LARGE TRUCK SAFETY AND ROADWAY ELEMENTS

Final Report

Research Project 8404

Performed for

Georgia Department of Transportation

by

School of Civil Engineering
Dr. Paul H. Wright, Principal Investigator
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CHAPTER I

INTRODUCTION

Introduction

During the past three years, legislation has been passed at both the Federal and state levels which has liberalized truck travel in Georgia. The Surface Transportation Act of 1982 allowed larger trucks to operate on the Interstate and certain other Federal-aid highways. The law specified that states must allow twin-trailer combinations and may not establish overall length limits on tractor-trailer or tractor-twin-trailer combinations. The law established a width limitation of 102 inches and required that states allow:

1. Semitrailers in a tractor-semitrailer configuration 48 feet in length.
2. Trailers in a tractor-semitrailer-trailer configuration 28 feet in length.

The law required that the states allow the longer vehicles on interstate highways and on "those classes of qualifying Federal-aid Primary System highways as designated by the Secretary." It provided that the Secretary of Transportation designate as qualifying highways those Primary System highways that are capable of safely accommodating the longer vehicle lengths.

The 1983 General Assembly passed legislation authorizing the use of 48-foot trailers on Georgia roads, and in 1984, the General Assembly passed legislation that permits 102-inch wide tractor-trailers to operate on all Georgia highways that have 12-foot wide traffic lanes.

The liberalization of truck travel in the state has raised understandable concerns about possible hazards associated with larger truck use and created a need for further study of this problem.

In July, 1984, Georgia Institute of Technology was awarded a contract to perform a study of "Large Truck Safety and Roadway Elements." The primary objectives of the research were:

1. To measure the relative safety of various types of large trucks.
2. To identify types of roadways and specific roadway and traffic characteristics most closely associated with large truck crashes; and
3. To develop a procedure that could be used to deny certain classes of truck transportation access to specified sections or classes of highways.

The development of a specific work plan for the research was frustrated by a fragmented and to some extent unknown data base. It was necessary, therefore, to initially study available data sources in order to determine the need for collecting additional data by field surveys or other means.

Data for the research came from a variety of sources: Georgia DOT records of accidents and travel; accident reports that had been submitted to the Bureau of Motor Carrier Safety by carriers; special surveys on the nature of truck travel performed by the Office of Planning Data Services and the Office of Permits and Enforcement, Georgia DOT; and field surveys performed by Georgia Tech research personnel. (The specific methods for the engineering study of truck accident sites are given in Chapter IV.) The focus and scope of these studies were truck travel and truck crashes that occurred in Georgia during 1984.

Chapter II of this report describes the magnitude and nature of truck travel in Georgia, setting forth the amount of truck travel for various classes of roads. It also presents information on the type of cargo being transported and the types of violations of safety regulations.

Chapter III describes the current status of truck safety in the state and presents estimates of crash rates for tractor-semitrailer trucks using four major groups of highways.

Chapter IV describes the results of a special engineering study of truck accident sites designed to identify specific traffic and roadway characteristics associated with truck accident sites.

Chapter V presents an overall summary of the findings of this research, and Chapters VI, VII, and VIII give conclusions, recommendations for future research, and a general recommendation, respectively.

CHAPTER II

TRUCK TRAVEL IN GEORGIA

The purpose of this chapter is to describe the general nature and magnitude of truck travel in Georgia. Information was gathered on the amount of truck travel for various classes of roads, the sizes and configuration of the trucks using Georgia highways, the type of cargo being transported, and the extent of violation of safety standards.

Data provided by the Office of Planning Data Services, Georgia Department of Transportation indicate that the state's highway system accommodated approximately 2.8×10^9 vehicle miles of truck travel in 1984. Table 1 gives a breakdown of the estimated truck travel by functional class. Approximately 84 percent of this travel occurred on rural roads and 16 percent on urban roads. It is not surprising that the class of highways most heavily travelled by trucks is the rural Interstate System. The large vehicle miles of travel for that system reflects the large composition of trucks (21.8%) and the large mileage of that system (compared to the urban Interstate System).

Truck-Weight Survey

A truck-weight survey conducted by the GDOT Planning Division in September, 1984 provided information on the classes of trucks by axle types and by size. A sample of the truck-weight survey form is included in Appendix A. A total of 2,766 trucks were surveyed at 15 sites representing a variety of highway types. Table 2 shows a distribution of the trucks by axle configuration, and Table 3 breaks down the data by categories of length and width.

Table 1

Truck Travel on Georgia State Highway System, 1984

	Mileage	Annual Vehicle Miles of Travel, All Vehicles (millions)	Average Truck Mileage	Annual Vehicle Miles of Truck Travel (millions)
01 - Rural Interstate	902	7,269	21.8	1,585
02 - Rural Principal Arterial	2,743	4,100	8.4	344
06 - Rural Minor Arterial	5,827	5,334	4.8	256
07 - Rural Major Collector	6,227	2,950	5.3	156
08 - Rural Minor Collector	74	186	2.4	4
09 - NFA Local Roads	28	41	2.4	1
11 - Urban Interstate	317	7,134	4.4	314
12 - Urban Principal Arterial	133	1,112	2.8	31
14 - Urban Principal Arterial	1,253	6,039	1.3	78
16 - Urban Minor Arterial	444	1,844	1.5	28
17 - Urban Collector Streets	42	145	1.4	2
19 - NFA Local Streets	4	16	1.3	0.2

Table 2

Distribution of Trucks by Type and Axle Configuration Based on a Survey of 2,766 Trucks at 15 Sites by Office of Planning Data Services

Truck Type	Number	Percent
Single Unit		
Panel, pickup, 2P	60	2.2
Other 4-tire, 2S	16	0.6
2 Axle, 6-tire, 2D	306	11.1
3 Axle, 3A	77	2.8
4 Axle, 4A	24	0.9
Total single unit	483	17.5
3 Axle combination, 2S1	37	1.3
4 Axle combination, 2S2	234	8.5
4 Axle combination, 3S1	10	0.4
5 Axle combination, 3S2	1,898	68.6
6 Axle combination, 3S3	15	0.5
Tractor-twin trailer	82	3.0
Other types	7	0.2
Total	2,766	100.00

Table 3

Distribution of Large Trucks by Length and Width
Based on a Survey of 2,276 Trucks at 15 Sites
By Office of Planning Data Services

Category	Number	Percent
≤ 45 ft length and ≤ 8 ft width	1,857	81.6
> 8 ft trailer width	94	4.1
> 45 ft trailer length	160	7.0
Overwidth and overlength	165	7.3
Total	1,276	100.0

In the survey, the 5-axle combination truck was by far the most common type, comprising approximately two-thirds of the total. With 17.5 percent of the total, single unit trucks comprised the second most prevalent type, consisting predominantly of 2-axle, 6-tired trucks. The tractor-twin-trailer configuration comprised 5.0 percent of the sample on Interstate highways and 3.0 percent overall.

The purpose of the collection of the data summarized in Table 3 was to gauge the extent to which truck operators are taking advantage of recent legislation liberalizing limits on trailer length and width. The survey revealed that 18.4 percent of the trucks exceed the previous limitations on length or width or both length and width.

The distribution of truck travel varies significantly with class of roadway. Generally speaking, the Interstate highways have a larger percentage of tractor-semitrailer trucks than other classes of highways, as Table 4 illustrates. The tractor-twin-trailer configurations are largely confined to Interstate highways.

Permits and Enforcement Division Survey

At the request of the Principal Investigator of this project, the Division of Permits and Enforcement of GDOT undertook a special survey of trucks during the last week of August, 1984. The data were collected by two-man teams along noninterstate highways during the normal course of their inspection and enforcement work. A total of 1,159 completed inspection forms were analyzed from this survey. A sample survey form is shown in the Appendix to this report.

In this survey, nearly 85 percent (84.7%) of the trucks surveyed were using two-lane roads, 14.4 percent were travelling along four-

Table 4

Percentage of Trucks Observed in a Survey
Of 2,766 Trucks at 15 Sites by Office of Planning Data Services
By Truck Type and Functional Class

	Type of Truck			
	Single Unit	Tractor Semitrailers	Tractor Twin-Trailers	Total
01 - Rural Interstate	10.9	84.6	4.5	100.0
02 - FAP Principal Arterial	34.6	65.4	0.0	100.0
01, 02 Combined	19.2	77.8	2.9	100.0
11 - Urban Interstate	13.4	82.4	4.2	100.0
12 - FAP Connecting Link to Principal Arterial	16.9	83.1	0.0	100.0
11, 12 Combined	14.3	82.6	3.1	100.0
06 - NFA Local	43.1	56.9	0.0	100.0

lane roads, and 0.9 percent were using some other highway type. None of the data were collected along Interstate highways.

It will be noted from Table 5 that 81.4 percent of the trucks surveyed were 5-axle semitrailers while 13.6 percent were single unit trucks. The higher percentages shown in this survey for the larger truck categories is attributable to the manner in which the samples were selected. Only two of the trucks surveyed were of the tractor-twin-trailer configuration. This finding is not surprising since those trucks are generally prohibited from two-lane roads where most of the survey work was done.

Table 6 gives a distribution of the trucks surveyed by Permits and Enforcement Division personnel by length and width. The data shown here are not directly comparable with those in Table 3; however, it is interesting that of the trucks surveyed by the Permits and Enforcement Division, only 6.7 percent had trailers longer than 45 feet, and only 3.5 percent were wider than 8 feet. These lower percentages may be due to the fact that these data were predominantly taken along two-lane roads.

Of the trucks surveyed, 57.8 percent had gross weights greater than 70,000 pounds; 6.6 percent had gross weights greater than 80,000 pounds. See Table 7.

The trucks surveyed by the Permits and Enforcement Division transported a wide variety of cargo, as Table 8 indicates. The most common product category transported were logs, poles, and lumber; solids in bulk; and general freight. Nearly 11 percent of the trucks were empty.

Table 5

Percentages of Trucks Observed in a Survey by the Office of Permits and Enforcement by Truck Type and Axle Configuration

Truck Type	Number	Percent
Single Unit		
2-Axle	34	2.9
3-Axle	61	5.3
4-Axle	63	5.4
Total single unit	158	13.6
Tractor-semitrailer		
3-Axle	4	0.4
4-Axle	43	3.7
5-Axle	943	81.4
6-Axle	5	0.4
Tractor-twin-trailer	2	0.2
Not given or unknown	4	0.3
Total	1,159	100.0

Table 6

Distribution of Trucks by Length and Width, Based on a Survey by the Office of Permits and Enforcement

a. Length Distribution

Length	Number	Percent
< 45 ft	772	77.6
45 ft	156	15.7
45-48 ft	13	1.3
48 ft	41	4.1
> 48 ft	13	1.3
	995	100.0

b. Width Distribution

Width	Number	Percent
< 8 ft	15	1.3
8 ft	1,104	95.2
8 < width < 8.5 ft	7	0.6
8.5 ft	18	1.6
> 8.5 ft	15	1.3
	1,159	100.0

Table 7

Distribution of Trucks by Gross Weight
Based on a Survey by the Office of Permits and Enforcement

Gross Weight, Pounds	Number	Percent
< 10,000	4	0.4
10,000 - 19,999	11	1.0
20,000 - 29,999	124	10.7
30,000 - 39,999	81	7.0
40,000 - 49,999	48	4.1
50,000 - 59,999	50	4.3
60,000 - 69,999	171	14.7
70,000 - 79,999	594	51.2
80,000 - 89,999	71	6.1
90,000 - 99,999	4	0.4
≥ 100,000	1	0.1
	1,159	100.0

Table 8

Distribution of Trucks by Cargo Type
Based on a Survey by the Office of Permits and Enforcement

Cargo Type	Number	Percent
General Freight	104	9.0
Household Goods or Uncrated Furniture/Fixtures	18	1.6
Metal: Coils, Sheets, Rods Plates, Etc.	34	2.9
Heavy Machinery or Other Large Objects	15	1.3
Motor Vehicles	8	0.7
Gases in Bulk	29	2.5
Solids in Bulk	269	23.2
Liquids in Bulk	60	5.2
Logs, Poles, Lumber	340	29.3
Empty	126	10.9
Refrigerated Foods	50	4.3
Mobile Homes	5	0.4
Farm Products	55	4.7
Other	46	4.0
	1,159	100.0

Survey of Truck Safety Violations

The Georgia Public Service Commission is responsible for performing safety inspections for all for-hire vehicles operating in the state, including interstate carriers. Private carriers were included under a law that become effective June 15, 1984. The Public Service Commission has 16 roving officers working throughout the state in assigned counties. Inspections are normally made at roadsides and at industrial sites.

A total of 273 inspection forms were randomly selected from the Public Service Commission files for inspections that had been made during the first six months of 1984. The 273 trucks inspected represented 117 carriers. The sample indicated that there were an average of 5.4 violations per truck. Table 9 lists the most common violations cited by PSC inspectors. More than half (54.6%) of the trucks were placed out of service until the necessary repairs had been completed and the vehicle restored to safe operating conditions. Twenty-three (8.4%) of the drivers were arrested, and 2.5 percent of the trucks were required to be unloaded.

The results of the PSC survey are not a measure of the overall safety of trucks using Georgia's highways, since the vehicles are not chosen randomly. It is likely that inspectors choose for inspection those trucks suspected of safety violations. Nevertheless, the survey results give some indication of the types of safety violations that are most prevalent and give some cause for concern about the overall safety of truck transportation in the state.

Table 9

Most Common Types of Safety Violations Cited by Georgia Public Service Commission Inspectors

Violation	Code	Number	Percent
Lamps and reflectors, large semitrailers and full trailers	3.014	168	11.4
Lamps other than headlamps	3.025	164	11.1
Emergency equipment (fire extinguisher)	3.095	131	8.9
Tires	3.075	112	7.6
Brake tubing and hose, adequacy	3.045	106	7.2
Inspection, repair, maintenance	6.003	102	6.9
Lamps and reflectors, tractors	3.013	100	6.8
Turn signals	3.019	95	6.4

CHAPTER III

TRUCK ACCIDENTS IN GEORGIA

Trucks accounted for 7.7 percent of the travel on state routes in 1984 and 11.7 percent of the accidents that occurred on those routes. All classes of trucks accounted for 23.5 percent of the fatalities that occurred on the state highway system. Thus, the hazards associated with truck transportation are especially noticeable when accident severity is taken into account. This is especially true for the largest trucks. Tractor-semitrailer trucks, for example, accounted for 6.9 percent of all accidents in 1984 and 18.0 percent of the fatalities.

Tables 10, 11, and 12 list the accidents, injuries, and fatalities, respectively, by vehicle class for Georgia's highway system in 1984.

Crash Rates by Truck Type and Functional Class

In order to calculate crash rates for various types of trucks using different classes of highways, it is necessary to determine the distribution of truck crashes by truck type and highway class. To accomplish this, the researchers undertook two special studies:

1. A study that matched police officers' reports with reports filed by carriers with the Bureau of Motor Carrier Safety (BMCS); and
2. A study of police officers' reports that contained a special truck category code ("Alpha code").

A description of the methodology and results of these studies is given in the following sections.

Table 10

Traffic Accidents in Georgia, 1984 by Vehicle Class and Road System

	Road System		
Vehicle Class	Interstate	Other State Routes	All State Routes
All vehicles	16,013	72,862	88,875
All trucks	3,070	7,352	10,422
Tractor semitrailers	2,361	4,019	6,380
Tractor-twin-trailers	4	7	11

Table 11

Crash Injuries in Georgia, 1984
by Vehicle Class and Road System

	Road System		
Vehicle Class	Interstate	Other State Routes	All State Routes
All vehicles	6,306	29,959	36,265
All trucks	1,194	2,903	4,097
Tractor semitrailers	1,004	1,507	2,511

Table 12

Crash Fatalities in Georgia, 1984
by Vehicle Class and Road System

	Road System		
Vehicle Class	Interstate	Other State Routes	All State Routes
All vehicles	157	738	895
All trucks	57	153	210
Tractor semitrailers	46	115	161

Study of Bureau of Motor Carrier Safety Reports

The objective of this special study was to match the location information on each police officer's report with the truck size and configuration information contained in the corresponding BMCS report. With the specific crash location given on the police officer's report, it was possible to enter GDOT files and determine the functional class of the highway on which the crash occurred. Interstate carriers are required to file a report with the Bureau of Motor Carrier Safety for all truck crashes that involve an injury or fatality or involve property damage of $2,000 or more.

Copies of the BMCS reports were obtained for crashes that occurred in Georgia during the months of April through August, 1984. These reports were matched with the corresponding police reports.

The researchers were able to match 201 of a total of 425 BCMS reports to the corresponding police officer's report. The distribution of those crashes by truck configuration was:

Single unit truck accidents - 16
Tractor-semitrailer accidents, width $\leq$ 8 ft, length $\leq$ 45 ft - 178
Tractor-semitrailer accidents, width > 8 ft - 3
Tractor-semitrailer accidents, length > 45 ft - 1
Dimension information incomplete - 3
Tractor-twin-trailer - 0

The extremely small number of reports with oversized trailers cast doubt on the reliability of the length and width data given on the BCMS reports. This made it impossible to use these data to make any conclusions about the distribution of the larger trucks by class of roads. The distribution of the BCMS sample of tractor-trailer trucks is shown by functional class of highway as Table 13. Nearly two-thirds (63.5%) of those crashes occurred along rural highways and about one-third along urban highways. Sixty-four percent of those crashes occurred either on Interstate highways (37.6%) or principal arterial highways (26.4%).

Study Using the Georgia State Highway Patrol Alpha Codes

To supplement the results of the study just described, a study was undertaken using police reports marked with special "Alpha" codes to indicate truck configuration. At the request of Georgia DOT in 1984, the State Highway Patrol commenced marking truck accident reports with one of the following designations:

A - tractor-semitrailer with 45 ft trailer

B - tractor-semitrailer with trailer > 45 ft

C - tractor-twin-trailer

D - logging truck

Approximately 15 percent of the applicable truck accidents were so marked in 1984.

Copies of truck accident reports that had been designated with an "Alpha" code were obtained for the months of September through December, 1984. Functional highway classes for these crash locations were determined from Georgia DOT Planning Division files.

Table 13

Distribution of Tractor-Semitrailer Accidents by Functional Class

	Number (percent)	
Functional Class	BMCS Matched Cases	Alpha Coded Cases
01 - Rural Interstate	44 (24.2%)	68 (26.94%)
02 - Rural Principal Arterial	37 (20.3%)	53 (20.9%)
03 - Rural Minor Arterial	25 (13.7%)	82 (32.4%)
07 - Rural Major Collector	7 (3.9%)	28 (11.1%)
11 - Urban Interstate	23 (12.6%)	12 (4.7%)
12 - Urban Principal Arterial	10 (5.5%)	2 (0.8%)
14 - Urban Principal Arterial	1 (0.6%)	0 (0.0%)
16 - Urban Minor Arterial	11 (6.0%)	0 (0.0%)
17 - Urban Collector	18 (9.9%)	7 (2.8%)
19 - Urban Local	2 (1.1%)	1 (0.4%)
Unknown	4 (2.2%)	-----
Total	182 (100.0%	253 (100.0%)

Table 14 shows the distribution of the Alpha-coded crashes by truck type and functional class. The breakdown of the crash sample by truck type was as follows:

Category A - 44.5%
Category B - 14.7%
Category C - 1.0%
Category D - 39.8%

Calculation of Crash Rates

Because of the paucity of accident data when broken down by truck type and functional class, it was necessary to collapse the data to only one truck accident category (all tractor-semitrailer accidents) and four functional highway groupings. The percentages of tractor-semitrailer crashes that occurred on roads in the four functional groups are shown in Table 15.

The tractor-semitrailer accident rates for each of the four functional highway groups were estimated by the following procedure.

1. To estimate the number of accidents occurring in each functional grouping, the percentages were multiplied by the total truck accidents that occurred on the state highway system in 1984. That total, provided by Georgia DOT, was 6,273.
2. The total vehicle miles of tractor-semitrailer truck travel, VMST, for each functional group, i, was estimated by the following equation.

$$VMST_i = (VMTT_i)\ (P_i)$$

where $VMTT_i$ = total vehicle miles of truck travel for functional

Table 14

Distribution of Truck Crashes by Truck Category
and Functional Class Based on "Alpha" Codes

Functional Class	Number in Truck Category			
	A	B	C	D
01 - Rural Interstate	49	19	0	8
02 - Rural Principal Arterial	42	11	2	34
06 - Rural Minor Arterial	59	23	1	63
07 -Rural Major Collector	21	7	0	17
08 - Rural Minor Collector	0	0	0	0
09 - NFA Local Roads	0	0	0	1
11 - Urban Interstate	11	1	0	6
[illegible]	2	0	0	21
	0	0	0	8
	1	0	0	12
	5	2	1	0
	0	0	0	0
	190	63	4	170

Table 15

Percentage of Tractor-Trailer Accidents Occurring in Various Highway Functional Groups

Functional Classes	Percent
Classes 01 - Rural Interstate 02 - Rural Principal Arterial	47.8
Classes 06, 07, 08 - Other Rural State Highway System Roads	43.5
Classes 11 - Urban Interstate 12 - Urban Principal Arterial (controlled access) 14 - Urban Principal Arterial (uncontrolled access)	5.5
Classes 16, 17, 19 - Other Urban State Highway System Roads	3.2

group i (See Table 1).

P_i = percent of trucks that are tractor-semitrailer trucks (See Table 4).

3. The accident rate for each functional grouping, i, is the number of accidents divided by $VMST_i$.

The accident rates for tractor-semitrailer trucks thus computed are shown in Table 16.

There were a number of assumptions that went into the calculations of the accident rates given in Table 16. The final rates were therefore rounded off. The calculations leave little doubt that the minor arterial, collector, and local highways are more hazardous for trucks than Interstates and principal arterial highways by a large margin. The results show that for rural highways, the lower functional classes have accident rates that exceed those of Interstates and principal arterial highways by a factor of six. For the urban highways, the lower functional classes have an accident rate that exceeds that of the higher classes by a factor of about 13.

Table 16

Accident Rates for Tractor-Semitrailers for All State Routes

	Accidents	Annual Vehicle-Miles Of Truck Travel (millions)	Fraction of Truck Travel That is Tractor-Semitrailers	Accident Rate Accidents/100 million vehicle miles
01,02	2,998	1,929	0.7784	200
06,07,08,09	2,729	417	0.5*	1,300
11,12,14	345	423	0.826	100
16,17,19	201	30.2	0.5*	1,330

*Estimated by Planning and Programming Division, Georgia DOT.

CHAPTER IV

ENGINEERING STUDY OF TRUCK ACCIDENT SITES

Engineering surveys were made at 200 locations where truck crashes had occurred during the period April through August, 1984. The objective of these surveys was to gain a better understanding of the specific roadway and traffic characteristics at the crash locations.

The sites were chosen by a random selection of police accident reports for truck crashes that had occurred during the stated period. The reports were selected from the population of reports for all truck crashes, including single unit truck crashes, as well as those involving larger trucks. At each crash location, the following features of the roadway were measured or observed and recorded: (1) number of lanes, (2) lane width, (3) superelevation or crown, (4) shoulder width, and (5) shoulder slope.

Special studies were made for a one-mile section upstream of the crash site. (The upstream section refers to the section traversed by the truck driver just prior to the crash.) In each of those sections, the following data were collected:

1. Length and degree of each horizontal curve
2. Gradients at each 100 foot station
3. Number of intersections
4. Length of section that is two-lane
5. Length of section with no-passing sight distance, based on the length of yellow centerline stripes applicable to a driver approaching the crash site.

Simple measuring instruments that involved a minimum of time at the survey locations were used. Lane and shoulder widths were measured with a 100-foot cloth tape. Longer lengths and the 100-foot stations for the gradient measurements were determined with the aid of a Numetrics, Model K14S, distance measuring instrument connected to the transmission of the research van. The device was calibrated to read to the nearest foot.

Gradients were measured by a specially designed instrument consisting of a one-quarter inch tube mounted on an aluminum frame along a concave radius of 15 feet. The tube was partially filled with a liquid, and the gradients were calibrated in terms of the position of the bubble in the tube.

Horizontal curves were measured by the middle ordinate method described by Baker.[1] The curve measurements were taken at the edge of the roadway. The middle ordinates were converted to degrees of curve of the centerline of the roadway. Superelevations, crowns, and shoulder slopes were measured with a four-foot carpenter's level with a calibrated adjustable leg.

The annual average daily traffic and functional class of the roadway were recorded for each of the crash sites.

A typical field survey form is shown in Appendix A.

The roadway and traffic characteristics at the truck accident sites were compared with similar characteristics of comparison or control sites. Two groups of roads were used for comparison purposes:

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[1] Baker, J. Stannard, Traffic Accident Investigation Manual, The Traffic Institute, Northwestern University, 1975.

1. The Highway Program Management System (HPMS). This system consists of a statistically-based sample of roads in the Georgia highway system. Its traffic and geometric features characterize the conditions for all roads in the state highway system. As such, it seems to be a suitable control for the roadway crash site study.

A complete set of data was available in the HPMS files only for Interstates and for four functional classes other than the Interstate system:

Class 02 - Rural Principal Arterial
Class 06 - Rural Minor Arterial
Class 12 - Urban Principal Arterial, controlled access
Class 14 - Urban Principal Arterial, free access

The roadway and traffic characteristics of these four functional classes of HPMS sections were compared with those of 122 crash locations that were identified as belonging to one of those four functional classes.

2. The second set of comparison roads consisted of a 2,667-mile system of predominantly two-lane roads in the state. This system consists of 33 sections of roadway that had been proposed in 1983 as candidate links in a statewide network for larger truck use. State engineers had developed quantitative measures of curvature, gradient, pavement widths, lengths of two-lane segments, and other physical characteristics for this system.

An evaluation of the roadway and traffic characteristics of the truck crash sites is given in the following paragraphs.

Comparison of Crash Sites with Sections of the HPMS System

The following characteristics of the crash locations were compared with similar characteristics of comparable sections of the HPMS system: (1) number of lanes, (2) lane widths, (3) horizontal curvature, (4) gradients, (5) traffic volumes, (6) shoulder widths, and (7) signalized intersections per mile.

Distribution of Roadways by Number of Lanes

Table 17 compares the crash sites and the comparable HPMS system according to number of lanes. The percentages for the crash sites refer to number of lane designations made at a point, i.e., at the crash site. The numbers listed for the HPMS system are percentages of mileages in the stated four functional classes.

An additional measure was recorded for each of the truck crash locations: the percent of two-lane road in the one-mile upstream sections. It was found that 76.5 percent of the 122 one-mile sections upstream of the crash sites were two-lane roads. The comparable perecentage from Table 17 for the HPMS sections is 87.0. Thus, two-lane roads are not overrepresented in the crash sections, but, as Table 17 indicates, three-lane and five-lane roads appear to be.

Distribution of Roadways by Lane Width

Table 18 shows the distribution of roadways by lane width for the two roadway systems. These data do not show a preponderance of narrow-laned roads in the vicinity of crash sites when compared to the HPMS of the state highway system in comparable functional classes.

Table 17

Distribution of Roadways by Number of Lanes for Two Roadway Systems

Number of Lanes	122 Crash Sites Percent of Cases (Functional Classes 02, 06, 12, 14)	HPMS System (Functional Classes 02, 06, 12 14)
2	74.6	87.0
3	9.8	1.1
4	8.2	11.1
5	6.6	0.2
6	0.8	0.6
7	---	neg.
Total	100.0	100.0

Table 18

Lane Width Distributions for Two Roadway Systems

Lane Width, ft	122 Crash Sites Percent of Cases (Functional Classes 02, 06, 12, 14)	HPMS System Percent of Mileage (Functional Classes 02, 06, 12 14)
8	0.0	0.6
9	0.0	0.5
10	5.7	5.3
11	10.7	10.3
12	62.3	69.3
13	7.4	4.7
14	6.6	5.4
15	3.3	1.1
16	0.8	1.2
17	0.8	0.3
18	0.8	0.5
19	0.0	0.1
20	1.6	0.7
Total	100.0	100.0

Comparison of Horizontal Curvature

In the HPMS system, information is stored on the number and degree of curves on each highway segment. There are 13 categories of curvature, designated "a" through "m." Similar data were collected for one-mile sections upstream from each truck accident site.

Table 19 compares the number of curves in various categories for the HPMS and crash locations.

Table 20 lists the percentages of mileages in each of the 13 categories of curvature for the 122 miles upstream of the crash sites and for the HPMS system. These comparisons show a slight tendency for sharper curves at the crash locations than within the comparable classes of the HPMS system.

Comparison of Gradients

The HPMS file contains data on the number and lengths of grades distributed by six categories, designated "a" through "f." Table 21 shows a comparison of the percentage of grades in each category for the HPMS road sample and for the crash survey sections. The crash locations were overrepresented in the flatter grade categories, i.e., for grades less than 2.5 percent, and underrepresented otherwise. Seventy-four percent of the grades in the vicinity of the crash sites were less than 1.5 percent (categories "a" and "b"), but only 60.8 percent of the grades on the comparable HPMS sample were less than 1.5 percent. This comparison does not support the expectation that truck crashes tend to occur along steep gradients.

Table 19

Percent of Curves Within Crash Locations and HPMS Sections, By Degree of Curve

Curve Designation	Degree of Curve	122 1-mile Sections Upstream of Crash Sites	HPMS Sections
b	0.5 - 1.4	26.3	33.4
c	1.5 - 2.4	23.9	26.2
d	2.5 - 3.4	16.9	17.3
e	3.5 - 4.4	13.4	8.6
f	4.5 - 5.4	6.5	5.2
g	5.5 - 6.9	4.0	3.9
h	7.0 - 8.4	1.5	2.0
i	8.5 - 10.9	3.0	1.3
j	11.0 - 13.9	2.5	0.7
k	14.0 - 19.4	0.5	0.6
l	19.5 - 27.9	0.5	0.6
m	$\geq$ 28	1.0	0.2
Total		100.0	100.0

Table 20

Percentages of Mileages Within Crash Locations and HPMS Sections, by Degree of Curves

Curve Designation	Degree of Curve	122 1-mile Sections Upstream of Crash Sites	HPMS Sections
a	0.0 - 0.4	72.7	72.3
b	0.5 - 1.4	7.5	10.7
c	1.5 - 2.4	7.0	7.5
d	2.5 - 3.4	5.1	4.7
e	3.5 - 4.4	3.4	2.2
f	4.5 - 5.4	1.5	1.0
g	5.5 - 6.9	0.9	0.7
h	7.0 - 8.4	0.4	0.3
i	8.5 - 10.9	0.7	0.2
j	11.0 - 13.9	0.4	0.1
k	14.0 - 19.4	0.3	0.1
l	19.5 - 27.9	neg.	0.1
m	$\geq$ 28	0.1	neg.
		100.0	100.0

Table 21

Percent of Grades Within Crash Locations and HPMS Sections, by Gradient Category

Gradient Category	Gradient Range, %	122 1-mile sections Upstream of Crash Sites	HPMS Sections
a	0 - 0.4	28.9	20.0
b	0.5 - 2.4	45.0	40.8
c	2.5 - 4.4	18.9	25.2
d	4.5 - 6.4	5.7	10.7
e	6.5 - 8.4	1.3	2.9
f	≥ 8.5	0.2	0.4
		100.0	100.0

Comparison of Traffic Volumes

Table 22 compares the distributions of average daily traffic for the HPMS road sample and the 122 crash sites in functional classes 02, 06, 12, and 14. The crash sites were overrepresented in the ADT ranges up to 10,000 ADT but underrepresented otherwise.

Comparison of Shoulder Width

Table 23 gives the distribution of shoulder widths for the HPMS road sample and the 122 crash sites in the functional classes 02, 06, 12, and 14. The data suggest that truck crashes are occurring on highways with wider shoulders than those existing on the road system generally. The data in Table 22 revealed that 51.6 percent of the crash sites had shoulders wider than 8 feet, whereas only 11.4 percent of the HPMS roads with comparable functional classes had shoulders wider than 8 feet. This unexpected finding probably reflects greater truck travel (and greater exposure to accidents) on rural highways which tend to have wider shoulders.

Comparison of Signalized Intersections Per Mile

Crash locations had a greater density of signalized intersections (0.22 signalized intersections/mile) than the HPMS system (0.15/mile). However, for the 122-mile study sections, there were a total of only 27 signalized intersections, suggesting that this overall effect is not of great importance.

Table 22

Distributions of Average Daily Traffic (ADT) for Crash Locations and HPMS Systems (Functional classes 02, 06, 12, 14)

ADT Range	Percent of Sites with ADT Shown:	
	122 Crash Sites	HPMS System
0 - 5,000	64.8	56.6
5,001 - 10,000	25.4	21.3
10,001 - 15,000	3.3	9.5
15,001 - 20,000	3.3	4.6
20,001 - 25,000	0.0	3.1
25,001 - 30,000	1.6	2.0
30,001 - 35,000	0.8	1.2
35,001 - 40,000	---	0.7
40,001 - 45,000	---	0.3
45,001 - 50,000	---	0.2
50,001 - 55,000	---	0.3
55,001 - 60,000	---	0.0
60,001 - 65,000	---	0.2
> 65,000	---	neg.
no data	0.8	---
	100.0	100.0

Table 23

Distributions of Highway Mileages by Shoulder Width for Crash Locations and the HPMS Sections (Functional classes 02, 06, 12, and 14)

Shoulder Width	Percent of Mileage in the 122 Mile Sections Upstream of Crash Sites	Percent of Mileage in the HPMS Sections
1	12.3*	9.2
2	0.8	1.9
3	1.6	1.9
4	2.5	6.0
5	4.1	17.5
6	8.2	24.1
7	9.0	17.1
8	9.0	11.0
9	11.5	4.5
10	13.1	5.7
11	8.2	0.3
12	6.6	0.7
13	1.6	neg.
14	4.9	neg.
15	3.3	neg.
> 15		0.1
not recorded	0.8	---
	100.0	100.0

*Includes curbed or no shoulder

Comparison of Crash Sites with the "Designated" System

To further evaluate the findings from the 200 field surveys made at truck crash locations, certain of the data were compared with similar data developed by GDOT engineers for a 2,667-mile system that had been proposed in 1983 for larger truck use. That study provided five geometric or traffic measures that could be compared with that for the crash locations:

1. Percent of mileage that is two-lane
2. Pavement width of two-lane roads
3. Horizontal curves per mile
4. Percent of mileage with some curvature
5. No passing sight distance

Table 24 compares these measures for the two road systems.

The data in Table 24 shows that truck crashes are occurring on parts of the state highway system that have design features noticeably inferior to the road system that was proposed for access by larger trucks in 1983.

The crash locations had more two-lane roads, narrower pavements, more horizontal curvature, and more restrictions to passing. Such differences are widely recognized by highway engineers as being detrimental to safety. It is therefore not surprising that the crash sites were found to be deficient in these ways.

Table 24

A Comparison of Five Geometric/Traffic Measures for the 200 Crash Locations and the "Designated" System

	200 crash Locations	Designated System
% mileage that is 2-lane	78.5	74.6
% mileage with lane widths < 12 feet (2-lane roads)	53.3	5.0
Number of horizontal curves/mile (2-lane roads)	2.07	1.40
% mileage with no passing sight distance (2-lane roads)	43.9	26.0
% mileage with some curvature (2-lane roads)	29.7	21.6

CHAPTER V

SUMMARY OF FINDINGS

A review of the material presented in the previous chapters reveals three general findings about truck safety:

1. The truck safety problem on Georgia's state highway system is predominantly a rural problem.
2. The truck safety problem involves predominantly tractor-semitrailer trucks.
3. The truck safety problem varies significantly with the functional class of highway.

Georgia's Truck Safety Problem -- A Rural Problem

It should come as no surprise that the truck safety problem in Georgia is predominantly a rural problem. The state highway system is 87.8 percent rural, and 78 percent of the urban highways in the system fall into the safest categories of Interstate, principal arterials and minor arterials. Approximately 81 percent of truck travel on the state highway system occurs on rural highways, and 62-91 percent of the truck accidents occur in rural areas. (The BCMS data for interstate carriers showed 62 percent occurring in rural areas; the State Highway Patrol's "Alpha"-coded reports were 91 percent rural.) There is, of course, and important urban component to the truck safety problem, but it mostly falls under the domain of local governments.

Georgia's Truck Safety Problem -- The Effect of Truck Size

The truck safety problem is predominantly one involving the largest classes of trucks. In 1984, which was the focus of this study, this meant tractor-semitrailer trucks. Approximately two-thirds (68.6%) of the trucks surveyed by the Planning Division were 5-axle, tractor-semitrailer combinations (Type 3S2); combinations comprised 79.3 percent overall, single units 17.5 percent, and tractor-twin-trailers 3.0 percent. Tractor-trailer-combinations accounted for 76.9 percent of the truck accidents, 84.1 percent of the injuries, and 80.7 percent of the truck crash fatalities in the state.

In 1984, only 18.4 percent of the trailers surveyed exceeded the earlier length and width limitations (> 45 feet long and > 8 feet wide), but the percentage of these larger trucks is undoubtedly increasing. The tractor-twin trailer configuration comprised 5.0 percent of the trucks surveyed on Interstate highways and 3.0 percent overall. Because of low exposures, traffic accidents by these trucks were correspondingly small.

Georgia's Truck Safety Problem -- The Effect of Class of Highway

Both the amount of truck travel and the number of truck accidents vary greatly with the class of highway system. This is shown by a casual perusal of the travel and accident statistics. The percentage of trucks in the traffic stream varies from 1.3 percent for local roads to 21.8 percent for rural Interstate highways. Interstate highways account for two-thirds (67.8%) of the truck travel in the state but only 29.5 percent of the accidents. Other state routes accommodate 32.2 percent of the truck travel but 70.5 percent of the accidents.

The relative safety of various classes of highways is shown by examining the accident rates, expressed in accidents per 100 million vehicle miles of travel for specified types of vehicles. Accident rates for tractor-semitrailer trucks travelling the higher functional classes of highways (Interstates and other principal arterials) were computed and compared with similar rates for the other functional classes. The crash rate for the lower functional classes of rural highways exceeded that of Interstates and other principal arterials by a factor of 6.5. That factor for urban highways was 13.6.

Engineering Study of Truck Accident Sites

Engineering surveys were performed at 200 locations where truck accidents had occurred. The objective of this phase of the research was to more clearly define the types of roads on which truck accidents commonly occur. At each crash site, roadway and traffic characteristics were measured and recorded and then compared with similar characteristics for a similar group of roads selected from the Highway Program Management System (HPMS). This study failed to reveal any remarkable differences between the crash sites and the randomly selected group of Georgia roads.

Certain of the data obtained from the surveys made at truck crash locations were compared with similar data developed by GDOT engineers for a 2,667-mile system that had been "designated" in 1983 for larger truck use. This comparison revealed that a number of the design features of the crash locations were noticeably inferior to those of the "designated" truck system. Specifically, the crash locations had narrower pavements, more horizontal curvature, a greater percentage of two-lane roads, and more restrictions to passing movements.

CHAPTER VI

CONCLUSIONS

1. The truck safety problem on the Georgia state highway system is largely concentrated in rural areas and predominantly involves one class of trucks: tractor-semitrailers (class 3S2).
2. The tractor-semitrailer accident rate for the lower functional classes of rural state highways exceeds that for rural Interstate and other principal arterials by a factor of about 6.5. That factor for urban highways is approximately 13.6.
3. An engineering study of 200 truck crash sites failed to reveal any remarkable differences between the roadway and traffic characteristics of those sites and similar characteristics of a randomly selected group of Georgia roads.
4. The design features of 200 truck crash sites were noticeably inferior to those of a 2,667 mile system of roads that had been "designated" in 1983 for larger truck use.
5. Further research will be needed to measure the accident rates of tractors with oversized trailers and tractor-twin-trailers. The relatively small amount of travel and the corresponding paucity of accident data precluded the computation of reliable accident rates for these configurations.

CHAPTER VII

RECOMMENDATIONS FOR FUTURE RESEARCH

1. The state should continue to categorize truck accident data by truck configuration and size. The most promising approach to better categorizing such data is to continue to use the "Alpha" code system that is in place and, through appropriate channels of the Department of Public Safety, to encourage investigating police officers to use it more consistently.
2. Additional studies are recommended to more accurately determine the magnitude of travel by various types of trucks on various classes of highways. Special studies are needed to measure the amount of travel by logging trucks which account for about 40 percent of all combination truck accidents in the state.
3. Additional research is recommended to further identify specific traffic and roadway characteristics associated with truck accident sites. It is suggested that any further research along this line be focused exclusively on the location of crashes of tractor-semitrailer trucks and other combinations rather than on truck accident sites generally.

CHAPTER VIII

GENERAL RECOMMENDATION

One of the objectives of this project was to develop a truck access disqualification procedure that could be used to deny certain classes of trucks access to specified sections or classes of roadways. Unfortunately, the data collected or made available to the researchers are insufficient to allow the development of such a disqualification procedure with specificity. Nevertheless, it has been shown that accident rates for tractor-semitrailer trucks on lower functional classes of highways are much higher than for Interstate and other principal arterial highways.

It is not surprising that Interstates and other principal arterial highways are much safer than two-lane rural highways or city streets. These facilities are designed to accommodate the most demanding traffic conditions: the fastest speeds, the heaviest traffic volumes; and the widest range of vehicle types, including the largest trucks. Thus, it is understandable that the highest functional classes of highways which place fewer demands on drivers also experience the lowest accident rates of all classes of highways.

Like other engineering structures, highways are designed to accommodate specified or design conditions. When the specified conditions are violated, the highway does not function as it should. A critical factor leading to the layout and design of a highway is the <u>design vehicle</u>. When vehicles larger and heavier than the design vehicle are permitted to use a highway, a number of undesirable consequences can be expected: delays and congestion; failed pavements, increased maintenance costs; and worst of all, injuries and loss of life due to traffic accidents.

If the economic realities of competition and industrial development dictate greater freedom of access for larger trucks, the logical course of action, and the course recommended here, would be to *first* upgrade the roadway system to meet the demands of the new design vehicle, and *then* grant truck users access to those segments of the highway system.

ACKNOWLEDGEMENTS

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The field surveys were performed under the direction of Graduate Students Chris Swenson and Trefor Williams. Graduate student Maureen English assisted with the analysis.

APPENDIX A

SURVEY FORMS

HPS-T-89 REV. 12/73

STATE OF GEORGIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF PLANNING AND PROGRAMMING
IN COOPERATION WITH
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

TRUCK WEIGHT STUDY—FIELD DATA RECORDING AND CODING FORM

Card Number	1	7
Georgia Code Number	2 3	1 3
Highway System (To be recorded in the office)	4 5	☐☐
Station Number	6 7 8	☐☐☐
Direction of Travel: N=1, NE=2, E=3, SE=4, S=5, SW=6, W=7, NW=8, NSc=9, EWc=0	9	☐
Station Operated: Year______ Month______ Day______	10 11 12 13 14 15	☐☐☐☐☐☐
Hour of the Day (00=Midnight-1 a.m.; 23=11 p.m.-Midnight)	16 17	☐☐
Vehicle Type ______	18 19 20 21 22 23	☐☐☐☐☐☐
Body Type ______	24 25	☐☐
Fuel Type: 1=Gas, 2=Diesel, 3=Propane, 4=Other	26	☐
State of Registration of Power Unit ______; of Trailer ______		
Vehicle Ownership: Fed. Government ___, Other Government ___, Private ___		
Gross Registered Weight Group Code (To be recorded in office)	27 28	9 9
Width of Trailer	29 30 . 31	☐☐.☐
Length of Trailer	32 33 . 34	☐☐.☐
Class of Operation: 1=Private, 2=Hire under ICC, 3=Other for hire	35	9
Commodity Carried ______	36 37 38 39 40	9 9 9 9 9
Empty or Loaded: 0=Empty, 1=Loaded, 2=Does not apply	41	☐
Total Weight of Truck or Combination ______	42 43 44 45	☐☐☐☐

Axle Weights (Hundreds of Pounds)			Axle Spacings (Feet and Tenths)		
Axle A ______	46 47 48	☐☐☐	A-B ______	61 62 . 63	☐☐.☐
Axle B ______	49 50 51	☐☐☐	B-C ______	64 65 . 66	☐☐.☐
Axle C ______	52 53 54	☐☐☐	C-D ______	67 68 . 69	☐☐.☐
Axle D ______	55 56 57	☐☐☐	D-E ______	70 71 . 72	☐☐.☐
Axle E ______	58 59 60	☐☐☐	Total (Wheelbase) ______	73 74 75 . 76	☐☐☐.☐

Serial Number ______	77 78 79	☐☐☐
Card Control: 0=This is only card, 1=Another card to follow—see reverse side	80	☐

STATE OF GEORGIA
DEPARTMENT OF TRANSPORTATION
OFFICE OF PERMITS AND ENFORCEMENT

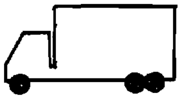
Date of Survey: ____________________

Location of Survey (Route No., Mile Post) ____________________

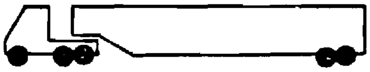
Number of Traffic Lanes, Both Directions ____________________

Truck Type (Check One);

☐ Single Unit (2,3,4 Axles)



☐ Tractor-Semitrailer (3,4,5,6 Axles)



☐ Tractor-Semitrailer-Trailer (Double bottom)

Type of Body: ☐ Van ☐ Flat ☐ Tank ☐ Auto ☐ Other

Fuel Type: ☐ Gas ☐ Diesel ☐ Propane ☐ Other

Engine Size (Should be available on Lease or Proof of Ownership): ____________

Number of Axles: ____________________

Trailer Length: ____________________

Total Length: ____________________

Total Width: ____________________

Gross Weight: ____________________

Weight of Cargo: ____________________

Principal Type of Cargo (Check One):

- ☐ General Freight
- ☐ Household goods or uncrated furniture/fixtures
- ☐ Metal: Coils, sheets, rods, plates, etc.
- ☐ Heavy machinery or other large objects
- ☐ Motor Vehicles
- ☐ Driveaway-towaway
- ☐ Gases in bulk
- ☐ Solids in bulk
- ☐ Liquids in bulk
- ☐ Explosives
- ☐ Logs, poles, lumber
- ☐ Empty
- ☐ Refrigerated foods
- ☐ Mobile homes
- ☐ Farm products
- ☐ Other (specify)

____

____

ECH CIVIL ENGINEERING SURVEY FORM (Rev. 9/84) Ga. Tech Case No. ______

1 ____________________ Accident No. ______

____________ Route ______ Mile Post ______

Crew ____________________ Survey Date ______

Georgia DOT Records:

T ______ % Trucks ______ Functional Class ______

Crash Site:

ane Width ______ No. of Lanes ______ S.E./Crown ______ %

Shoulder Width ______ Shoulder Type ______ Shoulder Slope ______ %

In One-Mile Section Upstream of Crash Site:

Length of Section That Is Two-Lane ______ ft

Length of Section With No-Passing Sight Distance ______ ft

No. of Intersections Within Section:

Signalized ______ Stop Signed ______ Others ______

Horizontal Curves in Section: (Use + for right turning curve and - for left turning curve as seen by driver approaching site.)	Middle Ordinate	Degree	Length, ft
	______	______	______
	______	______	______
	______	______	______
	______	______	______
	______	______	______

Gradients Starting 1 Mile Upstream: (+ Uphill Toward Site, - Downhill Toward Site)

Begin	Sta. 1	Sta. 2	3	4	5	6	7
	8	9	10	11	12	13	14
	15	16	17	18	19	20	21
	22	23	24	25	26	27	28
	29	30	31	32	33	34	35
	36	37	38	39	40	41	42
	43	44	45	46	47	48	49
	50	51	52				

NOTE: Last gradient is 80 feet from Crash Site.