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Operating Larger Trucks on Roads With Restrictive Geometry: Summary Report

Research, Development, and Technology
Turner-Fairbank Highway Research Center
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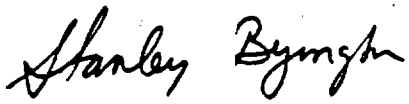
FOREWORD

This report is part of a four-part series summarizing recent research findings in the area of selected truck geometric features. One of the critical large truck research areas is safety impacts of trucks--including geometric and operational issues, vehicle stability and handling, and accident rates. A number of research studies have been completed in the following areas: truck climbing lanes, grade severity rating systems for trucks, interchange ramp geometry design, and the operation of larger trucks on roads with restrictive geometry. This report summarizes the findings of the research on the operation of larger trucks on roads with restrictive geometry. For specific details on the research, the reader should consult the research reports referenced in the summary report.

Sufficient copies of this report are being distributed to provide one copy to each Regional office, Division office, and State highway agency. Direct distribution is being made to the Division offices. Additional copies are available from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.



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Janet A. Coleman (HRT-20), Contracting Officer's Technical Representative. This summary report was based on the following study: "The Operation of Larger Trucks on Roads With Restrictive Geometry Volume I: Final Report: FHWA/RD-86/157."

16. Abstract

Changes in the 1982 Surface Transportation Assistance Act (STAA) allowing wider and longer trucks on the National Network have raised questions about highway safety. The Federal Highway Administration sponsored a study by Goodell-Grivas, Inc. that investigated the performance of trucks of various lengths and widths on roads with restrictive geometry. The report summarized here highlights the main findings of that study for transportation officials and practicing engineers.

Field studies at both urban and rural sites indicated that truck drivers compensate for the reduced operating capabilities of larger trucks. Despite driver skill, however, trucks on urban roads encroached into other lanes on streets with widths less than 12 ft. Intersections with less than 60-ft corner radii caused some problems for most truck types, especially those wider than 102 in. Prohibiting large trucks from turning onto narrow urban streets, employing turn movement templates in roadway design, adjusting signal and/or left-turn lane lengths, and manufacturing 48-ft semitrailers with axles forward only may minimize these and other problems.

On rural roads, lanes wider than 12 or 13 ft allowed oncoming vehicles to move further right to avoid trucks, and shoulders wider than 4 ft allowed oncoming vehicles a greater margin of safety. At sharp curves (7 to 15 degrees), opposing vehicles slowed down significantly and made other undesirable changes to pass large trucks. Consideration should be given to reducing the sharpness of curves greater than 7 degrees and to allowing large trucks only on two-lane rural roads with lanes at least 12 ft wide and shoulders greater than 4 ft.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

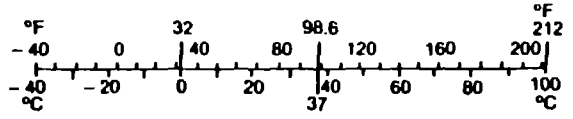
Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
AREA				
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
VOLUME				
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
AREA				
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
VOLUME				
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
TEMPERATURE (exact)				
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

These factors conform to the requirement of FHWA Order 5190.1A.

(Revised April 1989)

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CHAPTER I
INTRODUCTION

Changes in the Law

The 1982 Surface Transportation Assistance Act (STAA) mandates acceptance of wider and longer trucks on the National Network, the system of interstate and other designated Federal-aid highways. Trucks may be up to 102 in (259 cm) wide or 108 in (274 cm) wide in Hawaii, compared to the old maximum of 96 in (240 cm). In the past, the maximum trailer length in some States was less than 48 ft (15 m). Now, 48-ft (15 m) semitrailers and tractors with two 28-ft (8.5 m) semitrailers are allowed everywhere, and some States allow semitrailers up to 59.5 ft (18.1 m).

The STAA allows these larger trucks to operate only on highways that have been deemed adequate to accommodate these trucks. Nevertheless, the changes have raised questions about highway safety, especially on primary and secondary roads. Restrictive geometry on these roads, such as narrow, winding rural roads or sharp turns at urban intersections, could reduce the safety of large-truck operations.

Problems with Large Trucks

To investigate these concerns, the Federal Highway Administration (FHWA) sponsored a study by Goodell-Grivas, Inc., to investigate truck performance in urban and rural settings using various truck configurations: trailers of various lengths (40 ft [12 m], 45 ft [14 m], and 48 ft [15 m] with axles forward and back) and various widths (96 in [240 cm] and 102 in [259 cm]); and twin trailers each 28 ft (8.5 m) long.[1] The findings in the study reflect data collected under nearly ideal conditions. Many of the data came from tests with two highly experienced drivers knowledgeable about the purpose of the tests, operating trucks in good condition, on known routes, with dry pavement, during daylight hours. Furthermore, the test sites selected were

only somewhat restrictive. Even under nearly ideal conditions, however, the study found the following problems related to large trucks:

- Encroachment over edgelines and into other lanes, especially on curves.
- Difficulty negotiating turns at intersections (see figure 1).
- Delays to traffic flow.
- Abrupt speed drops and shifts in lateral placement by oncoming vehicles.

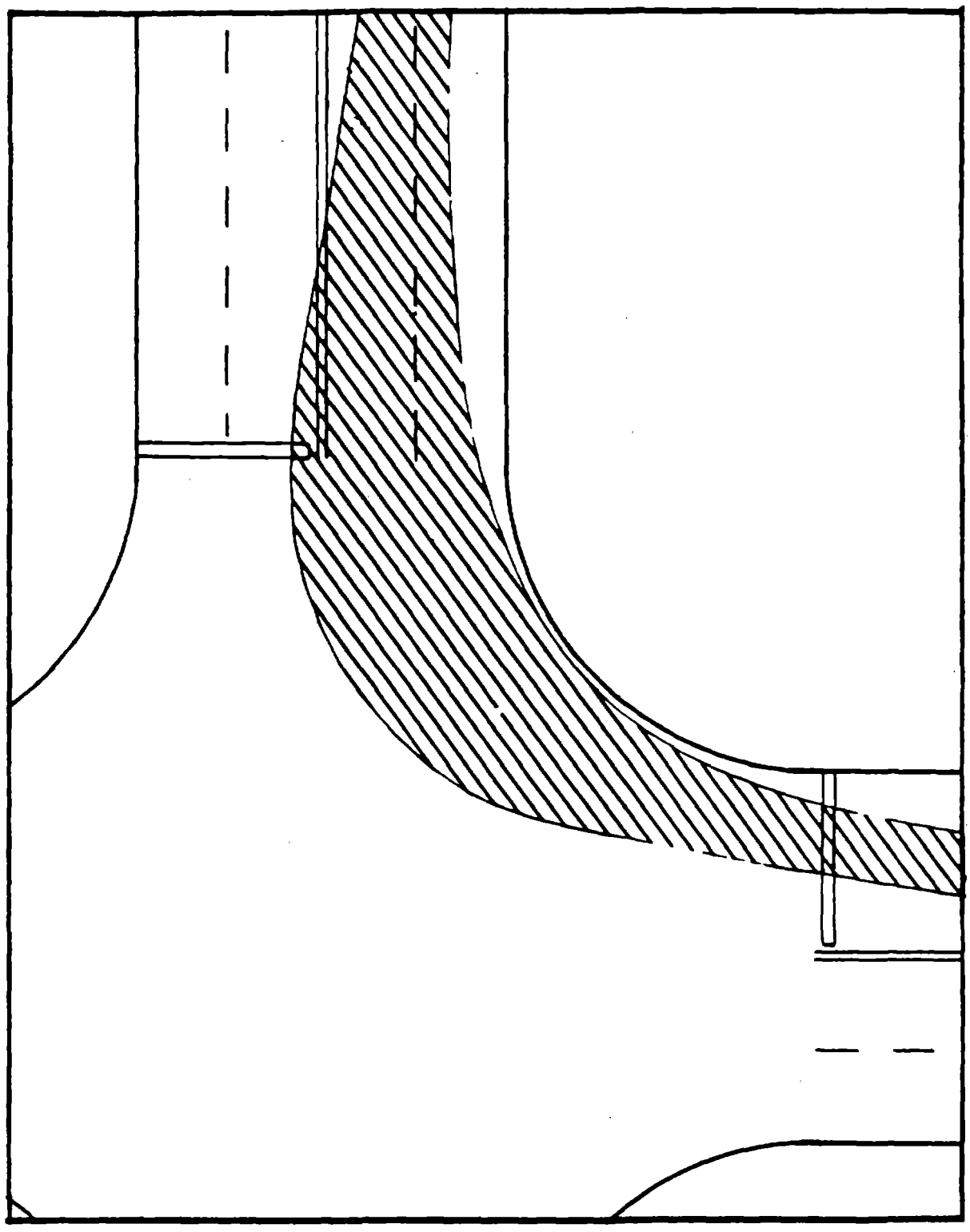


Figure 1. Illustration of lane encroachment by truck turning at intersection, shown with template.[1]

CHAPTER II
STUDY DESIGN

Computer-Based Analysis

To identify potential hazards and traffic flow problems when longer and wider trucks are operated on roads with restrictive geometry, researchers used a software package, "Off-Tracking Model and Computer Simulation," developed by FHWA and the University of Michigan Transportation Research Institute. This program plots the off-tracking paths of different types of trucks passing through curves meeting specified criteria. The plots allowed researchers to determine the maximum off-tracking distance and the amount of encroachment on other lanes.

Based on the results generated by the off-tracking model and a review of relevant literature, researchers identified two situations involving large trucks that may pose safety and traffic flow problems:

- Urban intersections with relatively short radii (i.e., less than 60 ft or 18 m).

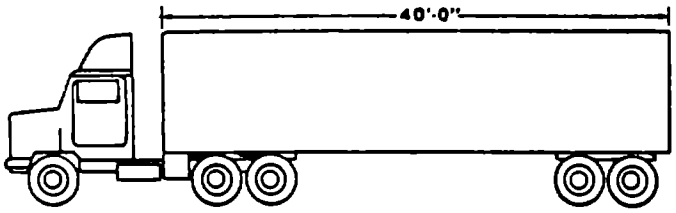
- Winding, two-lane rural roads with narrow lane widths (i.e., less than 12 ft or 3.7 m).

Field Studies

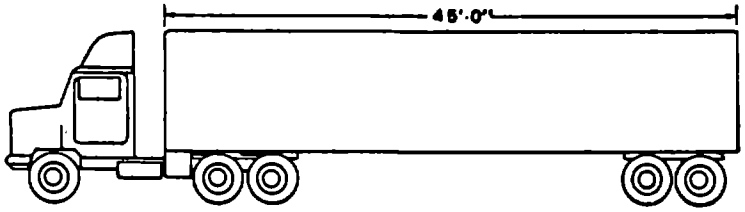
Analyses using field observations and measurements were then performed to evaluate the performance of the truck types shown in figure 2.

At six urban intersections in New Jersey and California, observers recorded clearance times, truck-vehicle conflicts, and encroachments by the truck into adjacent lanes, over the centerline, and over the curb, for a total of nearly 900 trucks turning left or right. Observations were made during

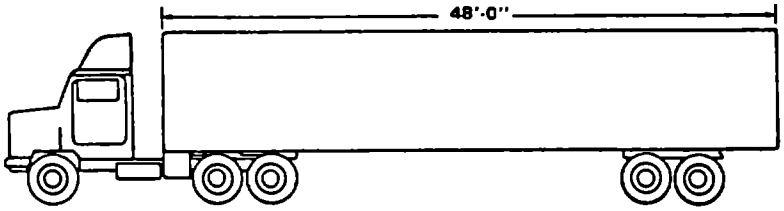
Tractor Truck with 40-ft long semitrailer



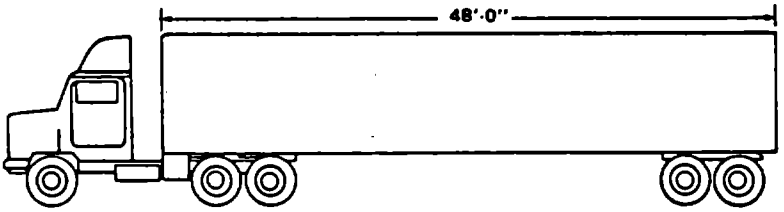
Tractor Truck with 45-ft long semitrailer



Tractor Truck with 48-ft long semitrailer with axles forward



Tractor Truck with 48-ft long semitrailer with axles back



Double with twin 28-ft long trailers

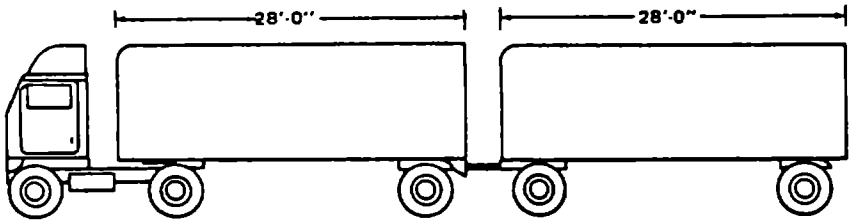


Figure 2. Trucks analyzed in field studies.

daylight hours with dry pavement conditions. In addition, paid professional drivers drove tractor control trucks at two sites to increase the sample. The control trucks included a range of configurations: a 40-ft (12 m) long, 96-in (240 cm) wide semitrailer; a 48-ft (15 m) long, 102-in (259 cm) wide semitrailer with axles back; and a 28-ft (8.5 m) long, 102-in (259 cm) wide twin trailers. Over 250 observations of control trucks were made.

Observers recorded over 3,300 vehicles passing trucks from the opposing direction on selected two-lane rural roads in New Jersey and California during daylight hours under dry pavement conditions. Collection of the data involved a caravan of a lead automobile, a control truck, and a following automobile as illustrated in figures 3 and 4. Data collected included the lateral placement of the opposing vehicle with respect to the truck's rear tires and the changes in lateral placement and speed of the opposing vehicle as it approached the truck. The analysis considered lane width, shoulder width, and horizontal alignment.

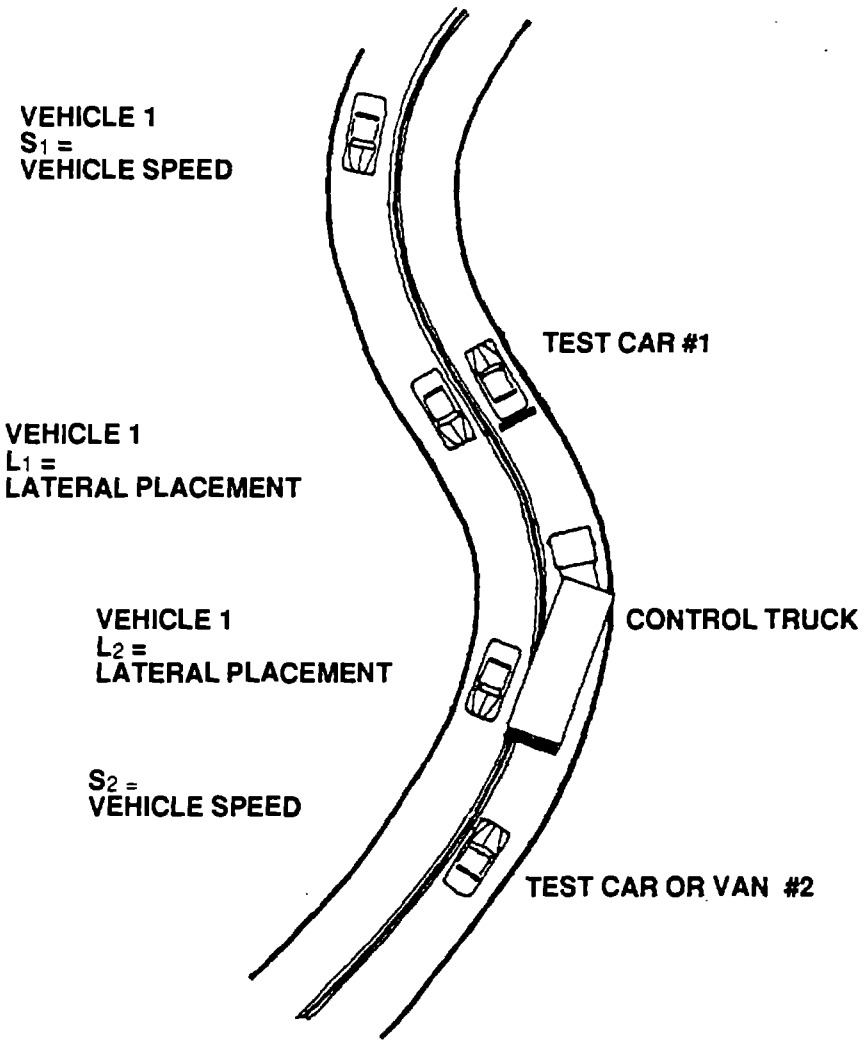


Figure 3. Overview of rural data collection.[1]

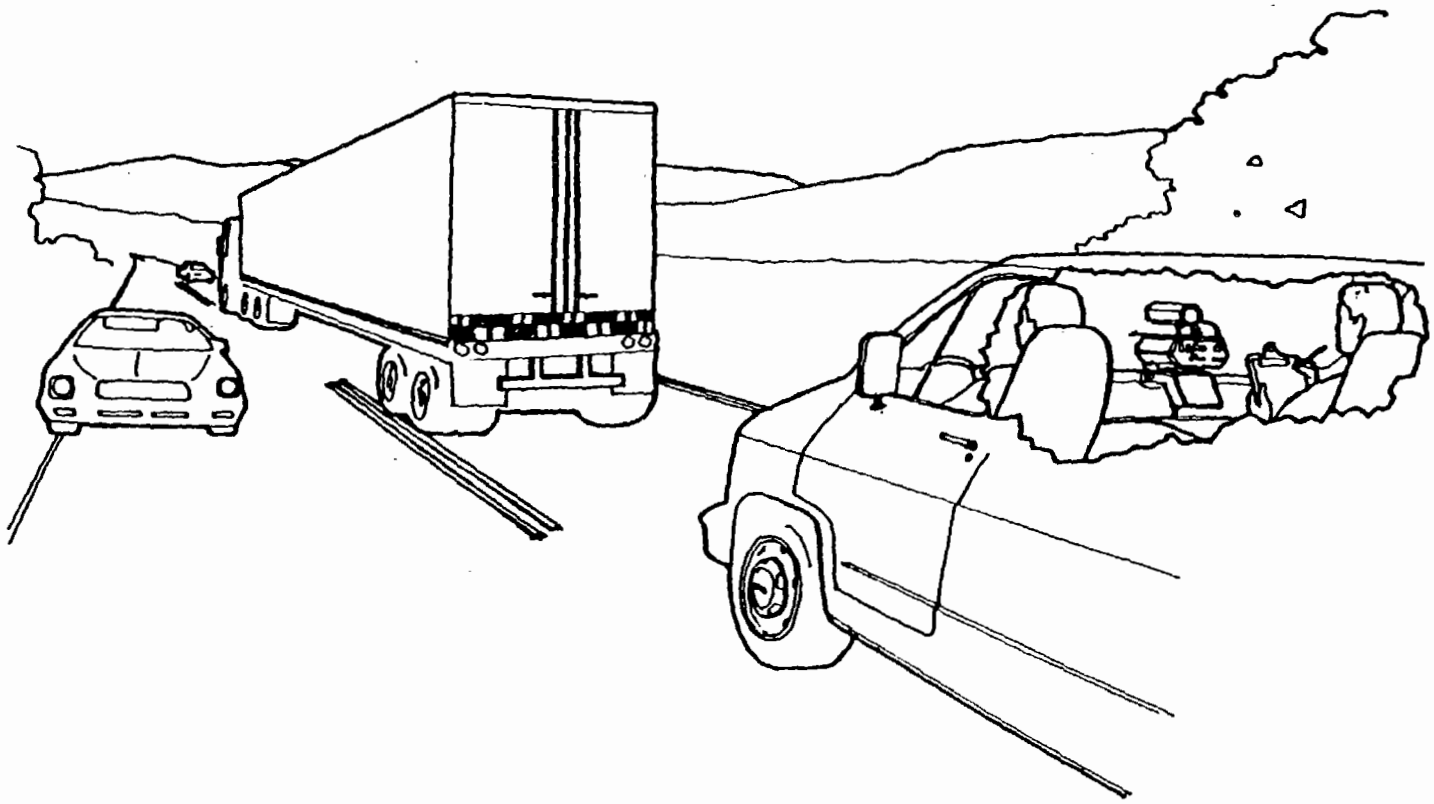


Figure 4. Illustration of data collection caravan.[1]

CHAPTER III
URBAN INTERSECTIONS

Findings

- This study confirmed the findings of earlier research that truck drivers compensate for the reduced operating capabilities of larger trucks. Driver experience and ability often outweigh the effect of restricted geometry on truck performance and safety.

- Where control trucks were observed, the 48-ft (15 m) semitrailer with axles back had significantly higher turning times and encroachment rates than the 40-ft (12 m) semitrailer. When these same trucks were observed in the traffic stream, however, no significant differences between the two truck types were found, most likely due to driver experience and ability.

- Good driving cannot compensate for all difficulties, however. At urban intersections, trucks encroached into other lanes on streets with narrow lane widths (i.e., less than 12 ft or 3.7 m).

- Intersections with less than a 60-ft (18 m) corner radius were found to cause some problems for most truck types, especially wider ones (e.g., 102 in or 259 cm).

- The 48-ft (15 m) semitrailer with axles back had significantly higher encroachment rates than the 48-ft (15 m) semitrailer with axles forward, particularly when making right turns. The 28-ft (8.5 m) twin trailers had longer turning times than the 40-ft (12 m) semitrailer and 45-ft (14 m) semitrailer at several of the intersection sites. However, no differences in encroachment rates or conflict rates were found between 28-ft (8.5 m) twin trailers compared to the 40-ft (12 m) semitrailers or 45-ft (14 m) semitrailers.

Implications for Design and Implementation

- Design engineers can take steps to minimize these problems, but the countermeasures may create other problems. Providing larger corner radii would more safely accommodate right turns, but would create longer crossing times for pedestrians and possibly longer clearance times. Moving stop bars back would more safely accommodate trucks turning left, but it would not prevent drivers from crossing over the bars to stop closer to the intersection. Moreover, it would require longer clearance times.

- Large trucks turning at intersections require multi-lane roadways with large curve radii. Consideration should, therefore, be given to prohibiting these trucks from turning onto narrower streets in urban areas.

- Highway designers and traffic engineers could more easily accommodate these vehicles if they used turn movement templates.

- The 48-ft (15 m) semitrailer should be manufactured only with axles forward.

- Although double trailers take a relatively long time to turn at urban intersections, it may not be necessary to base the timing of traffic signals on larger trucks. The probability that a large truck will begin to travel through an intersection just as the light turns yellow is small. Adjusting the signals to suit the larger trucks would lengthen the clearance interval and thereby penalize other traffic.

CHAPTER IV
RURAL ROADS

Findings

- As in the case of urban intersections, driver skill and caution on rural roads are very important to truck operation. One 1982 field study reported that drivers compensate for wider trucks when passing them by increasing their headways.[2] The study found no increases in shoulder encroachments due to drivers moving out to look around the truck and no acceptances of small gaps. In the more recent Goodell-Grivas study, drivers of control trucks compensated for the tendency of the 48-ft (15 m) semitrailers with axles back to off-track, for example, by driving further from the centerline.

- Rural roadway geometry that affects the safety of large truck maneuvers includes lane width, shoulder width, and horizontal alignment. Wider (12- or 13-ft [3.7 or 4.0 m]) lanes allow oncoming vehicles to move further right to avoid trucks, and fewer vehicles cross the edgeline. Wider (4-ft [1 m] or greater) shoulders generally allow oncoming vehicles a greater margin of safety.

- Where curves were present, especially sharp curves, the study found oncoming traffic generally making more undesirable maneuvers (shifts in lateral placement) and greater changes in speed. Gradual curves had little effect on the position of the vehicle in the lane, but sharp curves (7 to 15 degrees) caused opposing vehicles to slow down significantly when passing large trucks. The direction of the curve did not have a significant effect on speed or lateral placement.

- Oncoming motorists exhibited more extreme changes in speed and lateral placement when passing the 28-ft (8.5 m) twin trailer and the 48-ft (15 m) semitrailer than when passing other truck types. The greatest changes in speed were caused by the 28-ft (8.5 m) twin trailer (24 mi/h or 39 km/h) and the 48-ft (15 m) semitrailer with axles back (21 mi/h or 34 km/h).

Design Implications

- Reducing the sharpness of horizontal curves greater than 7 degrees would alleviate some problems associated with large trucks. If this were done on a large scale, the cost would be substantial.

- The Tandem Truck Safety Act passed in 1984 allows larger trucks on roads with lanes narrower than 12 ft (3.7 m), provided that these routes can otherwise safely accommodate the larger trucks. This study suggests that consideration be given to allowing such trucks only on two-lane rural roads whose lanes are at least 12 ft (3.7 m) wide and whose shoulders are more than 4 ft (1 m) wide.

CHAPTER V
CONCLUSIONS

More information is needed before appropriate regulations can be formulated. Still to be determined are the effect of large truck operations when less-than-ideal conditions or certain combinations of geometric conditions are present. Other issues that should be addressed include same direction passing of wider and longer trucks on narrow, multi-lane highways, the effect on operations and safety of longer semitrailers (i.e. 53- and 55-ft [16 m and 17 m]) allowed by some States, and the effect of the 102-in (259 cm) truck width versus the 96-in (240 cm) wide truck.

Nevertheless, larger trucks have the potential to cause accidents. Although many of the hazards can be avoided or minimized by driver skill, possible problems range from traffic congestion and property damage to highway accidents and casualties. The problems found in the study occurred even under ideal conditions--during daylight, in dry weather, at only moderately restrictive sites, and, often, with experienced drivers who were familiar with the sites.

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(2) E. L. Sequin, K. W. Crowley, P. C. Harrison, Jr., and K. Perchonok, The Effects of Truck Size on Driver Behavior, FHWA/RD-81/170, Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1982.