF VIRGINIA (AS AMENDED) I HEREBY DECLARE AND MARK THE ABOVE VEHICLE(S) "OUT OF SERVICE". NO PERSON SHALL REMOVE THE HEREIN NUMBER STICKER(S) OR OPERATE SUCH VEHICLE(S) UNTIL NECESSARY REPAIRS HAVE BEEN COMPLETED AND THE VEHICLE(S) RESTORED TO SAFE OPERATING CONDITION.

PLACED OUT OF SERVICE BY: | TEL. NO. OF STATE POLICE

UNDER SECTION 46.1-279.01

AFTER VEHICLE HAS BEEN REPAIRED COMPLETE SECTION A ON REVERSE SIDE

INSPECTED BY | CODE NO.

UNDER SECTION 52-8.4 | UNDER SECTION 10-306

COMPLETE SECTION B AND MAIL WITHIN 15 DAYS TO ADDRESS SHOWN ON REVERSE SIDE

LOCATION PLACED OUT OF SERVICE

SEAL NOS. REMOVED | DEPT. SEAL NOS. INSTALLED | OUT/SVC STICKER NOS. POWER UNIT | OUT/SVC STICKER TRAILER NO. 1 | TRAILER NO. 2

DEPT USE | COPY RECEIVED BY | TIME ENDED

Orginal — Safty Division

Figure 6

S.P. 99-MC (Proposed) **MOTOR CARRIER SAFETY INSPECTION REPORT FORM**

DATE:__________ MCSAP ☐ TYPE INSPECTION: ☐ Roving ☐ Stationary ☐ Fixed Scale

SHIFT 1, 2 or 3: ☐ FIXED LOCATION:__________________ COUNTY:__________

VIOLATIONS:	TRUCK		BUS		# Violations
DRIVER	#Viol.	#OOS Act.	#Viol.	#OOS Act.	Incl.in Summons
MCSR:					
Medical Certificate					
Hours of Service (Part 395)					
Commercial Driver License					
License Revoked or Suspended (CDL)					
Other (MCSR)					
Other Related:					
Safety Inspection					
VIN Plate					
Registration					
SCC					
Overweight					
Overlength					
Radar Detector					
Other					
EQUIPMENT:					
Brakes					
Coupling Devices					
Emergency Equipment					
Warning Devices, stopped vehicles					
Exhaust System					
Frames					
Fuel System					
Lighting					
Seat Belts					
Steering Mechanism					
Suspension					
Tires					
Wheels, Rims, Studs, Clamps, etc.					
All Other Equipment Violations					
HAZARDOUS MATERIALS:					
Shipping Papers					
Placards					
Marking					
Labeling					
Blocking and Bracing					
No Retest & Inspection (cargo tank)					
No Remote Shutoff Control					
Use of Non-Specification Container					
All Other Haz Mat Violations					
TOTAL VIOLATIONS					

SUMMARY:

TRUCK	Haz Mat	All Other
# Full Inspections		
# Walk-Around Driver/Vehicle		
# Driver Only Inspections		
# Defective Vehicles		
# Vehicles OOS/# OOS Violations	/	/
# Drivers OOS/# OOS Violations	/	/
# Other Violations (Not OOS)		

BUS	
# Inspections	
# Defective Vehicles	
# Vehicles OOS/# OOS Violations	/
# Drivers OOS/# OOS Violations	/
# Other Violations (Not OOS)	
# Commuter Bus Lines Company Audits	

SUMMONS ISSUED:	
52-8.4	
10-305	
46.1	
Total Summons Issued	

MEMBERS:	HOURS Reg	OvT
Total Man Hours		

Figure 7

vehicles and declare any seriously defective vehicle to be "out of service." All the inspection records on SP-233 are saved on a computer tape for reference.

Data Analysis and Use

Classification Counts: Data on average daily vehicle miles of truck travel received from the Traffic Engineering Division are used by the State Police in annual reports that require exposure information. These data are adopted from the "Average Daily Traffic Volumes on Interstate, Arterial and Primary Routes." An issue is whether or not to include 2-axle 4-tire vehicles, because most vehicles in this category are pickup trucks.

Accidents: The DMV and the VDOT furnish accident statistics to the State Police after processing the data. These statistics are used in public awareness programs and to help prevent truck accidents.

At this stage, data in the statistical indicator forms have not been extracted for analysis.

Others: The recorded speeds of trucks exceeding the speed limit are used by the State Police as a source of data in their efforts to enforce speed limits. Size and weight measured by the Truck Weight Unit at weigh stations or at the road side is a means for catching violators.

The aforementioned inspection history is provided to the court for identifying carriers with frequently defective vehicles and for determining penalty charges.

Needs

The Motor Carrier Safety Division believes that drivers are not the only ones responsible for safety violations. In most circumstances, drivers do not purposely jeopardize themselves by operating heavy trucks. The motor carriers themselves are responsible for the quality of equipment and the expertise of drivers on the roads, and an accident report should reflect this. Drivers are required to maintain the schedule established by the carriers. If they do not, others will. The current accident report does not indicate whether the trucks traveling over interstate highways are more dangerous than those hauling short-run shipments on other highways.

Department of Waste Management

As a regulatory agency, the Department of Waste Management is authorized to specify the qualifications and requirements for drivers and carriers of hazardous materials. State Police enforce hazardous materials transport on the highways, while the department assumes the administrative enforcement on companies carrying hazardous materials.

This agency indicated the need for more information about companies that are violating hazardous materials transport regulation. The temporary accident report form used by the State Police has information that could serve this need.

Other Agencies

Among the 17 agencies surveyed, four indicated they have little or no involvement directly with heavy truck data. They are the Secondary Roads, Environmental, Urban, and Right of Way Divisions.

COLLECTION AND USE OF HEAVY TRUCK DATA BY DATA CATEGORY

The collection and use of truck data can be divided into three categories: (1) for statistical reports and monitoring purposes, (2) for special studies or design, and (3) for enforcement programs.

Data of the first category are collected on a routine basis, and reports are prepared periodically. Data for special studies or design are collected at the site where investigation or design is being made; this occurs on an as-needed basis. Data of the third category are recorded only when an infraction of the law occurs. The following sections describe the extent of data collection and its use (see Table 3).*

Table 3 Categories of Data Elements

Statistical reports and monitoring purposes	Classification counts and accident
Special studies	Off-tracking, PCE, EAL, speed, size, and weight
Enforcement programs	Speed, size, and weight

Classification Counts

Data Collection

Heavy truck classification counts are included in the Traffic Engineering Division's "Interstate, Arterial & Primary Traffic Count Program." Vehicle classifications consist of Virginia passenger cars, out-of-state passenger cars, 2-axle 4-tire trucks, 2-axle 6-tire trucks, 3-axle 6-10 tire trucks, tractor-trailers, twin trailers, and buses. There are a total of 1,345 counting sites for this program. Counts are taken

*The Highway Traffic Research Information System (HTRIS) and the Traffic Count Conversion Program, when implemented, could substantially change the data collection and information base described. The section on classification counts describes the program prior to January 1, 1988.

either 2, 4, or 9 times a year at each location. The distribution is shown in Table 4. The Traffic Engineering Division publishes the count data every year in a manual entitled "Average Daily Traffic Volumes on Interstate, Arterial and Primary Routes," which is summarized by 24-hour average daily traffic (ADT) by section of roadway, 24-hour vehicle miles travelled (VMT) by route and county, and 24-hour VMT statewide. Twin trailers are included in the tractor-trailer category. Copies of this document are supplied to federal, state, and local governments. Specific agencies that request this document are: State Police, DMV, State Corporation Commission, Location and Design Division, Bridge Division, Transportation Planning Division, and Maintenance Division. Private companies and individuals may obtain the manual at a nominal fee.

Table 4 Number of Counting Stations by Frequency

Frequency/Year	Number of Stations
2	324
4	948
9	73
Total	1,345

The Traffic Engineering Division calculates VMT of trucks in order to derive truck accident rates if required. Classification counts are used by the Traffic Engineering Division in determining if truck travel should be restricted on a given roadway. The determination is made using data provided by the Transportaion Planning Division or collected by the Traffic Engineering Division.

The Maintenance Division conducts a weight study at about 20 locations biennially. It is composed of two items: vehicle classifications and truck weight data. These 20 pre-selected sites remain relatively constant from year to year. Table 5 shows the locations for the 1985 truck weight study. Classification counts are conducted each year at every station for a 24-hour period, where all vehicles in the traffic stream are counted and classified. Counts are made for the number of passenger cars, buses, and several truck types as detailed in Table 6 and Table 7. The sole purpose of this data collection activity is to comply with the Truck Weight Study compiled by FHWA. Recently, since the 13 classifications have been changed to be consistent with those used by FHWA, the classification counts are also used by the Traffic Engineering Division in HPMS reporting.

Table 5 Locations for 1985 TWS

Station	Route	Location
11	13	2.00 miles S. of MD state line
12	460	14.20 miles E. of Roanoke
13	50	0.20 miles W. of Rt. 15
15	58	7.30 miles W. of Rt. 501
16	220	2.00 miles N. of NC state line
17	189	2.00 miles S. of Rt. 58
20	460	1.00 miles W. of Rt. 100
22	58	SW city line of Portsmouth
23	250	City of Richmond
26	95*	1.40 miles S. of Rt. 35
27	11	2.83 miles S of Rt. 277
28	11	1.66 miles N. of Rt. 115
29	95*	1.20 miles N. of Rt. 234
30	81*	1.50 miles S. of Rt. 220
31	66*	2.26 miles E. of Rt. 28
32	64*	2.42 miles W. of Rt. 33
33	81*	2.98 miles S. of Rt. 277
34	85*	1.92 miles S. of Rt. 144
35	77*	4.35 miles N. of Rt. 717

*Interstate

Table 6 Vehicle Classification for 1985 TWS

Motorcycle-scooter	
Passenger cars:	Small in-state
	Small out-of-state
	Std-comp in-state
	Std-comp out-of-state
Buses:	Commercial buses
	School, non-rev buses
Single-unit trucks:	Panel and pickup
	2-axle 4-tire
	2-axle 6-tire
	3 or more axle
Tractor and semitrailers:	2-axle tractor
	3-axle tractor

Data Uses

The Traffic Engineering Division uses classification count data to meet HPMS reporting requirements. Information on the percentage of truck traffic is one of the nine factors that affect the change of a secondary road to a primary road, as was mentioned previously. Classification counts are also used by the Transporation Planning Division in the calibration and validation of models on an as-needed basis. Inputs in capacity analysis include classification counts because truck volumes are a major element of highway capacity.

Table 7 Vehicle Classification for 1987 TWS

Cars	
Motorcycles	
Pickups, vans and other 2-axle 4-tire	
Buses	
Single-unit trucks:	2-axle 6-tire
	3-axle
	4-axle or more
Single-trailer trucks:	4-axle or less
	5-axle
	6-axle or more
Multi-trailer trucks:	5-axle or less
	6-axle
	7-axle or more

The Environmental Division's environmental impact studies of air and noise are influenced by the amount of truck traffic on any road section studied. The Location and Design Division and the Construction Division also give special attention to highways with a high percentage of truck travel when designing facilities and traffic control strategies. The Bridge Division requests from the Traffic Engineering Division ADTT information, and these data are used to determine the design category of steel bridges according to AASHTO codes. The Department of Emergency Services uses heavy truck counts in its hazardous materials response program, and the Motor Carrier Safety Division of the State Police uses truck VMT in deriving rates of truck accidents and in deploying its enforcement forces.

Accident

Data Collection

The accident report form (FR300P) is completed by a police officer at the scene of an accident. The State Police then sends copies to the DMV and the VDOT for summary and analysis. The DMV is responsible for overall adminstration of the accident record system, which includes all accident data gathered, data maintenance, and subsequent use and compilation. About 80 percent of the data received from the State Police is coded and keypunched into the automated centralized accident processing (CAP) system by the Driver Services Administration (DSA). Reports are then transmitted to VDOT, where the remaining 20 percent of the information, which deals with highway characteristics, is coded by the Traffic Engineering Division. The CAP Maintenance and Enhancement Committee is reponsible for policy and procedures, and the Transportion Safety Administration (TSA) of DMV is responsible for overall maintenance of the system and the integrity of the data base. TSA also acts as liaison to other agencies that use the CAP system. VDOT codes and enters the highway location information into the system and verifies the correctness of DSA's coding.

As a result of a VDOT and State Police agreement, beginning in 1985 specific information pertaining to trucks is requested on the FR300P form. This information includes width, axle number, truck type, and length. With these elements in the record, truck accident histories can easily be extracted for analysis.

In January 1987, the Motor Carrier Safety Division of the State Police began to use a new data collection form designed especially for heavy truck accidents. This form, which supplements FR300P, includes substantially more information than was collected previously. Items noted are carrier and trip information and specifics about the driver, passenger, vehicle, cargo, and the accident. This truck-exclusive information is expected to furnish the first data base in the state that can be used to thoroughly explore truck safety issues. As a temporary test, the statistical indicator form is to be revised after the first year of implementation if necessary. Information from the new form has not been forwarded to other agencies, but is entered into a computer at the State Police Headquarters. The State Police has completed analysis of the data from the six-month period ending June 1987.

Data Uses

Accident data are mainly used for reporting purposes, either by number or accident rate for different jurisdictions and locations within the state. Identification of a hazardous site is the responsibility of the Traffic Engineering Division. This is achieved by identifying those locations where more than two fatal motor vehicle accidents occurred in three years. For example, the need for truck runaway ramps is identified from the accident data, which identify highway sections where runaway trucks have caused accidents on downgrades. Presently, 12 truck runaway ramps have been constructed on highways in Virginia.

The Department of Emergency Services reviews truck accident records as part of its hazardous materials response program.

Off-Tracking

Data Collection

Off-tracking of a truck is a function of truck type, turning radius, and the degree of a turn. If the dimensions and configurations of trucks do not change, then there is no need to update this information. The Location and Design Division is responsible for gathering the latest information on vehicle off-tracking.

Data Uses

When the Traffic Engineering Division conducts an investigation of a proposal for STAA route approval, it may require vehicle off-tracking data to help in identifying problem locations. Off-tracking data is also used in the revision of minimum standards for entrances to state highways by heavy trucks.

The Crash Investigation Team measures off-tracking whenever a truck is involved in an accident being investigated. This information is included in the investigation report. There has not been a systematic analysis of truck off-tracking and its impact on accidents. This may be because the number of truck accidents selected for investigation may be too small to produce a reasonable conclusion.

Passenger Car Equivalents (PCE)

Passenger car equivalency of large trucks on various road types and with different geometric and operating conditions has been established in the 1985 Highway Capacity Manual. The Transportation Planning Division uses a computer software package to calculate capacities at various levels of service that incorporate the percentage of trucks in the traffic stream. The results of capacity-analysis data developed by this division are furnished to the Location and Design, Environmental Quality, and Traffic Engineering Divisions and construction districts.

Equivalent Axle Loads (EAL)

The Traffic Engineering Division conducts traffic field studies that include estimated ADT, number of trucks, and axle load distribution of both single and tandem axles. This information is forwarded to the Materials Division for pavement design purposes. Traffic data collected for a period of 8 hours is converted into equivalent 18-kip axle loads. An analysis period of 20 years and a servicability index of 2.5 are the parameters most often used in design. There are approximately 10 requests per year received by the Traffic Engineering Division for EAL information.

Speed

Data Collection

The Traffic Engineering Division collects vehicle speed data on an as-needed basis, even though most of the automated counting machines also have the capability to detect the speed of any counted vehicle. Radar equipment is also used by the Traffic Engineering Division and the State Police. The State Police uses speed data primarily for enforcement purposes. Speed records are not maintained by the State Police except when citations are made. The Crash Investigation Team of DMV records the speed of vehicles that are involved in selected accidents, and this constitutes an important element of its investigative reports.

Data Uses

The Traffic Engineering Division summarizes speed data by peak and off-peak period, percentage under 55 MPH, percentage over 55 MPH, and speed at the 85th percentile. This information is used in special reports as a variable relating other elements under study. The Certification of Speed Enforcement prepared by the Traffic Engineering Division is submitted to FHWA annually. This submission summarizes the monthly number of citations issued by the State Police for violation of the 55 MPH speed limit, miles of highway with a 55 MPH speed limit by functional grouping , statewide percentage of vehicles exceeding 55 MPH, and analysis of newly adopted speed limit legislation. Speed data are also used in reviewing the adequacy of posted speed limits and by the State Police in allocating its forces. By identifying those locations with an unusually high rate of speed violation, the State Police may request the Traffic Engineering Division to study the adequacy of existing posted speed or needed improvements in highway design that will permit the speed limit to be increased safely.

A special application of truck speed data is the need for separate truck lanes in an ascending section of highway. In these sections, trucks with high ratios of gross vehicle weight to net horsepower (GVW/NHP) may impede traffic flow because of their low speed.

Size and Weight

Data Collection

The Vehicle Services Administration of DMV collects size and configuration data as well as empty weight and gross weight for registration purposes and to determine appropriate fee schedules. This is done annually or quarterly at the time of registration. Data are summarized in an annual truck-trailer survey, which gives a complete profile of registered trucks in the state by weight groups, vehicle combination, and carrier types based on licenses issued. Heavy truck size and weight data of vehicles involved in selected accidents is also collected by the Crash Investigation Team for reporting investigation results.

Besides the 20 stations used to gather data for TWS, the Maintenance Division, assisted by the State Police, operates 14 permanent weighing stations (see Table 8) and 10 mobile weighing units to enforce weight limits. When trucks are found to be overweight, the weight enforcement officer of the State Police prepares a "Virginia Overweight Citation" (DMV form VSA98), issues a copy to the driver of the overweight vehicle, and submits one to DMV. The weighing scale personnel also prepare a copy of "Truck Weigh Report" (VDOT form TW-14-A), which records information of each axle weight, driver, license, and owner. Effective January 1, 1987, DMV was made responsible for collecting and processing all fees for violations of overweight vehicles (see Fig. 8). Previously, the Virginia

Table 8 Locations of Permanent Weighing Facilities

Weighing Station	Location
Alberta	Rt. 85 - 4.70 Mi. S. of Rt. 46
Aldie	Rt. 50 - 0.20 Mi. W. of Rt. 15
Bland	Rt. 77 - 4.20 Mi. N. of Rt. 717
Carson	Rt. 95 - 1.39 Mi. S. of Rt. 35
Dahlgren	Rt. 301 - 1.00 Mi. S. of MD state line
Dumfries	Rt. 95 - 1.10 Mi. N. of Rt. 234
Fairfax	Rt. 66 - 2.50 Mi. E. of Rt. 28
Hollins	Rt. 11 - 2.25 Mi. S. of Rt. 604
Middletown	Rt. 11 - 2.80 Mi. S. of Rt. 277
New Church	Rt. 13 - 1.85 Mi. S. of MD state line
Sandston	Rt. 64 - 2.30 Mi. W. of Rt. 33
Stephens City	Rt. 81 - 2.50 Mi. S. of Rt. 277
Suffolk	Rt. 13 - 1.32 Mi. W. of Chesapeake city
Troutville	Rt. 81 - 1.40 Mi. S. of Rt. 220

courts had this responsibility. The fee is calculated by the officer who issues the citation according to the rate scale shown in Table 9.

Table 9 Rate of Liquidated Damage

Excess(lb)	Rate per Pound
5,000 and less	2 cents
more than 5,000	5 cents

The Maintenance Division conducts an annual monitoring activity to study truck bypassing of permanent weigh scales. Weigh-in-motion is being tested by the state. Even though it is not accepted in court as evidence, data collected by WIM describe the entire picture of truck weight without a sampling bias. The present procedure only maintains records of trucks that are cited. It is impossible to record the weight of each truck using current manual procedures.

Data Uses

Size and weight information maintained in the DMV registration file furnishes the basis for revenue predictions. Data are also available at any time for law enforcement purposes or legislative requests. The results of the Permanent Scales Bypass Route Survey provide the State Police and truck weighing personnel with potential locations where additional enforcement is needed.

VSA 98 (1/87)

VIRGINIA OVERWEIGHT CITATION

CITATION NO. VOC

☐ OWNER(S) ☐ LESSEE ☐ DRIVER ☐ OTHER

NAME(S) OF PERSON(S) CITED AS RESPONSIBLE FOR OVERWEIGHT CHARGE

SCC NUMBER

BUSINESS ADDRESS: STREET, RURAL ROUTE OR P.O. BOX | CITY | STATE | ZIP CODE

VEHICLE

PERSON(S) TO WHOM VEHICLE IS REGISTERED | ADDRESS

LICENSE PLATE NO. | YEAR | MAKE | TYPE | STATE | VEHICLE IDENTIFICATION NO.

OFFENSE

JURIS CODE: NAME | ROUTE NO. | LOCATION | PERMANENT/MOBILE UNIT NO.

DATE | TIME ______ AM ______ PM | AFFECTED CODE SECTION (CHECK ONE) ☐ 46.1-339 ☐ ______ | TYPE OF OVERWEIGHT ☐ SINGLE AXLE ☐ TANDEM AXLE ☐ GROUP OF AXLES ☐ GROSS ☐ ______

MAX. ALLOWABLE WT. | AMT. OVER ALLOWABLE WT. | RATE PER LB. OF LIQUIDATED DAMAGES | OFFICER'S SIGNATURE | CODE #

COMPLIANCE REQUIREMENTS

WITHIN 21 CALENDAR DAYS after the date that this Citation is served, as shown in the SERVICE OF PROCESS block at bottom of this form, the person cited above MUST DELIVER to the Virginia Department of Motor Vehicles either:

- Payment of the TOTAL AMOUNT ASSESSED

or

- Written notice of election to contest this overweight charge. If this election is made, complete the appropriate block below. Deliver this citation to DMV and trial will be scheduled on ______ (Trial Date - at least 60 days after Offense Date) at ______ in the ______ General District Court.

Complete the appropriate block below. Follow instructions on back of this Citation.

☐ Payment of TOTAL AMOUNT ASSESSED is attached.

☐ I elect to contest this overweight charge as signified by authorized signature below.

SIGNATURE ______ DATE ______

ASSESSMENTS

CIVIL PENALTY	$ 25.00
PROCESSING FEE	$ 20.00
WEIGHING FEE	$ 2.00
LIQUIDATED DAMAGES	$ ______
TOTAL AMOUNT ASSESSED	$

DMV/COURT COPY

SERVICE OF PROCESS

DRIVER'S NAME (FIRST, MIDDLE AND LAST)

DRIVER'S LICENSE NO. | STATE

DRIVER'S ADDRESS: STREET, RURAL ROUTE OR P.O. BOX | CITY | STATE | ZIP CODE

SIGNATURE OF DRIVER/AGENT ACCEPTING SERVICE (Signing this citation is not an admission of liability.) | DATE

Figure 8

The Certification of Size and Weight Enforcement prepared by the Maintenance Division is submitted to FHWA annually. This document includes analysis of newly adopted vehicle size and weight legislation, current operation, citations and permits issued, and enforcement efforts in the state.

NATIONAL STATISTICS

Highway Performance Monitoring System (HPMS)

The HPMS is a joint effort of federal, state, and local governments. Its purpose is to collect national data that will provide current statistics about the mileage and characteristics of the vaious highway systems throughout the nation. This data base is useful in obtaining specific highway and traffic volume data for a sample of different highway types.

The Traffic Engineering Division is responsible for organizing the material required to meet the HPMS reporting requirement. Each June, a magnetic tape that provides information on highway travel and accidents is sent to the FHWA. This information is furnished by the Traffic Engineering Division. No actual usage of these data by the state exists; however, possible application of HPMS data at state level is under investigation.

Truck Weight Study (TWS)

FHWA compiles TWS using information collected by the states. Two data elements are included: vehicle classification and truck weight. These are collected at selected sites where such operations can be accommodated. Classification counts are conducted for three 8-hour shifts (not necessarily consecutive) that cover all hours of the day. Weighing operations are conducted for an 8-hour period. For each vehicle surveyed, information relating to vehicle type, body type, class of operation, commodity carried, and type of weight excess is collected.

The Maintenance Division is responsible for collecting the TWS data. From 1956 to 1974, the study was done annually. Since 1975, it has been conducted biennially. Data is collected at twenty stations, and its primary purpose is to respond to the federal requirement. When there is a need for EAL data on highway sections directly adjacent to the weigh stations, TWS data are utilized in design. In other instances, additional weight data must be collected or data from prior studies may be used. These locations remain relatively constant year after year. The weigh stations with permanent scales are not used for TWS purposes but are for enforcement only. Information on TWS had not been used for any state purpose until 1986 when the

Transportation Planning Division utilized the classification counts for its submission to the HPMS.

Fatal Accident Reporting System (FARS)

FARS is a computerized data base containing information on all police-reported fatal accidents. It is managed by the National Highway and Traffic Safety Administration (NHTSA). Each accident in the data base involves at least one fatality. The FARS definition of a fatality is a death that occurs within 30 days of a motor vehicle accident and is a result of the accident.

Information on FR300P for fatal accidents is submitted weekly to the U.S. Department of Transportation by the DMV. Vehicle types are specified. In 1986, there were 1,002 fatal crashes reported to the FARS, among which 150 involved heavy-trucks (see Table 10). The Traffic Engineering Division provides highway information about fatal crashes to DMV using data extracted from the existing CAP files.

Table 10 1986 Fatal Truck Crashes

Vehicle Type	Number
Straight truck	55
Tractor-trailer	94
Multi-trailer	1
Total	150

Bureau of Motor Carrier Safety (BMCS) Accident File

BMCS collects truck accident data submitted by motor carriers that are subject to Department of Transportation regulations. The form used (MCS 50-T) is required when an accident results in death, bodily injury to a person who receives medical treatment away from the crash scene, or total property damage exceeding $4,200. When the reportable accident involves hazardous materials, a separate form has to be submitted within 15 days to the Department of Waste Management.

The DMV, Department of Emergency Services, and State Police have indicated that they use the BMCS accident data infrequently. There were fewer than 20 reports filed with the Department of Waste Management in 1986.

National Accident Sampling System (NASS)

The NASS has been administered by NHTSA since 1979. Its purpose is to provide national estimates of accidents and their characteristics. Statistical samples are selected to develop the estimates. The NASS teams perform in-depth accident investigations for each selected accident.

Some police agencies within the state are among the sampling units from which accidents are selected. A very small sample of truck accidents are included in this data base.

Truck Inventory and Use Survey (TIUS)

The U.S. Department of Commerce, Bureau of the Census conducts the TIUS every five years. It is designed to provide data on the physical and operational characteristics of the truck population and is based on a sample of private and commercial trucks registered in a state for a given survey year.

None of the seventeen organizational units surveyed indicates any involvement in the TIUS at this time.

CONCLUSIONS AND RECOMMENDATIONS

This study investigated the collection of data on heavy trucks by Virginia agencies, the uses of heavy truck data, and data needs. The study was limited to a direct examination of the data gathering process within the state, and no comparative evaluation was made with the way this activity is carried out in other states. Each area described as well as the activities in other states easily warrant more extensive discussion and documentation.

Conclusions

1. The collection of heavy truck data is the responsibility of many divisions within VDOT and other state agencies. Those divisions with a principal role in data gathering are Maintenance, Traffic Engineering, and Transportation Planning. Other state agencies with a principal role in heavy truck data acquisition are the DMV and the Department of State Police.

2. Two of the most important concerns of truck traffic are safety and the impact on roadway facilities. These two issues provide the primary justification for the acquisition of heavy truck data.

3. Heavy truck data is utilized within the VDOT primarily in the following divisions: Bridge, Location and Design, Materials, Traffic Engineering, and Transportation Planning. The DMV, the Department of State Police, and the State Corporation Commision also use heavy truck data for safety, inspection, and registration purposes.

4. The collection of heavy truck data and its use provide information for the following purposes: statistical reports, special studies or design, and enforcement programs. Statistical reports and monitoring require that heavy truck data be collected on a routine basis and that reports be prepared periodically. The data are also used to develop relationships and identify trends. The most common statistical reports are for accidents, traffic counts, and weight. Special studies where an investigation, design, or evaluation is being made require the acquisition of heavy truck data on an ad hoc basis. These studies occur as needed and may include data acquisition for speed, OD, counts, weight, and off-tracking. Heavy truck data for enforcement programs are recorded only when an infraction occurs. Data most commonly collected are for speed and

weight, but no record is maintained of trucks that operate at lower than legal limits.

5. The responsibilities of VDOT divisions and other state agencies for heavy truck data collection represent a wide spectrum of vehicle characteristics, with no one group maintaining a coordinating role. There are many reasons why a division has been given responsibility for particular heavy truck data. Rational or logical assignments of duties are not always in evidence.

   *The Traffic Engineering Division collects heavy truck data as part of the traffic classification program. It administers accident records submitted by the DMV, computes EAL values, and collects speed data as needed. Effective January 1988, this division assumed counting responsibilities of the Secondary Roads and Transportation Planning Divisions.

   *The Transportation Planning Division computes PCE values.

   *The Maintenance Division collects weight and classification data on a routine basis and operates permanent and mobile weigh stations for enforcement purposes. Weigh-in-motion units are also operated by this division.

   *The DMV summarizes and analyzes accident reports filed by the Department of State Police. This agency also collects information on size, configuration, and weight for registration purposes.

   *The Department of State Police files accident reports for heavy trucks, using a standard form as well as a special statistical indicator form developed in January 1987, which significantly expands the information obtained about the vehicle, driver, and owner.

   *The SCC registers heavy trucks for the purpose of economic regulation of motor carriers and the collection of the Motor Fuel Road Tax.

6. A substantial amount of heavy truck data is collected for federal reporting purposes. In many instances, these data are not utilized by the state, although national results may prove to be useful for understanding how a state compares with the nation as a whole with regard to level of safety, performance, trends in truck size, weight, and speed.

Recommendations

This study did not reveal major problems with or complaints concerning the availability and use of heavy truck data. However, several areas of improvement are possible, and these are stated in the following recommendations.

1. The creation of a separate office of Motor Carrier Transportation should be considered within VDOT. The function of this office would be to organize information regarding the status of heavy truck travel in Virginia, coordinate data gathering activities, and serve as a central clearing house for information.

2. The available data on heavy truck travel should be utilized to assist in developing strategies for improved management of truck travel on Virginia highways.

3. An investigation of heavy truck data collection in other states should be completed. The experience gained elsewhere might enable the state to improve the management of heavy trucks on Virginia highways.

4. Studies to determine the proper allocation of road funds that take account of heavy truck traffic should be undertaken. VMT is the measurement now used to allocate funds. Use of heavy truck volumes as determined by classification counts may provide a better indicator of road needs.

5. Studies to determine the level of accuracy of heavy truck data as gathered in Virginia should be undertaken. Comparisons with other states should be made including evaluations of the utilization of Federal guidelines. Consideration of accuracy and cost effectiveness of data applications should be included, especially in light of reduced funding for highway planning purposes.

6. Truck data collection should be improved in the following areas:
   *More detailed information regarding heavy truck accidents is required in order to investigate causes. The temporary accident report form created by the State Police should be carefully evaluated since it shows high promise for fulfilling this need. Compatibility with prior accident forms should be achieved to assure fullest use of both data sources.

   *Linkages should be developed between truck violations (accident, weight, vehicle inspection, hazardous materials, etc.) and the carrier (companies that own the trucks). Better information about the industry is needed to supplement that obtained about the vehicle and the driver.

*Weigh-in-motion techniques should be vigorously pursued to furnish more detailed and accurate information about heavy truck travel characteristics. These data could be used for both design and enforcement since speed, weight, and classification information are easily obtained at the same time.

*Operation of WIM in conjunction with permanent weigh stations can assist in efficiently enforcing truck weight laws as well as in collecting needed data.

*An assessment of the data collection process for federal reporting purposes should be undertaken with the objective of conforming more closely with state needs.

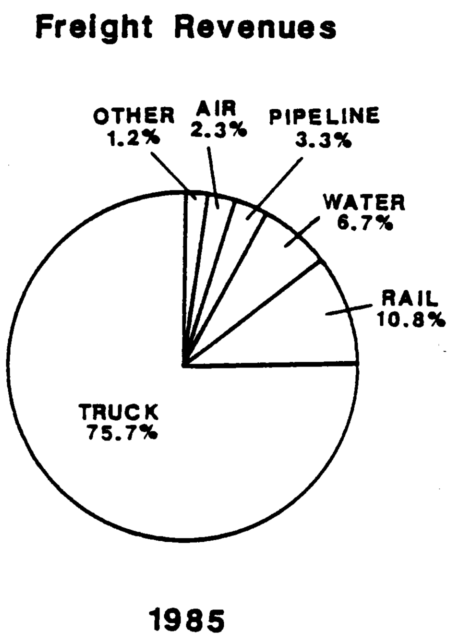
*Data relating to the impact of tire pressure on pavement performance should be acquired to assist in understanding the actual causes of pavement deterioration.

Appendix A

A Review of Heavy Truck Data and Characteristics

INTRODUCTION

The American trucking industry today is a $100 billion business that moves commodities from producer to consumer and accounts for more than three quarters of the country's freight revenues (see Figure 1) [1]. Trucking is a vital element in the state's economy since most goods in urban and suburban areas are transported by trucks. Also, interstate truck travel has an important role in the state's regional distribution network.



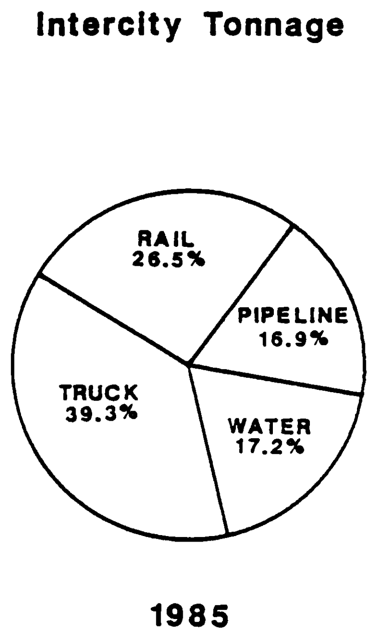


Figure 1

Source: American Trucking Trends-1986.

Trucking has long been recognized as a viable means of transporting goods in this country. In order to operate efficiently and productively, new technology and legislation have been developed that have improved trucking operations. This has had a significant impact on existing highway systems in terms of physical and operational characteristics. The enactment of the Surface Transportation Assistance Act of 1982 (STAA), which contains provisions that concern the length, weight, and width of commercial motor vehicles, represents a significant change in federal control that affects the entire industry and the nation's highway programs. The provisions of the STAA have required almost every state to make regulatory changes in order to conform to federal requirements.

Among the 33.8 million trucks reported in the 1982 Truck Inventory and Use Survey (TIUS) (the latest edition available), 89 percent have a gross vehicle weight (GVW) of 10,000 pounds or less (see Table 1) [2]. These lighter and

Table 1
Truck Distribution by Weight-1982 TIUS (In Thousands)

	10,000 Or Less Lb. GVW	10,001- 19,500 Lb. GVW	19,501- 26,000 Lb. GVW	26,001 Or More Lb. GVW
Total Trucks	30,222.8	1,194.7	796.2	1,620.7
Percentage	89.3	3.5	2.4	4.8

Source: Facts & Figures '86.

smaller trucks, which include most of the pickups, vans, panels, utilities, and station wagons, operate pretty much like passenger cars. What arouses the greatest concern is the remaining 11 percent: the heavy trucks that actually play the major role in freight transport.

It is predicted that the vehicle miles of combination truck travel will grow on the order of 2 to 4 percent annually through 1995 [3]. Consequently, trucking will continue to be a dynamic industry. As truck travel grows and becomes of greater importance to the economy, the influence of heavy trucks on highway systems in the areas of highway design, safety, and planning will be increased. To better facilitate the rapidly growing traffic, transportation and traffic professionals need to have a clear knowledge of heavy trucks.

This appendix summarizes heavy truck data, the methods of collecting it and its applications. Some of the national statistics on these data and results of statewide studies are also included. The focus is on pyhsical and operational characteristics, including weight, size, and classification counts; accidents, off-tracking, and lateral placement; PCE, EAL; and speed.

PHYSICAL CHARACTERISTICS

A study by NCHRP of state laws and regulations on truck size and weight indicates that the lack of uniformity in state laws concerning motor vehicle sizes and weights costs the American public from $1.6 to $2.8 billion annually [4]. This lack of uniformity not only cost the American public excessive amounts for transportation, but it also resulted in the unnecessary use of between 400 and 875 million gallons of motor vehicle fuel, mostly diesel [4]. There were also environmental effects produced by a larger number of truck trips than otherwise would be necessary to transport the same quantity of commodities, resulting in an additional increment of noise and air pollution that otherwise would be avoided. The study concluded with suggested uniform provisions.

An NCHRP study of motor vehicle size and weight regulations, enforcement, and permit operations for selected states found that there is a wide variation in state policy concerning permit issuance [5]. This variation has a greater impact on the trucking industry than enforcement. The problem stems partially from the fact that not all states have similar views on permit issuance. A state's ability to actually control sizes and weights on its highways is reduced because some truckers would rather risk getting caught than spend the time and money getting permits. Also, some states do not obtain as much as they should in permit fees. These are the result of permit issuance requirements that are difficult to comply with. The report concludes that there seems to be no reason why states could not cooperate and issue permits for interstate movements. Although STAA relieved some of the uniformity problem, it did not eliminate it. Rationalization instead of uniformity is seen to be a more feasible solution.

The following sections will discuss the physical characteristics of trucks such as weight, size, and classification.

A <u>truck</u> is a powered vehicle designed to carry a load. It may consist of a chassis and body or a chassis, cab, and body; or it may be of integral construction with the body and chassis forming a single unit [2]. A <u>tractor</u> is a motor vehicle that carries the weight of only part of its load by supporting a semi-trailer. A <u>semi-trailer</u> is a vehicle that places the weight of the load partly on its own rear axle(s) and partly on the tractor pulling it. A <u>trailer</u> supports its own load entirely; it is pulled by either a truck or tractor, or it may even be attached to another trailer or semi-trailer.

Weight

Weight data are essential to bridge design, pavement design and management, cost responsibility studies, enforcement programs, and road taxation. For highway maintenance purposes, weight data are a monitoring index, which is better than traffic counting for estimating rehabilitation or reconstruction needs.

In the past, weight data were collected by static scales in weight stations or by portable scales. Unfortunately, the data collected were expensive and typically unreliable owing to the fact that overloaded trucks often bypass weighing stations. It also causes delay and unsafe queues, which are the source of two of the trucking industry's most frequent and reasonable complaints. Another common complaint of truckers on long-distance hauls is that they are weighed or diverted to scales more than once in the same state and waste precious time even though they are operating legally. Although temporary bumper stickers of a different color and/or shape each day were recommended to provide one solution, it has not been widely implemented yet [5].

The use of weigh-in-motion (WIM) equipment has offered the potential for high-volume weighing of trucks without the attendant delays and safety problems often associated with conventional static weighing operations. Further, significant fuel savings may be realized by the application of WIM techniques. Weighing trucks in motion is a relatively new technique whereby truck weights are electronically recorded as a vehicle's wheels pass over scales in or on the pavement surface. Another technique, called a bridge weighing system (BWS), is to use instrumented highway bridge girders to act as equivalent static scales to obtain truck gross and axle weights [6]. This weighing equipment is portable and easy to install. The weighing operation is undetected by drivers of the trucks, so an unbiased sample is obtained. The BWS-WIM is used primarily on rural highways and is useful in determining which roads are used as bypass routes by overloaded trucks [7].

For any commodity at any density, truckers generally desire to maintain the highest possible payload to gross vehicle weight (GVW) ratio. There are economic incentives that often exceed the expected costs of overloading to the truckers. Unless effective sanctions are established, truckers are more likely to run overweight if they believe that the probability of being weighed is low and the penalities for being overweight are low. Even though claimed accuracy levels for WIM devices at highway speeds were found to be ±10 percent of static weights for any one axle, and cumulative truck weight accuracy levels as high as ±2.5 percent at a 95 percent confidence level have been experienced in Arizona [8], WIM weights have not been accepted by the courts. Because current WIM scales are relatively simple, cheap, efficient, and effective, especially as screening devices, they may well find wider acceptance as part of permanent fixed-scale installations in the future.

The Truck Weight Study (TWS) is compiled each year by FHWA from information collected by the states. Two sets of data are included: vehicle classification and truck weight. These are collected at preselected sites where such operations can be accommodated. There are between 10 and 20 sites per state, and locations remain relatively constant from year to year. More than 10 million vehicles are classified, and more than 200,000 trucks are weighed on an annual basis. Weighing operations occur as a separate activity but take place immediately upstream or downstream from the point of classification. They are normally conducted for an 8 hour period during daylight hours [9].

Most states determined the number and location of their truck weight stations on essentially a nonprobability, nonrandom basis. Budget consideration may limit the number of stations operated. Station locations may be selected for convenience, to minimize travel expenses, or just to provide coverage of major truck routes. To generate more representative and comprehensive data that better describe the truck population, Wisconsin and Texas conducted studies on truck weight sampling programs [10, 11]. Both of these studies used a standard statistical technique for determing the sample size required to achieve a desired level of accuracy. Stations were distributed across road types in proportion to the truck VMT or truck traffic percentage on each road type, and the sites of the stations were randomly selected.

An analysis of Georgia's interstate truck-weighing data was made to determine the effects of geographical area, percentage of trucks, and average annual daily traffic on the variation in weights and number of trucks for each classification [12]. A general conclusion of the study was that for research purposes, the number or location of truck weight stations on the interstate system would not have an effect on the overall results obtained.

In establishing criteria for evaluation of truck weight enforcement programs, an NCHRP study pointed out that most states have unloading requirements when overload violations occur. Many enforcement officers believe that the unloading requirement is the most effective deterrent for a truck weight enforcement program [13]. Some of the problems in truck weight enforcement can be attributed to insufficient personnel (usually the result of an insufficient budget) for proper operation of permanent and portable scales. The hours of operation of scales are contingent on the available personnel. Only permanent stations on routes with large volumes of truck traffic are operated continuously.

A truck-weight case study by FHWA covering selected weighing sites from six states--Arkansas, Florida, Iowa, Nevada, Oregon, and Wisconsin--concluded with the following highlights [14]:

-Average day weights for most vehicle types did not vary significantly from season to season if all functional classes were combined.

-If individual functional classes were considered, seasonal variation was significant for most vehicle types.

-The rural interstate system had the least seasonal variation for the largest number of vehicle types.

-The urban minor arterials/collectors had the lowest average gross weights for five of the classifications of truck combinations.

-Most combination trucks exhibited characteristics similar to the three-axle tractor with two-axle semi-trailer (3S2).

-The highest average gross weight for a 3S2 occurred on the rural interstate system, and the lowest occurred on the urban minor arterial/collector systems.

-Weights and EAL were dependent on functional class.

-Average weekend weights and EALs for 3S2s were consistently higher than average weekday weights.

-The average weight of a 3S2 on a weekday decreased during the middle of the day and increased at night.

-The average weight of a 3S2 on a weekend remained relatively consistent throughout the day.

-The variation in the average weight of a 3S2 during the weekday hours was greater than the variation during the weekend hours for every season of the year.

Size and Configuration

Truck size and combination will affect the following design elements: turning radius, pavement widening, sight distance, horizontal curves, vertical alignment of curves and grades, crossover crown, and median openings. Vehicle width is important for safety. The 96-in (2.44-m) width limitation is widely accepted by most states, while some states set up a limit to 102 in (2.59 m). Height is another important characteristic. Damage can occur to overpass structures that are designed to accommodate a vehicle of limited height. Safety problems could occur owing to decreased stability with respect to sway and rotation. Most states now restrict vehicle height to no more than 13.5 ft (4.11 m).

There are different classifications of trucks by different agencies; but they are commonly classified in terms of gross vehicle weight (GVW), number of axles, number of tires, and number of towed units. The longer combination units must be assessed in order for the highway engineers to consider appropriate modifications to currently accepted highway geometric design policies and procedures. There are three terms widely used for truck combinations that will be described herein; namely "triple trailers", "Rocky Mountain doubles", and "turnpike doubles" (see Figure 2).

The <u>triple trailer</u> combination consists of a tractor, a 28-ft semi-trailer, and two 28-ft trailers. This combination has an overall length of 100.2 ft if a two-axle cab-over-engine tractor is used or a length of 107.4 ft if a three-axle conventional tractor is used. When loaded, this combination may have a GVW of 110,000 pounds. The <u>Rocky Mountain double</u> combination consists of a three-axle conventional tractor pulling a 48-ft semi-trailer and a 28-ft trailer. This combination has an overall length of 93.2 ft, and when loaded, has a GVW of more than 100,000 pounds. The <u>turnpike double</u> combination consists of a three-axle tractor pulling a 48-ft semi-trailer and 48-ft trailer. This combination has an overall length of 115.1 ft and when loaded has a GVW of more than 122,000 pounds [15].

The only way to obtain truck size data is direct measurement when the vehicle is stationary. It is generally measured in weighing stations when trucks are weighed. This avoids safety and delay problems, but the sampling number is usually small and highly dependent on the weighing station operation schedule. Since width and height are physical constants for any vehicle type, they have generated less controversy and concern in enforcement programs.

TIUS is one of three surveys comprising the Census of Transportation, a product of the U.S. Department of Commerce, Bureau of the Census (BOC). It is designed to provide data on the physical and operational characteristics of the U.S. truck population and is based on a probability sample of private and commercial trucks registered in a state for a given survey year. The survey is conducted every five years. The 1982 TIUS represents the latest in the series. The survey is sent directly to the person or firm to whom the truck is registered. For nonvariable factors such as model year and size of carrier operation, TIUS is a good source of national estimates. However, the accuracy of the resulting estimates is affected by the difficulty in obtaining complete truck-type profiles [9].

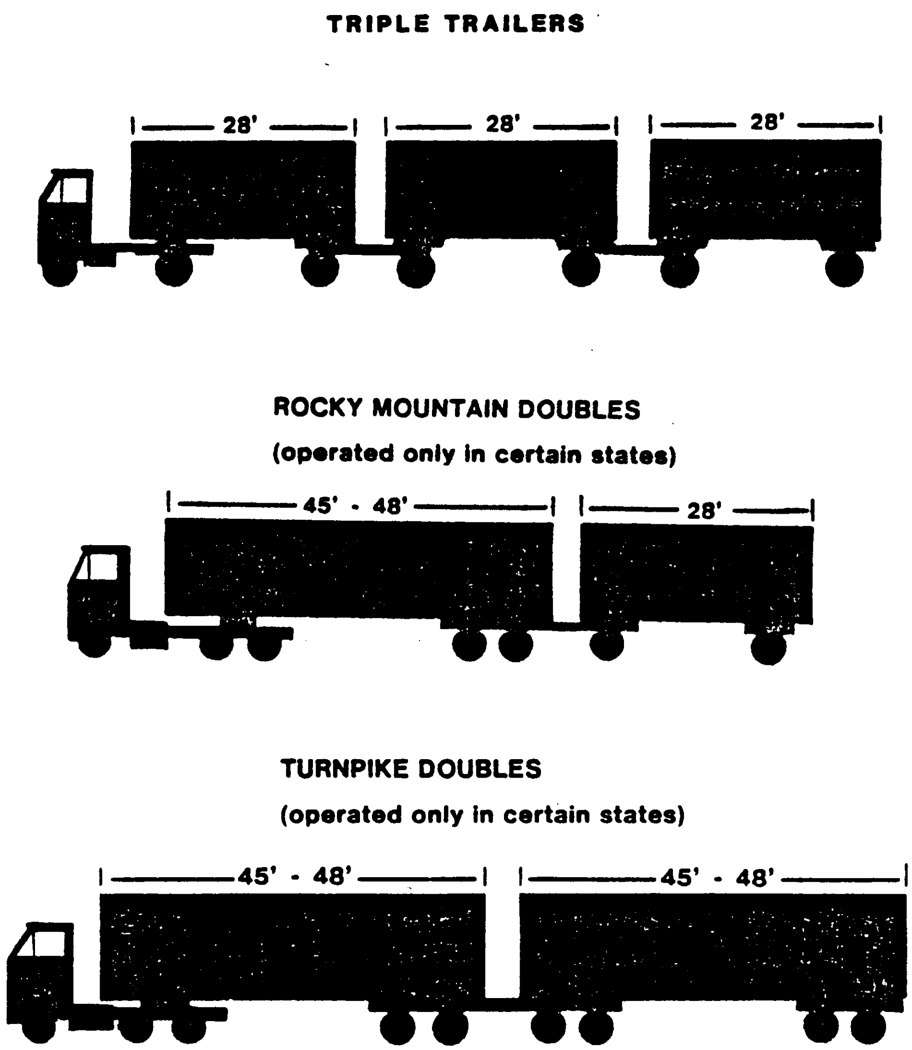


Figure 2

OPERATIONAL CHARACTERISTICS

Six operational characteristics of heavy trucks are considered in the following sections. They are traffic counts, accidents, off-tracking and lateral placement, PCE, EAL, and speed.

Counting

Traffic volume counts provide basic information for transportation analysis and forecasting, as well as for facility design, monitoring, and operation. Truck volume estimation can be divided into two categories: (1) annual vehicle miles of travel (AVMT), and (2) average daily truck traffic (ADTT). AVMT is important as a basis for comparing the total accidents or share of highway use. Ton-miles is sometimes preferred, but more often for considerations of financing than highway planning. Stratified by weight, ADTT is what engineers need most for pavement design and management strategies.

In addition to total traffic count, the traffic variation during the day and during different months or seasons is also needed for traffic planning and design. Thus, the ideal truck counting data would address a wide variety of needs and purposes; this means the more detailed the data is, the more useful it will be. Increasing fiscal austerity at all levels in all program areas means that agencies must ensure that adequate information is obtained at reasonable cost. Except for studies of specific locations, truck volume is always contained in the overall traffic count as a percentage.

The needs for classified traffic count data are various. Simple classification into some five or six broad vehicle categories is a common requirement for highway design or traffic signal timing procedures based on PCE. Long-term monitoring of classified traffic flows provides the basis for forecasts of future traffic. The economic appraisal of highway schemes may also require a knowledge of the mix of vehicle classes and their characteristically different operating costs. The allocation of road damage costs to different classes of vehicle on toll highways or via general vehicle taxation again requires the detailed classification of trucks.

Truck classification data have usually been obtained by manual counting at designated locations and during designated periods. Limited amounts of data can be collected owing to limited resources. Many automatic vehicle classifiers have been developed. One of them, made by the Golden River Corporation (GRC), separates vehicles into categories according to their overall length, which gives simple classification into a small number of vehicle categories [16]. When configured as a length classifier, this portable microprocessor-based system records classified traffic flows separated into length categories specified by the user. The road sensors consist of up to three pairs of matched inductive loops; each pair of loops is located in a single traffic lane. The loops can either be cut into permanent slots or be attached temporarily to the road surface. The traffic data recorder (TDR) used at the Virginia Transportation Research Council, which consists of a pair of parallel sensors attached temporarily to the road surface, classifies vehicles by the number of axles. Both of these devices are capable of recording the speed of vehicles at the same time.

One weakness of length classification is its inability to distinguish buses from long freight trucks. Chassis height is an additional criterion that can extend the classification to additional vehicle categories. A detailed classification system developed by the U.K. Transport and Road Research Laboratory estimated the chassis height from the inductive signal strength from road sensors consisting of one inductive loop and two triboelectric axle sensors per lane. The microprocessor compares a vehicle's wheelbase, overhang, and chassis height with established values held in memory. When a match is found, the vehicle class is identified. Twenty-five categories of vehicle are distinguished by the existing system [16].

It was pointed out that even for closely supervised, well-conducted surveys, results of manual classified counts are much less reliable than might commonly be supposed [16]. A length detection classification in Arizona offered nineteen categories of vehicles with a vehicle classification accuracy approaching 96% [8]. Automatic classification offers opportunities to overcome some accuracy problems, but it can lead to errors of a different nature from those resulting from manual enumerations.

Classification counts for TWS are conducted for three 8-hour shifts (not necessarily consecutive) that cover all hours of the day. At each location, all of the vehicles in the traffic stream are counted and classified. This includes the number of passenger cars, buses, and a multitude of truck types, from pickups to multitrailer combinations. For each truck type, the number of axles and the axle configurations are also recorded. For each vehicle surveyed, information relating to vehicle type, body type, fuel type, class of operation, loading status, commodity carried, and axle spacing is collected. The main deficiency of the TWS as a data base is that the counting sites are not statistically representative of the the states' highway systems and cannot be used to estimate truck VMT by vehicle type [9]. The collection stations tend to be oriented towards the interstate and rural primary systems. Thus, the program to date is useful only as a site-specific count.

The Highway Performance Monitoring System (HPMS) is a joint effort of federal, state, and local governments the purpose of which is to amass national data that will provide current statistics on the mileage and characteristics of the various highway systems throughout the nation. The sample sections are established using a statistically designed sampling plan based on the random selection of road sections within predetermined AADT volume groups for each functional highway classification. The areawide data base includes a combination of highway, travel, and accident data. These areawide statistics are too gross to address specific truck issues on a national basis. This data base is useful for obtaining specific highway and traffic volume data for a sample of different highway types. Volume data for trucks are sometimes estimates that tend to be less accurate for highways of lower functional classes with less traffic [9].

Accident

Trucks are now not only heavier and longer but have different axle lengths and numbers of axles, as well as numerous other changes. As double and triple trailer trucks become more common and the limits of restrictions increase, the importance of realizing the potential safety impact of such changes becomes critical. Accident data can be used to identify locations or vehicle types that are unsafe in truck operations. Possible measures that can be used to quantify truck safety include [9]:

1. accident frequency,
2. fatality and/or injury frequency,
3. accidents per vehicle-mile,
4. accidents per vehicle-ton-mile, and
5. all of the above considering only those types of accidents likely affected by the independent variable.

A report on the development of large truck safety data needs by FHWA has identified a comprehensive list of truck safety issues [9]. They were grouped into the following six categories:

1. relationships and relative safety,
2. truck accident characteristics and causation,
3. countermeasure effectiveness,
4. vehicle handling and performance,
5. highway design related to safety, and
6. others.

It is often stated (without evidence) that "owner-operators" are over-involved in truck accidents compared to employees of fleet operators [9]. One of the articles cited indicates that double tanker trucks were hazardous because of their high center of gravity and the consequent relative ease of rollover and recommends the use of a 102-in axle rather than a 96-in axle [17]. Available data on accidents by vehicle configuration reflect favorable, or at least equal, accident rates for doubles compared to tractor semi-trailers [4].

The Bureau of Motor Carrier Safety (BMCS) collects and automates truck accident data submitted by motor carriers subject to the U.S. Department of Transportation Act on form MCS 50-T. Requirements for filing the 50-T accident form are described in Section 394 of the "Federal Motor Carrier Safety Regulations and Noise Emission Requirements" [18]. The accident is supposed to be reported if it results in the death of a human being, bodily injury to a person who must receive medical treatment away from the scene of the accident, or total property damage exceeding $2,000. Approximately 30,000 accidents are reported annually. For truck types that apply, it is useful for developing distribution of accidents by type, circumstance, time, location and other variables for which data are collected. However, there are several limitations to this data source. It includes data only for interstate carriers. Intrastate and other exempt carriers are not subject to the Federal Motor Carrier Safety Regulation; therefore, they are not required to submit accident reports. This situation would limit the analyses to certain truck types, to certain classes of highway, and to certain types of drivers. Another deficiency is that some accidents for which reports are required may go unreported. BMCS estimates that between 20% and 40% of the reportable accidents go unreported [9].

The Fatal Accident Reporting System (FARS) is an ongoing data collection program of the National Highway Traffic Safety Administration. The data are drawn from various sources, which generally include police accident reports, driver license files, motor vehicle registration files, records from bureaus of vital statistics, and state highway department records. Each accident in the data base involves at least one fatality that has occurred on a highway. The FARS definition of a fatality is a death that occurs within 30 days of a motor vehicle accident and which is the result of the accident. Data on fatal accidents occurring since 1975 have been automated. Its relevance for some truck safety issues is limited, since it deals only with fatal accidents. It cannot supply the national distribution for all accident severities, i.e., the non-fatal injury and property-damage-only (PDO) accidents. Another problem is the lack of information about the characteristics of the truck involved in the reported fatal accidents. Between 1975 and 1982, FARS could only distinguish between single and multiple trailer trucks and did not differentiate between straight truck and tractor. This was changed in 1983 so that trucks could be distinguished by configuration and body style. However, key truck characteristics of length and weight are still not available [9].

The National Accident Sampling System (NASS) has been administered by NHTSA since 1979. The goal of NASS is to provide national estimates of accidents and the characteristics of those accidents. NASS has been structured so that statistical samples can be drawn from throughout the nation. For each accident selected, the NASS teams perform in-depth accident investigations. The starting point is the police accident report, but the teams follow-up by collecting information on accident location and the vehicles involved, by obtaining medical reports, and by interviewing persons involved in the accident. Data are collected on the accident, the driver, the vehicle, the occupant, and the pedestrian. Because of the scope of information obtained for each accident, this could be a good data source for some detailed truck safety issues. However, the main disadvantage of NASS is the relatively small sample. Between 1979 and 1981, only 11 double trailers were cited in the NASS sample. In 1983, 26 doubles accidents were reported [9].

The national accident data files, such as BMCS, FARS, and NASS, seem to address only the first and the second categories of the aforementioned truck safety issues. Any special interest has to be fulfilled by carrying out the individual study of concern. The relatively low number of accidents associated with truck types makes it difficult to amass statistically sufficient sample sizes of accident counts.

Off-Tracking and Lateral Placement

Off-tracking is the difference in paths of the front-most inside wheel and rear-most inside wheel of a vehicle as it negotiates a turn. Track width (also called swept width) is the total width of the path a vehicle makes as it traverses a corner, and it is measured from the front-most outside tire to the rear-most inside tire [19]. Both are essential factors in determining the minimum width necessary to accommodate the vehicle around a corner. They can also be used by highway design personnel to select the maximum degree of curvature that would permit a vehicle to stay within the selected lane width and an adequate width of entrances to terminal facilities. Off-tracking could also be used to plot the movement of oversized trucks. The regulatory agency that issues permits for oversized truck operations could determine the routes these trucks can use and the critical points along the route where special traffic controls must be exercised to protect both the normal traffic and the oversized truck.

The two most important factors in off-tracking are (1) the radius of turn and (2) vehicle length and configuration. However, speed, driver expertise, weather, and road surface condition may also be important. Methods used to determine the amount of off-tracking for a given vehicle at a given turning radius include:

1. observation of actual vehicle operation,
2. graphic representation,
3. mathematical formulation, and
4. simulation with models [19].

The Society of Automotive Engineers has provided mathematical formulations, which are based on the wheelbase size and front wheel width of a truck and turning radius, to calculate off-tracking. Comparisons made by the California Department of Transportation and the Western Highway Institute showed that graphic methods were as accurate as mathematical methods in plotting truck off-tracking [20, 21]. The Western Highway Institute also developed formulas that are much simpler than those of the Society of Automotive Engineers. Studies addressing the off-tracking of larger vehicles such as Turnpike doubles and triple trailers have been done by Zegeer, et al. and Millar, et al [17, 19]. Tables and plots of off-tracking by different kinds of trucks at various turning radii and angles were presented in these studies.

Lateral placement of truck wheel loads within traffic lanes may change as highway geometry and traffic characteristics change. This may have significant implications for pavement design processes. Premature failure of pavement edges indicates that wheel placement may be an important factor. Very little research has been done on this subject. A study by Taragin concluded that trucks travel closer to the pavement edge than passenger cars [22]. A color video recording system mounted in a van was used in a Texas study to follow selected trucks and continuously record their lateral placement [23]. It found that these vehicles traveled generally closer than the single units to the pavement edge and that vehicles traveled nearer the lane edge where the horizontal alignment contained curvature. However, no statistically significant effects on placement could be attributed to the type of pavement surface or to the particular lane in which sampled vehicles traveled.

Passenger Car Equivalents

PCE values represent the extra amount of time or space required by any particular vehicle type in terms of the passenger car unit. The PCE for any vehicle type at any volume level is defined as the ratio of the mean lagging headway of that vehicle type divided by the mean lagging headway of the basic passenger car [24]. Lagging headway is defined as the time from the rear of the leading vehicle to the rear of the vehicle in question. The Highway Capacity Manual defines PCE as "the number of passenger cars displaced by a single heavy vehicle of a particular type under prevaling roadway, traffic, and control conditions" [25]. Proper consideration of trucks in the design and operation of the street would result in reducing travel time delay and increasing vehicular capacity.

The operational effects of trucks on grades are addressed in the Highway Capacity Manual [25]. For a freeway, six-lane highway, four-lane highway, or two-lane highway on level terrain, one heavy truck is the equivalent of two passenger cars. Suggested PCE's of heavy trucks are given in this guide by percent and length of grade and percent of trucks (Tables 3-6, 7-6, 8-6), which range from 3 to 28. Owing to the changes in highway physical and geometric conditions coupled with the change in heavy truck design, it is necessary to update PCE values on a periodic basis.

Since the presence of trucks in the traffic stream is accompanied by an increase in the mean headway, single unit trucks and tractor trailers have PCE values that are sensitive to volume: as volume level increases, PCE values increase [24]. Contrary to complaints often expressed by automobile drivers, truck drivers do not appear to operate their vehicles too close behind other vehicles. Instead, they seemed to allow more room to the front than did automobile drivers [26].

Equivalent Single Axle Load

ESAL is defined as the tire load that will cause the same magnitude of stress, strain, deflection, or distress as a preset single axle load will cause within a specific pavement structure. Thus, an ESAL factor defines the damage per pass caused to a specific pavement by the vehicle in question relative to the damage per pass of an arbitrarily selected standard vehicle moving on the same pavement. The total ESAL for a design life is the most important element for pavement design and maintenance process. One of the most widely used forms of equivalency factors for highway analysis are those developed from the AASHO road test equation. The common denominator used is an 18-kip (80KN) single-axle load.

It should be noted that ESAL factors are not linearly in proportion to the applied loads. Heavy trucks, which have generally higher axle loads, may cause the most damage to highways, although their traffic share in a highway may be low. In pavement design the tire-pavement contact pressure is assumed to be equal to the tire inflation pressure. But ESAL does not address the effects of weight density(penetrating force or contact pressure) on the highways. A Texas study found that the high contact pressures from truck tires is a major factor causing the significant increase in rutting observed on Texas highways [27].

Speed

The speed and acceleration performance of heavy trucks represent an important consideration in highway design. Trucks generally posses the lowest level of acceleration performance, which in combination with their size, makes them most likely to impede other traffic. Truck speed and acceleration influences highway design in areas such as:

1. the need for climbing lanes on long upgrades,

2. lengths of acceleration lanes at traffic merge areas,
3. sight distance and signal timing at traffic intersections, and
4. clearance times at rail-highway crossings [28].

Also, speed data is useful for enforcement programs in determining the speed trends on specific highway sections and in identifying the need for more police forces.

In the Highway Capacity Manual, the effect of truck speed on highway capacity is also addressed. The current AASHTO(1984) criteria for determining critical lengths of grades and climbing lane design for the safe and efficient operation of existing heavy five-axle trucks assume a gross vehicle weight to net horsepower(GVW/NHP) ratio of 300 lb/hp. A variety of devices, ranging from mechanical contacting to electronic optical, have been developed for detecting vehicle speed. Continuous detection from a few hours to a couple of days can be automatically recorded. Some of the equipment can also demonstrate functions to measure acceleration, vehicle density, and lateral placement, etc.

A research study found that passenger car drivers, whose preferred speed is higher than average in a low volume situation, are forced to lower their speed as the proportion of heavy vehicles increases [29]. It has been experimentally established that speed has only a minor influence on the contact pressure for a free-rolling tire [27].

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17. Zegeer, C.V., J.E. Hummer, and F. Hanscom. 1986. The Operation of Larger Trucks on Roads With Restrictive Geometry. Washington D.C.: FHWA.

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22. Taragin, A. 1943. Transverse Placement of Vehicles as Related to Cross Section Design. Highway Research Record 23. Washington D.C.: Highway Research Board.

23. Lee, Clyde E., P.R. Shankar, and Bahman Izadmehr. 1983. Lateral Placement of Trucks In Highway Lanes. Austin: University of Texas.

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Appendix B

Annotated Bibliography

ANNOTATED BIBLIOGRAPHY

GENERAL

1. American Trucking Associations. 1986. American Trucking Trends-1985. Alexandria.
   This report presents a general profile of motor carrier statistical results on equipment, employment, financial state, taxes, and operation. A brief summary of 1982 Truck Inventory and Use Survey (TIUS) findings is provided.

2. Commonwealth of Virginia. 1985. Size, Weight, Equipment and Other Requirements for Trucks, Trailers and Towed Vehicles. Richmond.
   This pamphlet contains materials condensed from the requirements of the Motor Vehicle Code of Virginia. Vehicles travelling on Virginia highways, whether licensed in Virginia or another state, are required to conform to the requirements set forth in this pamphlet.

3. Motor Vehicle Manufacturers Association of the United States. 1986. Facts & Figures '86. Washington D.C.
   This annual report provides statistical numbers, graphs, and charts that describe the vehicle manufacture industry and the use of motor vehicle products in the United States.

ACCIDENT & SAFETY

4. Jackson, Lawrence E. 1985. Truck Accident Studies. Washington D.C.: National Transportation Safety Board.
   This paper compiles facts and analyses of many of the in-depth multi-disciplinary heavy truck accident investi-gations that have been conducted by the National Transportation Safety Board.

5. McGee, H. W. 1986. Development of A Large Truck Safety Data Needs Study Plan; Volume II-Technical Report. Washington D.C.: FHWA.
   This report describes large truck safety issues and their required data elements. Existing sources of accident data files and exposure data files are investigated. The author finds that the relatively small number of accidents associated with certain truck types makes it difficult to amass statistically sufficient sample sizes of accident counts.

6. St. John, A.D., and D.R. Kobett. 1978. Grade Effects on Traffic Flow Stability and Capacity.. NCHRP Report 185. Kansas City:

Midwest Research Institute.

This project provides and applies a methodology for determining the performance capabilities of vehicles on highways to determine the role that performance and size play in traffic instabilities, accidents, and loss of capacity. The acceleration and speed-maintenance capabilities of a wide range of vehicles were investigated with performance tests and analyses of data. A computer simulation is developed to determine equivalencies and to explore the accident implications of two-lane, two-way traffic situations.

7. Virginia Department of Motor Vehicles. 1986. 1985 Virginia Traffic Crash Facts. Richmond.

This annual report presents Virginia driving trends, crash summaries, and crash tables. Truck crashes are stratefied by three categories: straight trucks, tractor-trailers, and tractor-twin trailers.

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This report describes the magnitude and nature of truck travel and the current status of truck safety in Georgia. It includes estimates of crash rates for tractor-semitrailer trucks using four major groups of highways, and the results of a truck accident site study are presented.

OFF-TRACKING & LATERAL PLACEMENT

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This paper evaluates the use of a tapeswitch detector to record vehicle speed and lateral placement simultaneously. The tapeswitch system compares the changes in vehicle speed and lateral placement with changes in bridge shoulder width and type of barrier.

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This report describes the California Department of Transportation's observations of the operational tests of Triple Trailers, Rocky Mountain Doubles, and Turnpike Doubles. The report covers the observations in the following areas: freeway interchanges, open-road travel, urban traffic, narrow lanes, two-lane roads, off-tracking, speed on grades, braking, acceleration, travel during rain and wind, noise generation, and fuel economy.

12. Lee, Clyde E., P.R. Shankar, and Bahman Izadmehr. 1983. Lateral Placement of Trucks In Highway Lanes. Austin: University of Texas.

A procedure is presented for combining vehicle classification information with axle weight frequency for various classes of vehicles determnied by in-motion weighing techniques to estimate cumulative traffic loading on multilane highways. Frequency distributions of truck wheel placements for single-unit and tractor-trailer trucks determined by video taping the rear view of trucks are described.

13. Millar, David S., and Michael Walton. 1985. Offtracking of the Larger, Longer Combination Commercial Vehicles. Austin: University of Texas.

This paper reviews several studies concerned with off-tracking. The off-tracking characteristics of very long vehicles as well as shorter vehicles are presented. Mathematical formulation and an adjustable scale model are used in measuring off-tracking. An evaluation of tractor-length effects is made using both methods.

14. Otte, C.W. 1972. Truck Paths on Short Radius Turns. Washington D.C.: FHWA.

This report describes the development of templates of turning track widths of a 3-S2 type truck-tractor-semitrailer combination on short radius turns by a model called Tractrix Integrator. Off-tracking results are compared with data developed from field tests using actual trucks. Tabulated data for total track widths developed by a design vehicle on 48-, 58-, 73- and 98-foot radii are presented.

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This report presents a simplified procedure for computing vehicle off-tracking on curves. The procedure developed can be used by highway design personnel to select the maximum degree of curvature that would permit a vehicle to stay within the selected lane width and by regulatory agencies when permits are requested for movement of vehicles that exceed the legal maximum width, length, or both.

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This report presents findings concerning the equivalency value in passenger cars of a commercial vehicle at signalized intersections, the travel time delay caused by commercial vehicles at signalized intersections, and the optimum corner radii to accommodate vehicles with minimum detrimental effects.

17. Zegeer, C.V., J.E. Hummer, and F. Hanscom. 1986. The Operation of Larger Trucks on Roads With Restrictive Geometry. Washington D.C.: FHWA.
The effect of large truck configurations on traffic operations while negotiating roads and streets with restrictive geometry are determined in this study. Truck types of concern include truck-tractor-semitrailers with trailer lengths of 40, 45, and 48 feet with trailer widths of 96 and 102 inches. Twin trailer combinations with 28-foot trailers are also described. The report concludes that driving behavior at urban and rural sites and site differences have more of an effect on operations than the different truck types tested.

PASSENGER CAR EQUIVALENTS & CAPACITY

18. Cunagin, Wiley D. and Edmund C. Chang. 1982. Effects of Trucks on Freeway Vehicle Headway Under Off-peak Flow Conditions. TRR 869. Washington D.C.: Transportation Research Board.
This report describes the results of a study to determine the effects of the presence of heavy trucks on traffic flow of freeway sections as an operational measure of capacity. Time headway is used as the variable to evaluate truck impact. The types of vehicles involved in the headway interaction are found to be the major determinant in length of the headway.

19. Cunagin, Wiley D., and Carroll J. Messer. 1982. Passenger Car Equivalents for Rural Highways. Washington D.C.: FHWA.
This study determines the PCE value for fourteen different vehicle types under varying traffic and roadway-geometry conditions by analyzing field data collected in several states on both two-lane and four-lane rural highways. A calibrated model based on speed distributions and traffic volumes is used to estimate PCE values for these fourteen vehicle types, of which nine are trucks.

20. Hu, Yi-Chin, and Ralph D. Johnson. 1981. Passenger Car Equiva-

lents of Trucks in Composite Traffic. Rockville: CounselTrans Inc.

New methods are described for developing the general PCE of trucks on multi-lane rural highways, urban freeways, and rural two-lane highways. A method is also described for developing passenger car equivalents at signalized intersections on two- or four-lane arterial streets. Matrices of the PCE of trucks and an annotated bibliography are presented.

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This study proposes a model for estimating PCE values for vehicles under free-flowing, multilane conditions. A deterministic model of traffic flow is used to estimate the impedance-flow relationship. PCE values are shown to relate to speed and length of subject vehicles and to vary with the proportion of trucks in the traffic stream.

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Truck equivalents for specific grades are recalibrated in revising and updating the 1965 Highway Capacity Manual. The recalibration is based primarily on the results of freeway simulations, conducted at the Midwest Research Institute, and studies of truck weight-to-power ratios and operating characteristics, conducted at Pennsyvania State University.

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25. Seguin, E.L., K.W. Crowley, and W.D. Zweig. 1982. Passenger Car Equivalents on Urban Freeways. Washington D.C.: FHWA.
The results of a study to determine passenger car equivalents (PCE) of trucks and other vehicles on urban freeways are presented in this report. The small automobile with a wheelbase less than 105 inches is considered to be the basic unit for PCE determination in this study.

26. St. John, A.D. 1976. Nonlinear Truck Factor for Two-lane Highways. TRR 615. Washington D.C.: Transportation Research Board.
This paper presents a microscopic simulation model for traffic flows on two-lane, two-way highways. The simulation provides results in agreement with field data and indicates that the truck factor should be nonlinear. A truck-factor is used to adjust the flow rate of mixed vehicles to the equivalent flow rate of passenger cars only.

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This document is the third edition of the Highway Capacity Manual, which reflects over two decades of comprehensive research conducted by a variety of research agencies since the second edition was published in 1965. The fourteen chapters represent revisions and updates of material contained in the earlier editions and new material reflecting the many changes in the characteristics of travel and in the information needed to conduct highway capacity analysis.

29. Yurysta, Thomas H. 1974. The Effect of Commercial Vehicles on Intersection Capacity and Delay. West Lafayette: Purdue University. (See #16)

EQUIVALENT SINGLE AXLE LOADS & TIRE PRESSURE

30. Alabama Highway Department, Bureau of Materials and Tests. 1983. Truck Weights as Related to Pavement Design in Alabama. Montgomery.
This study determines the truck distribution factor defined as the average number of equivalent 18K axle loads per truck for purposes of both rigid and flexible pavement design for ten weigh-in-motion sites in Alabama. The results indicate that the lane distribution factor for the design lane of a four lane highway should be at least 85 percent.

31. Roberts, F.L., J.T. Tielking, D. Middelton, R.L. Lytton, and K. Tseng. 1986. Effects of Tire Pressures on Flexible Pavements. College Station: Texas A&M University.

The results of a field study to determine the tire inflation pressures carried by Texas highways are described. The report also presents an analytical study to evaluate the effect of these contact pressures on the stresses and strains in typical Texas flexible pavements. The study indicates that thin flexible surfaces or thick stiff surfaces offer the best protection against the high contact pressures.

32. Roberts, Freddy L., Robert L. Lytton, and Zakaria Hajeer. 1987. The Development of New Load Equivalence Factors for Flexible Pavement Design in Texas. College Station: Texas Transportation Institute.

This report summarizes the development of a new method of predicting load-equivalence factors for flexible pavements within the state of Texas. Different tables of load equivalence factors are produced for each environmental zone and each distress type. The format of each table is the same as those produced from the AASHO Road Test.

33. Salsman, J.M., and J.A. Deacon. 1984. Evaluation of Equivalent Axleloads. Lexington: University of Kentucky.

This report describes three computer programs that summarized truck weight data and classification data and combine the two data bases to estimate EAL for each site where classification counts are available. The programs also present the data in two matrices to charactierize the effects that geographic area, federal-aid classification, coal-haul volume and total volume have on each of the traffic parameters necessary to compute EAL.

SPEED & ACCELERATION

34. Byrne, Bernard F., Robert R. Roberts, Ellis King, and Ronald G. Arbogast. 1976. Testing of the Tapeswitch System for Determing Vehicle Speed and Lateral Placement. TRR 615. Washington D.C.: Transportation Research Board. (See #10)

35. California Department of Transportation. 1984. Longer Combination Vehicles Operational Test. Sacramento. (See #11)

36. Ching, P.Y., and F.D. Rooney. 1979. Truck Speeds on Grades in California. Sacramento: California Department of Transportation.

The speeds of more than 14,000 trucks and more than 2,600 recreational vehicles, pickup trucks, vans, and other vehicles on grades along rural freeways and expressways in California were measured. Graphs of speeds for five-axle trucks along various grades are presented.

37. Firey, Joseph C., and Edward W. Peterson. 1962. An Analysis of Speed Changes for Large Transport Trucks. HRB Bulletin 334. Washington D.C.: Highway Research Board.
A mathematical method was devised for calculating the speed versus distance history of large trucks traversing various types of vertical highway curves. The equations that resulted were used to develop several charts relating vehicle speed to distance over the specified ranges of values of vehicle and highway properties.

38. Gillespie, Thomas D. 1985. Startup Accelerations of Heavy Trucks on Grades. Ann Arbor: The University of Michigan Transportation Research Institute.
This paper reviews the guidelines on truck acceleration performance on level grades for highway design. An analysis of the mechanics of the startup process is presented. The analysis is applied to the problem of predicting heavy-truck clearance times at rail-highway grade crossings.

39. Leisch, Jack E., and Joel P. Leisch. 1977. New Concepts in Design-Speed Application. TRR 631. Washington D.C.: Transportation Research Board.
A new concept in the definition and application of design speed is presented to overcome the problem of speed differential between automobiles and trucks. The function of this concept is to design and redesign highways that will better meet driver expectations.

40. Lin, Han-Jei, Clyde E. Lee, and Randy Machemehl. 1980. Texas Traffic Data Acquisition Program. Austin: University of Texas.
This report presents an analysis of traffic data acquisition, distribution processes, and techniques as performed by Texas Department of Transportation. Four principal types of traffic data are included--volume, speed, classification, and weight.

41. Moses, Fred, and Michel Ghosn. 1981. Weighing Trucks-In-Motion Using Instrumented Highway Bridges. Cleveland: Case Western Reserve University.
An in-motion weighing system is described in this report. It used instrumented highway bridge girders to act as equivalent static scales to obtain truck gross and axle weights, dimensions, and speed. The weighing equipment is portable and easy to install. The operation is undetected by passing trucks. Therefore an unbiased sample is obtained. Tests at ten sites are described in detail.

42. Polus, Abishai, Joseph Craus, and Itzhak Grinberg. 1981. Applying the Level-of-Service Concept to Climbing Lanes. TRR 806. Washington D.C.: Transportation Research Board. (See #23)

43. Polus, Abishai, Moshe Livneh, and Joseph Craus. 1984. Effect of Traffic and Geometric Measures on Highway Average Running Speed. TRR 960. Washington D.C.: Transportation Research Board.

This paper documents the effect of geometry on flow characteristics of two-lane rural highways. Percentage of trucks as well as volume and density are the traffic parameters considered. It is demonstrated that multiple linear regression models may be used for prediction of the average running speed.

44. Schmitt, Louis A. 1985. Heavy Vehicle Electronic License Plate (HELP) System. Washington D.C.: Society of Automotive Engineers.

This paper presents a review of the history of the development of the heavy vehicle electronic license plate (HELP) concept developed by the Arizona Department of Transportation. The review encompasses a detailed technical explanation of the HELP concept and gives the various components' relationships to the total system. Nineteen categories of vehicle are classified with length detection loops. Speeds and weights of vehicles are also obtained.

45. St. John, A.D., and D.R. Kobett. 1978. Grade Effects on Traffic Flow Stability and Capacity. NCHRP Report 185. Kansas City: Midwest Research Institute. (See #6)

46. Walton, C. Michael, and Clyde E. Lee. 1977. Characteristics of Trucks Operating on Grades. TRR 631. Washington D.C.: Transportation Research Board.

New data characterizing trucks and combinations on grades are presented to reassess climbing-lane design practices. Field data collected at several locations in central and east Texas were analyzed, and speed-versus-distance curves were developed for a range of grade profiles.

COUNTING & CLASSIFICATION

47. Brogan, James D., K.W. Heathington, A. Chatterjee, and F.J. Wegmann. 1977. An Analysis of Truck Travel Demand Forecasting Techniques and Data Requirements. Knoxville: University of Tennessee.

This study investigates a range of techniques available for use in forecasting urban truck travel demand and examines in detail the use of a truck trip survey at the business establishment level for estimating localized urban truck movements. The stratification of truck trips by truck type, trip purpose, and destination land use is investigated as a means of improving traditional multiple regression models.

48. Campbell, Kenneth L., James O'Day, Brian G. Wolf, and Leda L. Ricce. 1983. Tractor-Trailer Combinations: National Estimates of Their Distribution and Use, Based on the 1977 TIUS. Ann Arbor: The University of Michigan Transportation Research Institute.
This report presents descriptive statistics on the national population of tractor-trailer combinations. Included are estimates of the distribution of vehicles in the national population and their average annual mileage. These estimations are repeated for various subgroups defined by selected descriptive characteristics such as cab style, area of operation, and operator classification.

49. Davies, Peter, David R. Salter, and Michael Bettison. 1982. Loop Sensors for Vehicle Classification. Traffic Engineering & Control, Vol. 30, No. 2. London, England.
This paper presents results of experimental investigations carried out at the University of Nottingham on the fundamental properties of different inductive loop layouts that can be used for automatic vehicle classification.

50. Davies, Peter, and David R. Salter. 1983. Reliability of Classified Traffic Count Data. TRR 905. Washington D.C.: Transportation Research Board.
This paper examines the reliability of classified traffic-count data collected for the planning and operation of highway systems. Both manual and automatic vehicle classification count data are determined to be subject to accuracy problems. The results of evaluations of automatic classification equipment carried out by the Maine Department of Transportation and the United Kingdom are described.

51. Federal Highway Administration. 1981. 1975-1979 National Truck Characteristic Report. Washington D.C.
This report presents tabulated information based on data collected during the Annual Truck Weight Study. Information on truck weight, fuel type, and vehicle type is provided.

52. Federal Highway Administration. 1985. Traffic Monitoring Guide. Washington D.C.
This guide provides direction on the monitoring of traffic characteristics. However, it is not to be considered a Federal standard. Traffic characteristics included are those data obtained through programs of traffic counting, vehicle classification, and truck weighing.

53. Gericke, Ogilvie F., and C. Michael Walton. 1981. Effect of Increased Truck Size and Weight on Rural Highway Geometric Design Principles and Practices. TRR 806. Washington D.C.: Transportation Research Board.
This paper summarizes a study of the effects that an increase in legal truck limits would have on highway geometric design elements and on the cost implications for the Texas highway system.

54. Hallenbech, Mark E. 1985. Development of an Integrated Statewide Traffic-Mointoring System. TRR 1050. Washington D.C.: Transportation Research Board.
This study recommends a program framework providing traffic monitoring procedures for state DOT that allow each state to establish a productive traffic monitoring process that meets state and federal needs, reduces the total amount of data collected, and improves the quality of the data that are obtained.

55. Hartgen, David T. 1983. Characteristics of Double-Trailer Trucks in New York State. Albany: New York State Department of Transportation.
This paper describes the characteristics of double-trailer trucks operating at a selected location on the New York State Thruway in upstate New York. The paper concludes that despite the flexibility permitted in operations, the double-trailer market operating on the Thruway is represented by a fairly narrow spectrum of vehicle types and companies.

56. Hartgen David T., and John H. Lemmerman. 1983. Streamling Collection and Processing of Traffic Count Statistics. Albany: New York State Department of Transportation.
This paper examines the New York state traffic volume counting program and procedures and looks ahead at new technology in order to streamline this process and reduce costs. Implementation of the improvements resulted in a 35% reduction in counting with little or no loss of information.

57. Lee, Clyde E., P.R. Shankar, and Bahman Izadmehr. 1983. Lateral Placement of Trucks In Highway Lanes. Austin: University of Texas. (See #12)

58. Lin, Han-Jei, Clyde E. Lee, and Randy Machemehl. 1980. Texas Traffic Data Acquisition Program. Austin: University of Texas. (See #40)

59. Rhode Island Statewide Planning Program. 1978. Rhode Island Statewide Truck Travel: Base Year and Forecast Year Estimates. Providence.
This paper describes the application of the various

surveys conducted as part of the 1971-1972 Rhode Island Origin-Destination Update Study. The purpose of the process was to establish travel patterns for auto, truck, and taxi travel within and through the state as part of the statewide forecasts.

60. Salsman, J.M., and J.A. Deacon. 1984. Evaluation of Equivalent Axleloads. Lexington: University of Kentucky. (See #33)

61. Snow, Edward J., and Gloria Jillson. 1982. Accuracy, Cost and Responsiveness of Continuous Traffic Counting System. Albany: New York State Department of Transportation.
The report summarizes a field test by the New York State Department of Transportation to evaluate the accuracy, responsiveness, and cost of mechanical versus telephone-based continuous counting systems.

62. Schmitt, Louis A. 1985. Heavy Vehicle Electronic License Plate (HELP) System. Washington D.C.: Society of Automotive Engineers. (See #44)

63. Zavattero, David A., and Sidney E. Wesman. 1981. Commercial Vehicle Trip Generation in Chicago Region. TRR 834. Washington D.C.: Transportation Research Board.
This paper describes the results of an analysis of the relation between commercial vehicles and trip generation. Relations between the volume of truck traffic generated or attracted to subareas of the Chicago region are estimated based on the land-use characteristics of the area. Separate regression models for light, medium, and heavy trucks and for six basic land-use types are presented.

SIZE, CONFIGURATION & WEIGHT

64. Alabama Highway Department, Bureau of Materials and Tests. 1983. Truck Weights as Related to Pavement Design in Alabama. Montgomery. (See #30)

65. Chow, William. 1982. Evaluation of the PAT and StreeterAmet Weigh-In-Motion Systems. Sacramento: California Department of Transportation.
This study evaluates the PAT and the StreeterAmet weigh-in-motion systems for performance, reliability, and durability. Both systems are found to be suitable for in-motion weighing, but they are dependent on speed of traffic and user's need for degree of accuracy.

66. Colucci-Rios, Benjamin, and Eldon J. Yoder. 1980. Truck Size and Weight Issues. Proceedings of the 66th Annual Road School.

West Lafayette: Purdue University.

This paper presents an overview of the current issues concerning truck size and weight in the United States. Emphasis is given to the information obtained from the 1977 truck weight study concerning overweight trucks presently traveling on Indiana highways, especially the 3-S2 and 3-S3 trucks. It is concluded that overweight trucks cause an increase in highway deterioration (decrease in the life of the pavement) as well as an increase in routine maintenance costs.

67. Cunagin, Wiley D. 1986. Use of Weigh-in-motion Systems for Data Collection and Enforcement. NCHRP Synthesis of Highway Practice 124. Washington D.C.: Transportation Research Board.

The report discusses WIM data needs, uses, and requirements. Seven WIM equipment types currently used are described. Experiences in 21 states and Canada are briefly presented.

68. Ervin, R.D., R.N. Nisonger, C.C. MacAdam, and P.S. Fancher. 1986. Influence of Size and Weight Variables on the Stability and Control Properties of Heavy Trucks. Washington D.C.: FHWA.

This study has determined the influence of variations in truck size and weight constraints on the stability and control properties of heavy vehicles. The size and weight constraints of interest include axle load, gross vehicle weight, length, width, type of combinations, and bridge formula allowances. The influence of these parametric variations on stability and control behavior is explored by both full-scale vehicle tests and computer simulation.

69. Federal Highway Administration. 1981. 1975-1979 National Truck Characteristic Report. Washington D.C. (See #51)

70. Federal Highway Administration. 1985. Traffic Monitoring Guide. Washington D.C. (See #52)

71. Gardner, William D. 1983. Truck Weight Study Sampling Plan in Wisconsin. TRR 920. Washington D.C.: Transportation Research Board.

The procedures used by the Wisconsin Department of Transportation for determining the number and locations of sampling stations for its truck weight study are described in this paper. By using data from the 1980-1981 Wisconsin truck-weight case study, the number of required stations is calculated on the basis of the average variability of truck weights in the state. Criteria are presented for selecting corridors and sites where stations should be established.

72. Graves, Richard A., III. 1972. Special Interstate Truck Weight Study. Atlanta: Georgia Department of Transportation.

An analysis of Georgia's interstate truck-weighing data is made to determine the effects of annual average daily traffic, percentage of trucks, and geographical area. The results were used in selecting the number and location of permanent interstate truck weighing stations in Georgia.

73. Hage, Robert J. 1982. Truck Forecasts and Pavement Design. TRR 889. Washington D.C.: Transporation Research Board.
    The uncertainties associated with making design load estimates for use in determining pavement structure requirements are discussed in this paper. The discussion focuses on the five-axle tractor-semitrailer, which is regarded as causing more than 80% of traffic-attributable pavement damage to Minnesota's trunk highway system.

74. Hallenbech, Mark E. 1985. Development of an Integrated Statewide Traffic-Mointoing System. TRR 1050. Washington D.C.: Transportation Research Board. (See #54)

75. Hibbs, John O., and William T. Baker. 1980. Operational Aspects of Weighing Trucks in Motion for Enforcement. Compendium of Technical Papers. Washington D.C.: Institute of Transportation Engineers.
    This paper describes the operational characteristics of three types of WIM equipment--high speed WIM, moderate speed WIM, and low speed WIM. The problems associated with signing, signalization, and speed change operations are addressed. Suggested traffic control plans for the three basic applications of WIM are provided.

76. Kochanowski, Richard J., and Daniel P. Sullivan. 1980. An Investigation of Truck Size and Weight Limits. Cambridge: Transportation Systems Center.
    This document presents reported truck and rail operating data and analytical methods developed to estimate changes in transportation processes attributable to specific sets of truck size and weight limits. The effects of various truck size and weight limits are examined in terms of changes in the competitive relationships among various highway and rail carrier services.

77. Krukar, Malan, and Loyd Henion. 1985. The Oregon Experiment With Automatic Vehicle Identification Devices and Weigh-In-Motion Systems. Salem: Oregon Department of Transportation.
    This paper describes the eight elements of the Oregon Weight-In-Motion and Automatic Vehicle Identification (WIM/AVI) Demonstration Project. Nineteen vehicle types are measured by the WIM and classifier equipment. The uses of the WIM/AVI data are discussed. The reasons for the limited use of the data and how this is being rectified are presented.

78. Lee, Clyde E., P.R. Shankar, and Bahman Izadmehr. 1983. Lateral Placement of Trucks In Highway Lanes. Austin: University of Texas. (See #12)

79. Lee, Clyde E., Bahman Izadmehr, and Randy B. Machemehl. 1985. Demonstration of Weight-In-Motion Systems for Data Collection and Enforcement. Austin: Univeristy of Texas.

This report summarizes a study in which over 800 trucks selected from the traffic stream in Texas were weighed in motion by a WIM system at three different speeds and then statically by three different axle-load scales and by three different sets of wheel-load weighers. The accuracy and efficiency of weighing trucks by these means is compared. The potential usefulness of WIM systems for enforcement is identified.

80. Lill, Richard A. 1986. Geometric Design for Large Trucks. TRR 1052. Washington D.C.: Transportation Research Board.

This paper describes how the trucking industry adapted to the 1982 STAA criteria and why there is minimal overall impact on the highway network. Specific examples of how size and weight regulations affect trucks are presented.

81. Lin, Han-Jei, Clyde E. Lee, and Randy Machemehl. 1980. Texas Traffic Data Acquisition Program. Austin: University of Texas. (See #40)

82. Maxwell D.A., T. Chira-Chavala, H. Nassiri, and J.M. Mason. 1986. Evaluation of the Texas Truck Weighing Program. College Station: Texas Transportation Institute.

This report documents the findings of an evaluation study of the Texas Weighing Program. The evaluation includes an analysis of the data from six existing sites. Current and future data needs, existing highway system and related truck traffic stream, statistical sampling techniques, and procedures for economic design sample distribution are described.

83. Moses, Fred, and Michel Ghosn. 1981. Weighing Trucks-In-Motion Using Instrumented Highway Bridges. Cleveland: Case Western Reserve University. (See #41)

84. Paxson, D.S., and J.P. Glickert. 1982. Value of Overweighting to Intercity Truckers. TRR 889. Washington D.C.: Transportation Research Board.

This paper presents an analysis of the problem of truck overweighting. The penalty structures and permit costs are examined in comparison with the cost of additional pavement damage caused by overweight trucks. It is concluded that economic incentives often exceed the expected costs of overweighting to the trucker and the cost of overweight permits does not reflect the additional pavement damage.

85. Schmitt, Louis A. 1985. Heavy Vehicle Electronic License Plate (HELP) System. Washington D.C.: Society of Automotive Engineers. (See #44)

86. Staley, Richard A. 1981. Foreign Truck Size and Weight Limits. Washington D.C.: American Trucking Associations.
This report presents the result of a survey of single- and tandem-axle weights, gross weights and combination length limits worldwide, which reveals extremely wide variations among nations. It is found that other nations of the world apparently have a different concept of how they wish to apply their investment in highway facilities. Economic need more than possible highway wear seems to be a controlling factor.

87. Stowers, Joseph R., H.S. Cohen, J.H. Sinnott, H. Weinblatt, J. R. Morris, and J. Cirenzo. 1983. Federal Truck Size and Weight Study. TRR 920. Washington D.C.: Transportation Research Board.
This report examines the need for and desirability of uniformity in maximum truck length and weight limits throughout the United States. Several alternatives to federal limits on truck length and weight are investigated, and the impact that these changes would have on truck productivity, modal diversion, freight costs, pavement and bridge costs, safety, energy, air quality, and noise are estimated.

88. Transportation Research Board. 1979. State Laws and Regulations On Truck Size and Weight. NCHRP Report 198. Washington D.C.
This report describes the effects of current state size and weight laws, regulations, and interstate agreements on trucks. The potential benefits and disadvantages of increased uniformity in truck size and weight limits among the states are investigated, and the available alternatives for eliminating or minimizing the differences in these limits are evaluated. It is concluded that significant benefits would accrue from adoption of an optimal level of uniformity in the regulation of interstate truck taffic.

89. Transportation Research Board. 1980. Size and Weight Regulations, Enforcement, and Permit Operations. NCHRP Synthesis of Highway Practice 68. Washington D.C.
This report describes state legal limits of truck size and and weight and enforcement programs. Requirements, restrictions, and trends of permit issuance as well as types and application procedures of permits are summarized. The report strongly recommends that uniform standards for interstate overlimit travel be established.

90. Transportation Research Board. 1981. Criteria For Evaluation of Truck Weight Enforcement Programs. NCHRP Synthesis of Highway Practice 82. Washington D.C.

The report reviews weighing-site selection criteria and equipment. Laws regarding weight limits, enforcement agencies, fine structure, unloading requirements, and permit operations are discussed. Recommendations for evaluation of truck weight enforcement programs are made.

91. Walton, C. Michael, and Dock Burke. 1980. Highway Economic Effects of Increased Truck Size and Weight. Compendium of Technical Papers. Washington D.C.: Institute of Transportation Engineers.

This paper presents the findings of an effort to assess the effect of increased truck size and weight on Texas highways. Four alternative scenarios characterized by forecasted truck ton-miles over twenty years, highway classifications, commodity flow, and truck configuration are studied to determine the effects each would have on highway and bridge costs, truck operating costs, and fuel consumption over the same twenty-year planning horizon.

92. Walton, C. Michael, and Ogilvie Gericke. 1981. An Assessment of Changes in Truck Dimensions on Highway Geometric Design Principles and Practices. Austin: University of Texas.

This report presents the assessment of the various issues and effects of an increase in truck size and weight on rural highways in Texas. The cost implications and the effects that an increase in legal truck limits would have on highway geometric design are summarized.

93. Walton, C. Michael, Chien-pei Yu, Paul Ng, and Susan Tobias. 1982. An Assessment of Recent State Truck Size and Weight Studies. Austin: University of Texas.

This report documents the status of current legislation of each state with respect to laws governing truck size and weight. Emphasis is placed on laws pertinent to the operation of larger motor carriers such as "doubles" and "triples", overall vehicle length, width, axle weight, and gross vehicle weight.

94. Walton, C. Michael, and Chien-pei Yu. 1983. An Assessment of the Enforcement of Truck Size and Weight Limitations in Texas. Austin: University of Texas.

This study assesses the economic effects of oversize and overweight vehicle movements within Texas. It is recommended that the current fine and permit fee structure be revised so that violators would pay for their share of the estimated damage to highways.

95. Winfrey, R., P.D. Howell, and P.M. Kent. 1976. Truck Traffic Volume and Weight Data for 1971 and Their Evaluation. Washington D.C.: FHWA.

This report presents an analysis and evaluation of the results of the 1971 annual traffic classification count and weighing of trucks at roadside stations as conducted by state highway departments in cooperation with the Federal Highway Administration. Recommendations are included for improving truck weighing procedures and application of truck volume and weight data.

96. Yoder, Eldon J., Benjamin Colucci-Rios, John Fraczek, and James A. Skees. 1979. Effects of Raising Load Limits on Pavements and Bridges in Indiana. West Lafayette: Purdue University.

This study evaluates possible changes in maintenance costs that might arise if heavier loads were to be permitted on Indiana highways. Pavement maintenance costs were determined for all highways on the Indiana state highway system including interstates, U.S. routes, and state routes. The report presents estimates of increased costs that might result if weight limits were increased in Indiana.

97. Yu, Chien-pei, and C. Michael Walton. 1984. Characteristics of Double and Triple Trailer Truck Combinations Operating in the United States. TRR 966. Washington D.C.: Transportation Research Board.

This paper summarizes the characteristics of doubles and triples based on the Truck Inventory and Use Survey (TIUS) and the Truck Weight Study (TWS).

Appendix C

Questionnaire

QUESTIONNAIRE

TRUCK DATA & TRAVEL CHARACTERISTICS FOR STATE HIGHWAY PURPOSES

Please answer all of the following questions. If requested, results will be kept confidential and used only in summary form. For the purpose of this questionnaire, heavy trucks are those with gross vehicle weight of more than 10,000 pounds, which excludes 2-axle, 4-tire pick-up trucks. Please return by March 24, 1987 to **Lester A. Hoel, Virginia Transportation Research Council, Box 3817, University Station, Charlottesville, VA 22903.**

1. Which statement characterizes the status of your organizational unit with regard to heavy truck data needs. Check those which apply.

   (a) We are users of heavy truck data that is collected by others.
   (b) We collect heavy truck data primarily for our own needs.
   (c) We collect heavy truck data for use by other units within VDOT and/or other agencies.
   (d) We do not collect or use heavy truck data.
   (e) There is a lack of heavy truck data for our needs.
   (f) Heavy truck data presently available is sufficient for our needs.

2. Indicate which of the following types of heavy truck data are collected and/or used by your organizational unit.

COLLECTED	USED	
______	______	Traffic Counts
______	______	Accidents
______	______	Off-tracking & Lateral Placement
______	______	Passenger Car Equivalents(PCE)
______	______	Equivalent Single Axle Load(ESAL)
______	______	Speed
______	______	Weight
______	______	Size & Classification
		Others (Please list)

First, some questions about counting procedures.

3. Does your organizational unit **collect** traffic count data for heavy trucks?

_____NO (Please go to question 4.)
_____YES (Please answer the questions below.)

*Describe the traffic count program for heavy trucks.

*How often do you collect heavy truck traffic count data?

*How is heavy truck count data summarized?

*What other units or organizations in Virginia use heavy truck count data that you collect?

4. Does your organizational unit **use** heavy truck count data?

_____NO (Please go to next page.)
_____YES (Please answer the questions below.)

*What agency or organizational unit furnishes this heavy truck data that you require?

*How is this heavy truck data used and applied by your organization?

Now, some questions about accident data.

5. Does your organizational unit **collect** accident data for heavy trucks?

   _____NO (Please go to question 6.)
   _____YES (Please answer the questions below.)

   *Describe the accident data program for heavy trucks.

   *When is heavy truck accident data collected?

   *How is heavy truck accident data summarized?

   *What other units or organizations in Virginia use truck accident data that you provide?

6. Does your organizational unit **use** heavy truck accident data?

   _____NO (Please go to next page.)
   _____YES (Please answer the questions below.)

   *What agency or organizational unit furnishes this heavy truck data that you require?

   *How is heavy truck accident data used or applied by your organization?

Now, some questions about offtracking and lateral placement.

7. Does your organizational unit **collect** offtracking data for heavy trucks?

_____NO (Please go to question 8.)
_____YES (Please answer the questions below.)

*Describe how off-tracking and lateral placement data of heavy trucks are collceted.

*How often do you collect off-tracking and lateral placement data for heavy trucks?

*How is the off-tracking and lateral placement data summarized?

*What other units or organizations in Virginia use off-tracking and lateral placement data for heavy truck that you provide?

8. Does your organizational unit **use** heavy truck offtracking data?

_____NO (Please go to next page.)
_____YES (Please answer the questions below.)

*What agency or organizational unit furnishes this heavy truck data that you require?

*How is this heavy truck data used or applied by your organization?

These next questions refer to Passenger Car Equivalents(PCE).

9. Does your organizational unit **develop** PCE data for heavy trucks?

   _____NO (Please go to question 10.)
   _____YES (Please answer the questions below.)

   *Describe how PCEs are determined for heavy trucks.

   *How often are PCE data developed?

   *What other units or organizations in Virginia use PCE data for heavy trucks that you povide?

10. Does your organizational unit **use** heavy truck PCE data?

    _____NO (Please go to next page.)
    _____YES (Please answer the questions below.)

    *What agency or organizational unit furnishes the heavy truck PCE values that you require?

    *How is this heavy truck data used or applied by your organization?

The next set of questions refer to Equivalent Single Axle Load. (ESAL)

11. Does your organizational unit **determine** ESAL value for heavy trucks?

_____NO (Please go to question 12.)
_____YES (Please answer the questions below.)

*Describe how ESALs are determined for heavy trucks.

*How often are ESALs data developed?

*What other units or organizations in Virginia use ESAL data for heavy trucks that you provide?

12. Does your organizational unit **use** heavy truck ESAL data?

_____NO (Please go to next page.)
_____YES (Please answer the questions below.)

*What agency or organizational unit furnishes the heavy truck ESAL values that you require?

*How is this heavy truck data used or applied by your organization?

Now, some questions about speed data.

13. Does your organizational unit **collect** speed data for heavy trucks?

_____NO (Please go to question 14.)
_____YES (Please answer the questions below.)

*Describe the program for determining the highway speeds of heavy trucks.

*How often do you collect speed data for heavy trucks?

*How is heavy truck speed data summarized?

*What other units or organizations in Virginia use highway speed data for heavy trucks that you collect?

14. Does your organizational unit **use** heavy truck speed data?

_____NO (Please go to next page.)
_____YES (Please answer the questions below.)

*What agency or organizational unit furnishes the heavy truck speed data that you require?

*How is this speed data used or applied by your organizational unit?

Next, some questions about weight data.

15. Does your organizational unit **collect** weight data for heavy trucks?

_____NO (Please go to question 16.)
_____YES (Please answer the questions below.)

*Describe the program for collection of heavy truck weight data.

*How often is heavy truck weight data collected?

*How is heavy truck weight data summarized?

*What other units or organizations in Virginia use heavy truck weight data that provide?

16. Does your organizational unit **use** heavy truck weight data?

_____NO (Please go to next page.)
_____YES (Please answer the questions below.)

*What agency or organizational unit furnishes the heavy truck weight data that you require?

*How is this weight data used or applied by your organization?

And finally, some questions about size and classification.

17. Does your organizational unit **collect** size & classification data for heavy trucks?

_____NO (Please go to question 18.)
_____YES (Please answer the questions below.)

*Describe the program for collection of heavy truck size and classification data.

*How often is size and classification data collected?

*How is size and classification data for heavy trucks summarized?

*What other units or organizations in Virginia use heavy truck size and classification data that you provide?

18. Does your organizational unit **use** heavy truck size and configuration data?

_____NO (Please go to next page.)
_____YES (Please answer the questions below.)

*What agency or organizational unit furnishes this heavy truck size and classification data that you require?

*How is this size and classification data used or applied by your organization?

19. Please describe data collection procedures for **other** heavy truck characteristics that are collected by your organization. Also, describe how **other** truck data are used by your organization. (Use separate sheets if necessary)

20. Has your organization ever utilized any of the following statistics concerning trucks?

YES	NO	
_____	____	Highway Performance Monitoring System(**HPMS**)
_____	____	Annual Truck Weight Study(**ATWS**)
_____	____	Truck Inventory and Use Survey(**TIUS**)
_____	____	Bureau of Motor Carrier Safety Accident File (**BMCS**)
_____	____	Fatal Accident Reporting System(**FARS**)
_____	____	National Accident Sampling System(**NASS**)

21. What other information about trucks have you used or collected?

22. What information will you use in the future?

23. Please describe truck data needs of your agency or organizational unit that are currently not met by existing sources.

If you have any additional information regarding heavy truck data, please feel free to send it along with your response.

Your Name ______________________________

Title ______________________________

Business Telephone ______________________________

Mailing Address:

Appendix D

Agencies and Individuals That Furnished Information for the Study

VDOT Divisions	
Bridge:	H.C. Scott, Jr.
	F.G. Sutherland
Construction:	Claude D. Garver
Environmental:	R.L. Hundley
Location and Design:	R.E. Atherton
	E.C. Cochran, Jr.
Maintenance:	L.G. Barnum
Materials:	J.P. Bassett
	M.K. Elfino
	M.F. Menefee, Jr.
	W.E. Winfrey
Rail and Public Transportation:	R.G. Corder
Right of Way:	G.W. Alexander
	Lewis Rabbe, Jr.
Secondary Road:	D.E. Keith
	Gerald E. Fisher
Traffic Engineering:	J.L. Butner
	G.C. Campbell
	G.A. Vernable
Transportation Planning:	Claude Aylor
	J.P. Hopkins
	H.A. Hypes
	W.C. Jeffrey
	R.C. Lockwood
Urban:	J.K. Skeens
Department of Emergency Services:	Michael M. Cline
Department of Motor Vehicles:	Joseph B. Burrell
	Michie Longley
	David McAllister
	Susan R. Metcalf
	Stuart Napier
	Jerry L. Stein
State Corporation Commission:	William S. Fulcher
Department of State Police:	Lt. B.E. Chisholm, Jr.
Department of Waste Management:	Kory Gabrielsen