Operational and Safety Problems of Trucks in No-Passing Zones on Two-Lane Rural Highways

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ABSTRACT

Two-lane rural roads in mountainous terrain with large truck volumes pose a real problem for the motorist. Extended roadway sections with severe sight restrictions and inadequate passing opportunities can make overtaking and passing a slow-moving vehicle extremely difficult. Further, the ability of large trucks to maintain speed decreases drastically over lengthy gradient sections. The inability of motorists to pass slower moving vehicles on these highways causes reductions in throughput and increases in delay, conflict, and hazard. Passing maneuvers on two-lane highways require a series of complex information-processing and decision skills, which makes these maneuvers one of the most demanding and risky operations performed by the motorist. Trucks require considerably longer distances than do automobiles to pass on two-lane rural roads. Even with their greater eye heights, truckers are placed at a disadvantage under the current system of marking no-passing barriers. The purpose of this paper is to discuss the interactive effects of geometric design elements and traffic composition (with particular emphasis on truck traffic) on traffic accidents and operational aspects on two-lane highways in mountains. Included in this analysis are passing-related accidents, human factors elements, and the impact of passing lanes and four-lane sections. Conclusions and recommendations, which draw on the findings of various research studies on the topics of truck traffic and no-passing zones, are also presented.

There are more than 3 million miles of two-lane rural highways in the United States that comprise about 97 percent of the total rural system and 80 percent of all U.S. roadways (1). These highways have about 3.4 million intersections and more than 100,000 railroad crossings. Further, more than two-thirds of the two-lane mileage is in mountainous or rolling terrain characterized by steep grades and sharp curves. Geometric design standards vary considerably within this rural system, and the use of traffic control devices is sparse. An estimated 68 percent of rural travel and 30 percent of all travel occur on the rural two-lane system. Many of these roadways experience significant increases in traffic on weekends and during peak vacation periods.

It has become increasingly evident that there are some serious safety and operational problems on rural two-lane highways resulting from their age, geometric standards, and traffic composition. About 80 to 90 percent of two-lane accidents occur in the rural environment and certain accident categories are prevalent among them, including passing maneuver, run-off-the-road, and railroad crossing accidents.

The recent growth in recreational vehicle and truck traffic on these roads has led to serious operational problems. The limited ability of these large vehicles to maintain speed on long grades causes following motorists to initiate passing maneuvers, often in the most hazardous situations. Trucks and recreational vehicles are also likely to encroach on the opposing lane because of their widths and dynamic characteristics. The terrain, pavement widths, and traffic characteristics of the rural two-lane system frequently limit passing opportunities and make this maneuver difficult and hazardous. These operational problems manifest themselves in reduced levels of service, delay, and increases in passing attempts, as well as in aborted passes and greater driver frustration.

Possible solutions to this problem include the addition of lanes, vehicle turnouts, and truck climbing lanes and the installation of signal controls; however, factors such as limited funds, the nature of the terrain, and potential environmental impacts often restrict the use of these solutions. Alternate passing zones on three-lane roads, or short four-lane sections with appropriate traffic control devices, may also represent feasible solutions. Unfortunately, little is known about the relative characteristics and effectiveness of these solutions.

SURFACE TRANSPORTATION ASSISTANCE ACT

The passage of the Surface Transportation Assistance Act (STAA) of 1982 makes it possible for wider, longer, and heavier trucks to operate on selected Interstate and other federally aided highway systems. The increased limits specified by this new act are as follows:

- Length: Truck unit 65 ft long, twin-trailer combinations with 28-ft-long trailers, semitrailer combinations with 48-ft-long trailers.
- Width: Maximum width of 102 in.
- Weight: Maximum single axle weight of 20,000 lb, maximum tandem axle weight of 34,000 lb, maximum gross weight of 80,000 lb.

Before 1982 the federal government, as well as individual states, placed size and weight restric-

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tions on trucks operating on Interstate and state-maintained highways. A complete description of the pre-STAA limit ranges is presented in NCHRP Report 198 (2). The 1982 act has raised questions about possible hazards associated with the operation of larger, heavier trucks on roadways with inadequate geometrics. Concurrently, there is an increased need to identify roadways that can support these larger trucks. The 1982 act not only increased the allowable weights and size of vehicles but also designated a National Highway Network consisting of Interstate and other primary highways on which these longer and wider vehicles could operate. A set of criteria has been defined for designating such a national network. Among the criteria are included two factors that have raised some questions in the minds of traffic safety experts:

1. The route has adequate geometrics to support safe operations, considering sight distance, severity and length of grades, pavement width, horizontal curvature, shoulder width, bridge clearances and load limits, traffic volumes and vehicle mix, and intersection geometry.
2. The route consists of lanes designed to be a width of 12 ft or more.

The controversial part of the act is the lack of exact definition of geometric adequacy, and the question of inclusion of highways with 12-ft or wider lanes over much but not all of the length. The outcome of these unresolved issues and other clarification in the near future may dictate whether large trucks will operate on roadways with restrictive geometrics. Specifically, for a given stretch of highway, "What should be the maximum allowable percentage of no-passing barriers that can be considered safe for such heavy truck operation?" Similarly, "How should a two-lane section be regarded, if, over a given stretch, a majority (but not all) of the facility has 12-ft pavements?" The passage of the act has raised new questions about truck safety and operational problems, an area that has been of great concern to many highway engineers for a long time.

PASSING-RELATED ACCIDENTS

Overtaking and passing maneuvers require motorists to make complex decisions regarding roadway, environmental, and vehicular characteristics. The average motorist is considered a poor judge of speed and distance and has difficulty performing the four basic tasks required in a typical passing situation (3). It has also been estimated that passing-related accidents constitute about 3 to 4 percent of the total number of accidents reported in the United States (4). Furthermore, nationally, approximately 1,500 fatalities may be related annually to passing maneuvers. Moreover, the incidence of passing-related accidents is much greater on two-lane roads. For example a 1972 study conducted by Kemper et al. (5) found that approximately 20 to 23 percent of total reported accidents in Virginia were passing related. Also, between 40 and 50 percent of all passing-related accidents generally occurred at intersections and driveways (4,5). Further, many of these accidents at intersections and driveways were the result of a motorist attempting to pass another vehicle making a left turn at an intersection. It should be noted here that none of these studies mentioned any specific analysis with regard to truck traffic.

A recent FHWA-sponsored study conducted by Parker et al. (6) attempted to assess the nature and magnitude of passing-accident problems at rural intersections on two-lane highways. As a part of this study, the authors collected accident, traffic, and geometric data from 1,028 rural intersections in Michigan in an effort to identify and analyze specific passing-accident problems. On the basis of analysis of these data and a detailed review of the accident reports, roadway deficiencies and other causal factors were identified. The feasibility of using geometric design treatments to reduce the number and severity of intersection-related passing accidents was examined.

The major finding of the study is that a passing accident is a rare event at a rural intersection. Only 20 percent of the 1,028 intersections sampled experienced any passing accident during a 3-year period. Fewer than 8 percent of the intersection accidents were found to involve passing maneuvers. However, in the context of passing accidents only, those that occurred at intersections and driveways comprised a major proportion. Approximately 58 percent of the passing accidents involved intersections and driveways. Although this high percentage of passing-related intersection accidents might suggest a major safety problem, an analysis of the distribution of passing accidents by intersection revealed that fewer than 1 percent of the 1,028 intersections had an average of one or more passing accidents per year. A rural intersection with two or more passing accidents during the 3-year period was a rarity. Thus, to summarize this finding, passing-related accidents comprise a small fraction of all intersection accidents. However, of all passing-related accidents, those that occurred at or near an intersection comprise a major proportion. The findings of Parker et al. generally agree with those of an earlier study that also concluded that a high percentage of passing accidents occurred at intersections and driveways (1).

Another important finding of the study by Parker et al. is that the severity of injuries in passing-related intersection accidents is significantly less than that in other types of rural intersection accidents. This result is because a majority of passing-related accidents at intersections are the result of collisions of vehicles traveling in the same direction caused by a motorist attempting to pass another motorist making a left turn. The authors, however, note that "the results of this study should not be construed to imply that there are no safety problems at intersections." The authors conclude that some specific accident problems occur in sufficient numbers at specific sites to economically justify the implementation of geometric design and traffic engineering treatments.

An earlier FHWA study, conducted by the Texas Transportation Institute (7), used passing-accident data from three states, California, Kentucky, and Texas, for the purpose of developing improved criteria and guidelines for establishing no-passing zones. The findings of this study generally correspond with those of the study by Parker et al. in that a high percentage of passing accidents was found to occur at intersections and driveways; again, the severity of these accidents was much less than that of those at nonintersections. A second FHWA study conducted by the Texas Transport Institute used accident data from North Carolina, Texas, and Utah to identify passing-related problems (4). The study concluded that passing accidents are rare events for any special highway condition, including rural intersections. However, the study also reconfirmed the earlier finding that a high percentage of passing accidents occurs at intersections and driveways. In none of these studies was the phenomenon of truck accidents studied in any depth, nor was any conclusion reached regarding any possible relationship among passing accidents and geometric and other roadway or traffic factors.

TRUCK ACCIDENTS

Numerous studies of truck accidents have been conducted during the last 10 years. Unfortunately, there does not appear to be a consensus among researchers as to whether large trucks have a higher or a lower accident rate compared with other vehicles. One of the earlier studies conducted by the author of this paper in 1977 used the 7-year (1970-1977) Michigan accident data base to assess the relative magnitude of truck accidents compared with those involving all other vehicles (8). The primary finding of the study was that the relative involvement of large trucks in fatal accidents was much greater than that of all other vehicles. The author, in a later study, used the concept of "opportunity for interaction" in estimating exposure and used the same Michigan accident data base to demonstrate the approach (9). This second study reconfirmed the earlier finding that large trucks are involved in a high percentage of fatal accidents.

A comprehensive study of large truck safety was sponsored by NHTSA and conducted by Wagner-McGee & Associates with the objective of synthesizing all significant information relative to large trucks and large-truck accident countermeasures (10). Nearly 200 references identified from previous studies were reviewed in this project. This study found that single-vehicle truck accidents account for 32 to 50 percent of fatal truck accidents. Run-off-the-road and overturning were the two most frequent dynamics for single-vehicle truck accidents. In multiple-vehicle accidents, trucks are more likely to be the striking vehicle, and angle accidents produce the most fatalities. Accidents involving trucks hauling hazardous cargo are infrequent.

Table 1 gives the results of three studies that have developed accident rates for trucks and for all other vehicles, including those developed by the author of this paper in 1977. The obvious disparity among results of these studies can be attributed to differences in data base and criteria for measuring exposure. In none of the studies was any attempt made to categorize accident data by type of facility. A later study by Vallette et al. (11) developed accident rates for large trucks and nontrucks for four types of roadways in California and Michigan. The data in Table 2, reproduced from the Vallette study, indicate that large-truck accident rates were lower than those for nontrucks in three of the four roadway types. It is clear from Tables 1 and 2 that the basic issue of whether trucks experience more or fewer accidents per unit exposure compared with all other vehicles has not been satisfactorily resolved. The Vallette study, however, had a few other important findings:

TABLE 1 Accident Rates for Trucks and Other Vehicles

	Accidents per Million Vehicle-Miles			
Source	Straight Trucks	Tractor-trailer Combinations	All Trucks	Other Vehicles
Six states, 1976-1977[a]			2.35	3.12
Michigan, 1977[b]	37.2	4.98	7.47[c]	5.42
21 toll expressways 1976-1978	1.95[d]	1.79		1.13

[a]From Vallette et al. (11).
[b]From Khasnabis and Atabak (8).
[c]Includes pickups, panel trucks, and vans.
[d]Identified as light trucks.

TABLE 2 Accident Rates of Total Traffic, Nontrucks, and Large Trucks by Roadway Type (11)

	Accidents per Million Vehicle-Miles			
	Roadway Type			
Vehicle Type	Rural Freeway	Rural Nonfreeway	Urban Freeway	Urban Nonfreeway
Total traffic	0.90	2.61	3.59	4.92
Nontrucks	0.87	2.69	3.65	5.07
Total large trucks	1.12	2.34	2.73	3.02

1. Empty trucks have substantially higher accident rates than do loaded vehicles.
2. Otherwise, within the range of vehicle sizes observed, there were no major differences in accident rates or severity in the heavier truck weights, lengths, and widths.

Since 1975 the National Highway Traffic Safety Administration has initiated a program of collecting comprehensive data on all accidents nationwide. This data base, commonly referred to as the Fatal Accident Reporting System (FARS), was used by O'Day et al. (12) in 1980 to analyze the first 5 years of accident experience of combination trucks (tractor-trailers). The O'Day study generally shows that a majority of truck accidents occur on U.S. or state routes and that freeways are safer than nonfreeways.

GEOMETRIC FEATURES

Perhaps more important than the type of road is the specific location on the various road types where truck accidents are prevalent. An effort to identify specific geometric features by the Wagner-McGee study led to the general conclusion that particularly hazardous locations for trucks are interchanges and intersections, with off-ramps being more hazardous than on-ramps. For example, a data base containing approximately 34,000 reports on truck accidents prepared in 1978 for the Bureau of Motor Carrier Safety (BMCS) by various motor carriers shows a 53:47 split between off-ramp and on-ramp accidents (13). When the BMCS accidents are divided between collision and noncollision, there are, however, more collision accidents at on-ramps (likely due to merging) and more noncollision accidents at off-ramps (likely due to overturning on sharp curves). The FARS data file provides even further evidence of the off-ramp hazard reported by O'Day et al. (12).

The study by O'Day et al., using the 5-year FARS data, also indicated that approximately 25 percent of fatal truck accidents are intersection related and 4.7 percent occur near a driveway. A similar finding is reported by Lohman et al. (14) from an analysis of truck accidents in North Carolina in 1973, which showed that nearly 33 percent of large-truck accidents occur at intersections and another 13.5 percent occur at driveways and alley intersections.

The question of truck operation and safety on steep grades and sharp curves has been a topic of research for many years. The scope of this paper does not allow any elaborate discussion of this topic, other than to mention that large trucks have special safety problems on vertical grades. On an upgrade, they are likely to be struck by overtaking vehicles, and on a downgrade they may strike slower moving vehicles. O'Day et al. report that 30 percent of fatal truck accidents occur on grades, and that gradient sections generally experience higher levels of fatal truck accidents than do nongradient sections. Among recent studies that have addressed the question of truck operation on grades are the works of Glennon (15), Walton and Lee (16), Humphreys (17), and Polus et al. (18).

Sharp curves are considered hazardous for vehicles, particularly for trucks. Past studies by Vallette et al. and others, using the FARS data, generally attest to this hypothesis, although the analysis of O'Day et al. indicates that, compared with straight sections, curved sections showed a slightly lower accident rate. Obviously, more information is needed before generalized conclusions can be drawn.

Two recent research studies conducted by Chira-Chavala et al. (19,20) at the University of Michigan deal with the topic of truck accidents. In their 1984 study, the authors investigated the severity of accidents involving large trucks and combination vehicles using the 1980 BMCS data. This study reports that on undivided rural roads collisions involving trucks can be severe under all conditions, particularly at night. Truck-car collisions on divided rural roads were found to be less serious than those on undivided rural roads. The second study attempted to investigate the degree of association between truck accidents and other influencing factors. The analysis indicates that most doubles and singles showed higher accident involvement rates than did straight trucks. In both of these studies, the authors reiterated their concern about the safety of undivided rural highways.

PASSING BEHAVIOR

A recent study by Sequin et al. (21) attempted to assess the effects of truck width on passing behavior on a two-lane rural road. This study is considered particularly pertinent in view of the 1982 STAA. The authors used as an experimental vehicle a tractor-trailer combination that was systematically varied in width from 96 to 114 in. by 6-in. increments. A summary of the data compiled in this study, with the truck as the "passed vehicle," is given in Table 3. The authors inferred from the results that there are no significant differences in passing time, distance, and speed with varying truck width. The authors also analyzed speed data of oncoming vehicles. These results showed greater variation among "oncomers" than among "overtakers" as a function of truck width.

As a further test to assess any possible "intimidation effect" due to truck width, the authors analyzed the "accepted gap size"--the sum of decision time, passing time, and time margin (Table 4). Contrary to common expectation, total gap size and time margin measures were found to be significantly lower for trucks of greater widths. However, the extent of driver uncertainty, as reflected by the amount of decision time, was found to be independent of truck width.

An analysis of the prepass and minimum headways demonstrated that following vehicles maintained greater separation when encountering wider trucks. This was due to the need for greater sight distance or to the intimidation effect. Regardless of the cause, the authors found that truck followers are definitely sensitive to truck width but found no evidence of increased hazard resulting from wider trucks. The authors also concluded that truck width is an intimidating factor in lateral placement of vehicles during passing.

Sequin et al. also analyzed the effects of increasing truck size on the speed and lateral placement of oncoming vehicles at or near a narrow bridge site in Nevada. No significant differences were noted in the speed behavior of nontrucks when interacting with oncoming trucks of increasing length. Similarly, no significant differences in lateral placement were found to occur during approach, bridge, or exit interactions involving longer trucks. In spite of the general reduction in lateral distance from the road edge, increased truck width was not shown to be a source of increased hazard in this regard.

Sequin et al. also studied the impact of increased truck length on driver behavior. Unfortunately, none of these analyses were related to passing maneuvers; more specifically, these analyses included driver behavior in freeway entrance merges

TABLE 3 Summary of Passing Time, Distance, and Speed Statistics by Truck Width

	Truck Width (in.)											
	96			102			108			114		
	X̄	σ	N	X̄	σ	N	X̄	σ	N	X̄	σ	N
Passing time (sec)	10.3	2.4	81	10.3	2.5	85	11.0	2.8	84	10.7	2.7	98
Passing distance (ft)	786.1	184.5	81	786.7	185.9	86	843.1	200.0	84	814.0	164.7	97
Passing speed (ft/sec)	76.7	8.1	81	76.6	6.3	85	76.8	5.6	84	77.1	7.8	97

TABLE 4 Summary in Seconds of Decision Time, Time Margin, and Accepted Gap Size Statistics by Truck Width *(21)*

	Truck Width (in.)							
	96		102		108		114	
	X̄	σ	X̄	σ	X̄	σ	X̄	σ
Decision time	7.3	8.1	5.6	7.6	6.3	6.5	8.1	9.5
Passing time	10.3	2.4	10.3	2.5	11.0	2.8	10.7	2.6
Time margin	29.9	18.1	24.6[a]	16.7	24.9[a]	14.5	24.8[a]	15.0
Accepted gap size	47.4	20.5	40.4[a]	18.6	38.3[a]	17.9	43.6	20.2

[a]Significant at or beyond p = 0.05 compared with 96-in. value.

and interactions of oncoming vehicles at narrow bridge sites. Although the authors noted increased traffic turbulence associated with longer trucks (such as forced lane changes, gore encroachments, and sudden braking), there was no basis for the argument that increased track lengths are associated with increased safety hazards.

There is some controversy about the adequacy of the procedure for determining passing zones, particularly when trucks are involved. A recent study by the FHWA (22), using information compiled by the Swedish Road Research Institute, concluded that truck-automobile passing zones should be at least 1.5 times as long as those for one automobile passing another. This observation is based on the assumption that passing distance is proportional to passing time. The Swedish study also concluded that passing zone markings based on automobiles passing trucks should be 1.25 to 2.0 times longer than those needed for one automobile to pass another. In the event of a truck passing a truck, the passing zone should be even longer. The increased distance can partly be attributed to the fact that an automobile driver passing a truck starts further back than he does when passing another automobile and thus requires longer decision distances. It thus appears that passing zones designed for automobiles are not adequate for trucks. Although trucks have a 17 to 27 percent sight distance advantage over automobiles on crest vertical curves, this does not fully compensate for the 50 percent greater truck passing distances. A more recent study by Gericke and Walton (23) essentially confirms the Swedish study results. The authors contend that if current pavement marking practice [as described in the Manual on Uniform Traffic Control Devices (MUTCD)] is maintained, an adverse safety impact may be expected.

The use of passing lanes and short four-lane sections has been suggested as a means of alleviating safety and operational problems on two-lane highways. A passing lane is defined as an added third lane that is placed to provide passing opportunities on a two-lane highway. A four-lane section on a two-lane highway is generally less than 3 mi long and is provided for the specific purpose of providing passing opportunities in both directions at the same location. A recent study by Harwood et al. (24) attempted an operational and safety evaluation of passing lanes and short four-lane sections to improve traffic services on two-lane highways. The authors used 5-year accident data collected at selected sites in 12 states for 66 passing lanes and 10 short four-lane sections. Some of the important conclusions of this study are discussed next.

Passing lanes and short four-lane sections are likely to provide significant operational benefits on two-lane highways. Both types of treatments significantly increase the passing rate in the direction of travel compared with a conventional two-lane highway. The percentage of vehicles platooned is reduced by nearly one-half in a passing lane. The percentage of vehicles platooned immediately downstream of a passing lane is even less than the upstream value. Further, the operational benefit of passing lanes can persist for several miles downstream from the treated section. On the question of highway safety, the study found that the installation of a passing lane does not increase accident rates and, indeed, probably reduces them. No unusual safety problems were found to be associated with either lane-addition or lane-drop transition areas. The rate of accident involvement for vehicles traveling in opposite directions was found to be the same or lower on passing-lane sections than on untreated two-lane highways, even for passing lanes where passing by vehicles moving in opposite directions is permitted. There was also no indication of any major safety problem in the lane-addition or lane-drop transition areas of passing lanes. No safety problems associated with vehicles making left turns from the treated direction of a passing lane were found.

A substantially lower accident rate was found for short four-lane sections than for comparable untreated two-lane highways. The authors, however, were not able to conduct any statistical significance tests on the addition of four-lane sections.

SIMULATION MODELS

Since the mid-1960s, computer simulation has been used extensively as an analytical tool in the field of traffic and transportation engineering. During the period 1969-1972 a computer simulation model was developed at the Civil Engineering Department of North Carolina State University (referred to as the NCSU model) to determine the effect of systematic alteration of no-passing zones (NPZs) on throughput traffic. The model was calibrated with traffic flow data from rural highways in North Carolina and then applied on a specific field site to evaluate traffic flow consequences of systematic reductions of no-passing barriers. The model was developed as an outgrowth of its predecessor developed at the Franklin Institute of Research Laboratory.

The major findings of this study have been reported in the literature, but for the most part these are somewhat irrelevant to the topic of this paper (25-27). However, during the initial model development process a series of sensitivity analyses, using the original computer simulation model (FIRL model), was conducted with the specific objective of evaluating the traffic operational impact of percentage NPZ, truck percentage, and input volume on speed, delay, and passing-related output. The model used for the sensitivity analysis was not calibrated with field data; however, the trends in the output data, as a result of changing the three input variables, are worth noting.

The input to the model consisted of a hypothetical 30,000-ft-long roadway on which five levels of no-passing barriers (imposed by horizontal or vertical sight restrictions singly or in combination), along with vertical grades, had already been established. Two types of trucks were specified: Type 1, a single-unit vehicle and Type 2, a heavy tractor-trailer combination. The distribution assigned to these two types was 43:57 and was taken from the AASHO policy manual, which reported the results of a nationwide survey of truck travel on rural roads in 1963.

The results of the sensitivity analysis for an input volume level of 800 vehicles per hour (vph) are presented in figures (25). The important features of these figures are as follows:

- Figure 1: An increase in the percentage of trucks shows a consistent decrease in mean speed for the 50 and 70 percent no-passing zone configuration.
- Figure 2: Increases in truck percentages generally produce an increase in the number of attempted passes per hour per mile.
- Figure 3: An increase in the no-passing zone percentage from 20 to 50 percent, or from 25 to 70 percent, reduces the number of completed passes per hour per mile approximately two- to sixfold. An increase in the percentage of trucks is accompanied by a substantial increase in the number of completed passes per hour per mile.
- Figure 4: The number of vehicles passed per hour per mile increases beyond the 50 percent no-

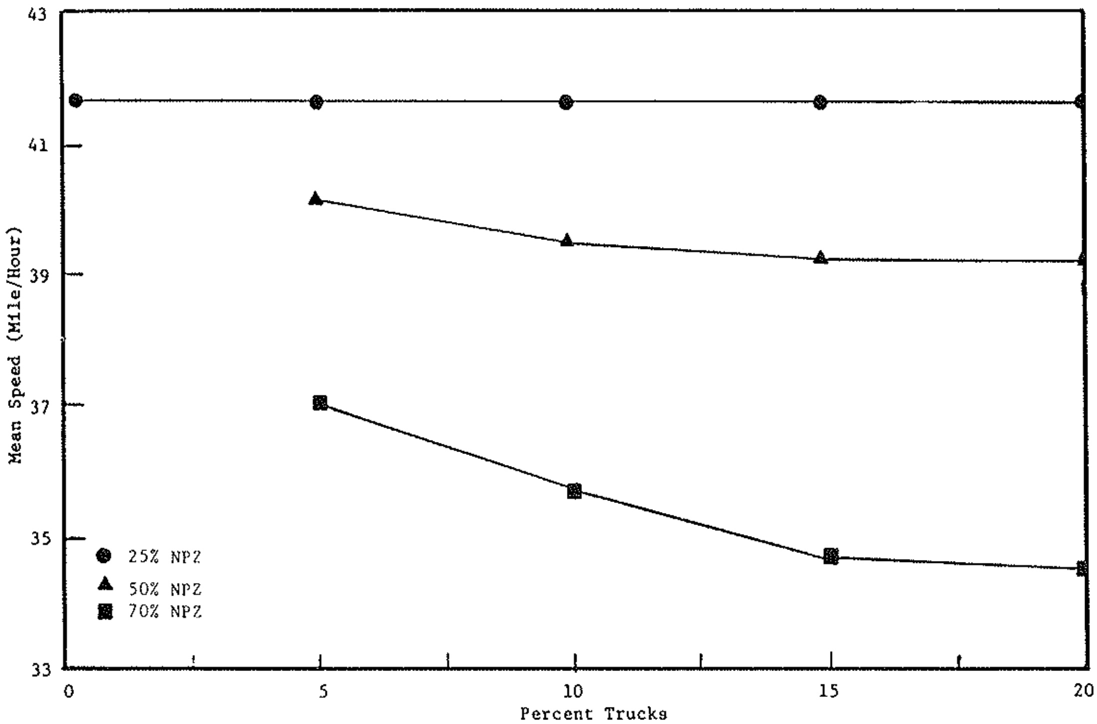

FIGURE 1 Mean speed for an input volume of 800 vph (two ways) versus percentage trucks *(25)*.

passing zone configuration when the percentage of trucks is 15 percent or greater. An increase in no-passing zones from 25 to 50 percent results in a decrease in the number of vehicles passed for all input volumes and for all truck percentages. For truck percentages greater than 10 percent, the 70 percent no-passing zone shows a greater number of vehicles passed than do the 25 or 50 percent zones.

• Figure 5: A reduction in the no-passing zone percentage causes a clear decrease in the delay per hour per mile for all truck percentages from 0 to 20 percent. The change in delay for increasing percentages of trucks is negligible for the 25 and 50 percent no-passing zone classifications. For 70 percent no-passing zones, there is a clear increase with increasing truck percentages.

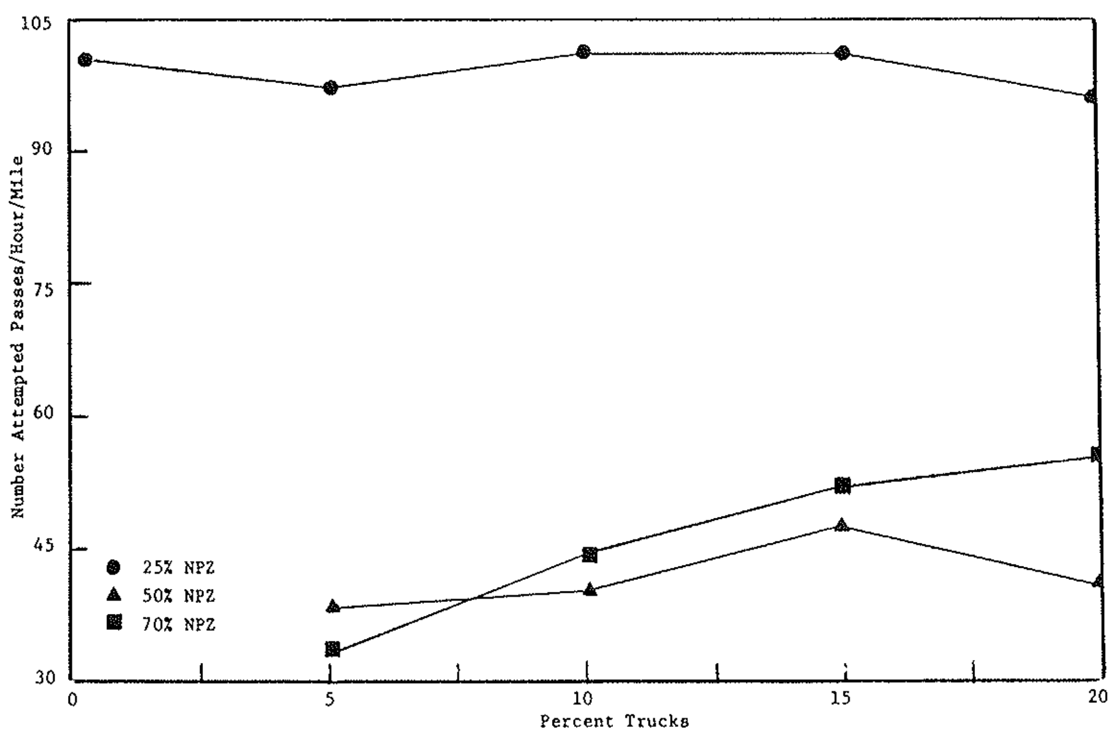

FIGURE 2 Number of attempted passes per hour per mile for an input volume of 800 vph (two ways) versus percentage trucks *(25)*.

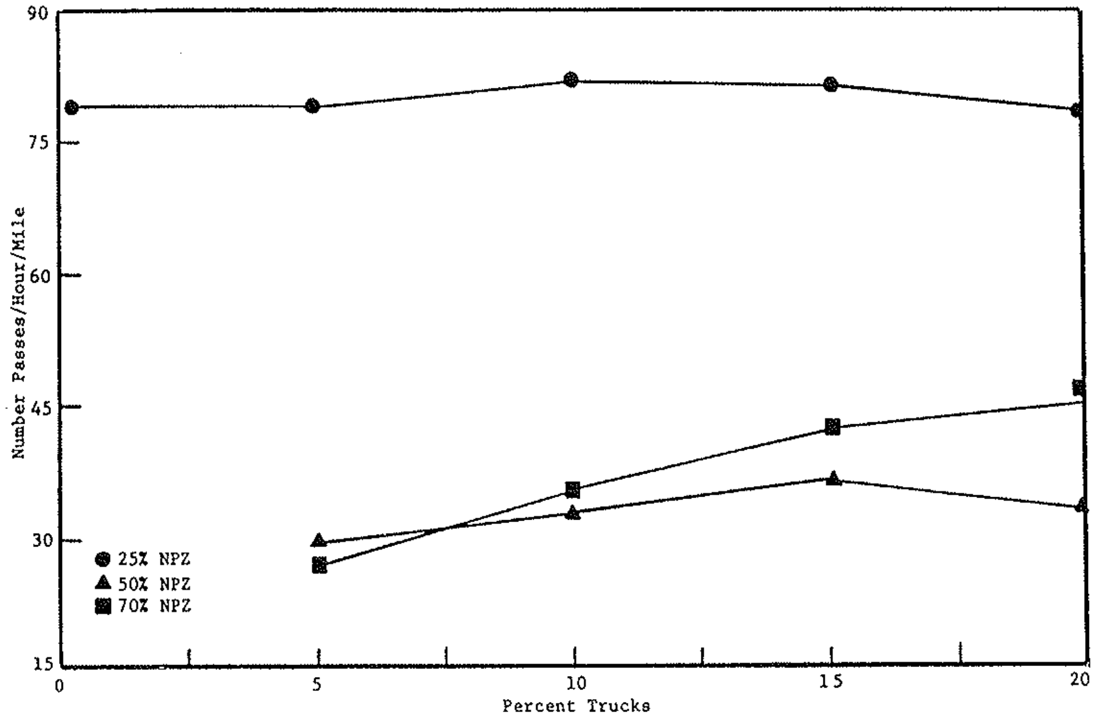

FIGURE 3 Number of passes per hour per mile for an input volume of 800 vph (two ways) versus percentage trucks *(25)*.

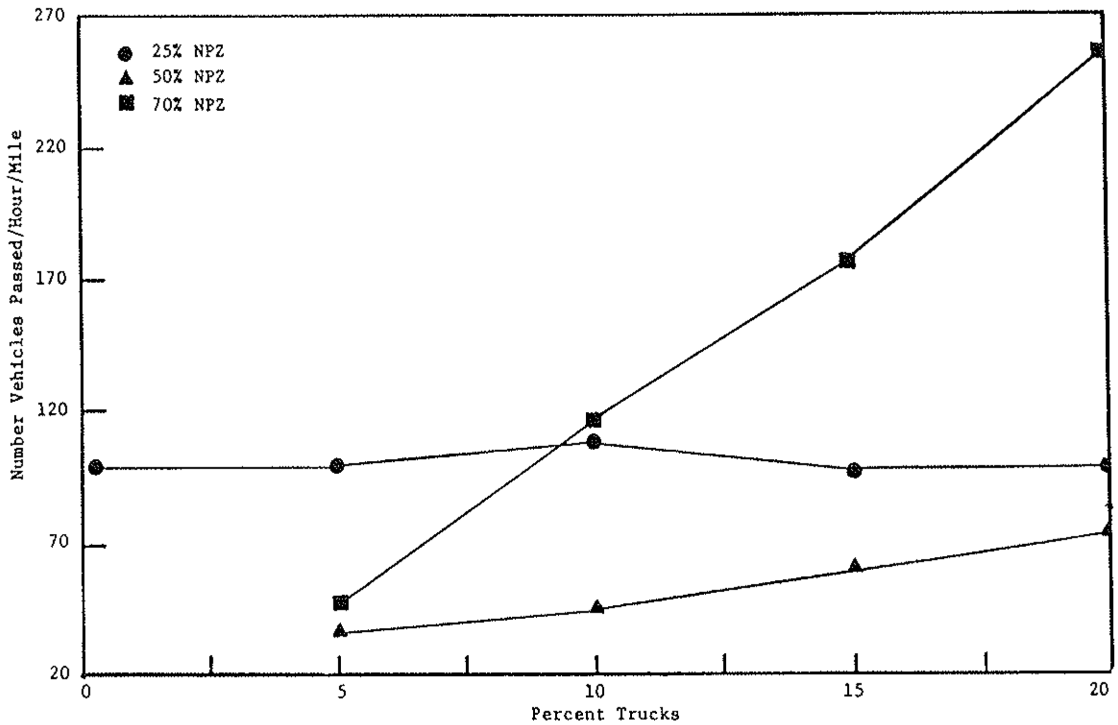

FIGURE 4 Number of vehicles passed per hour per mile for an input volume of 800 vph (two ways) versus percentage trucks *(25)*.

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this paper is to review the basic issues pertaining to truck safety and operational problems in no-passing zones on two-lane rural highways. As a result of this review and limited discussions with a number of researchers, the following conclusions are drawn:

1. Passing-related accidents are generally prevalent among the accident categories within the two-lane rural system of U.S. highways; however, these accidents comprise a small fraction of all accidents in the country.

2. Passing-related accidents comprise a small fraction of all rural intersection accidents. However, of all passing-related accidents, those that

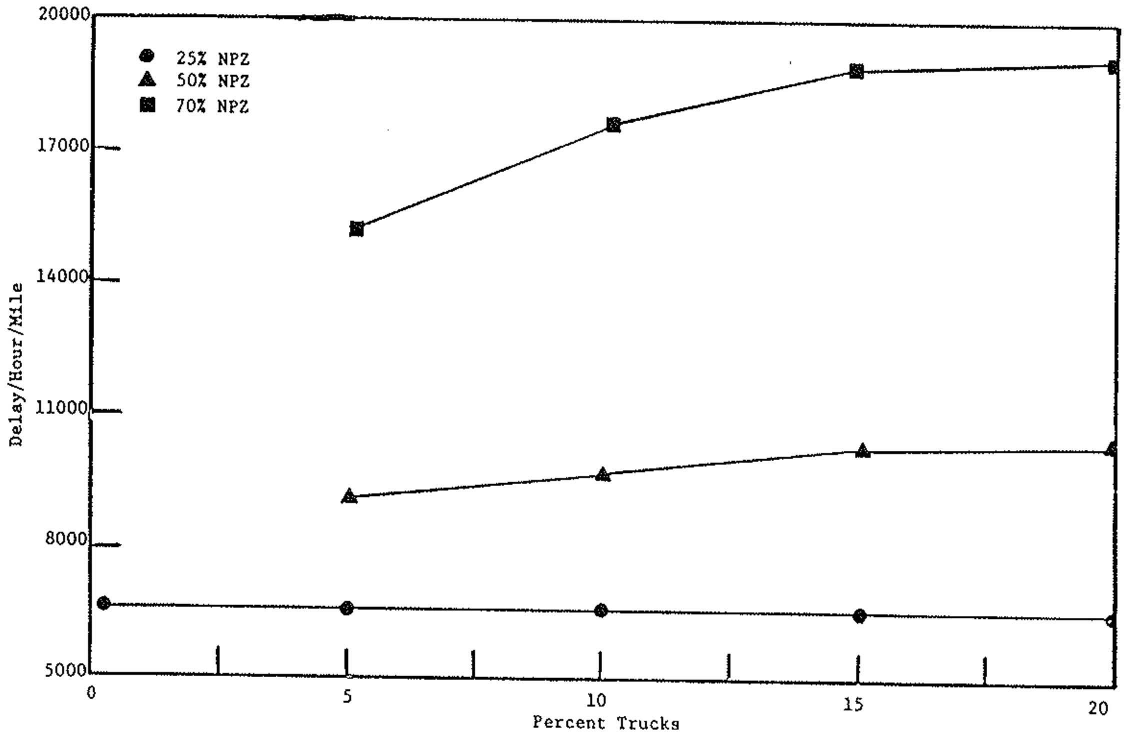

FIGURE 5 Delay per hour per mile for 800 vph (two ways) versus percentage trucks (25).

occur at or near intersections comprise a major proportion.

3. There does not appear to be a consensus among researchers as to whether the accident involvement rate of large trucks is significantly higher or lower than that of all other vehicles. Most truck accident studies, however, appear to indicate that the involvement rate of large trucks in fatal accidents is much higher.

4. Among fatal truck accidents, single-vehicle accidents comprise a major category. These single-vehicle fatal accidents may be indicative of roadway and geometric deficiencies. There is, however, no conclusive evidence in the literature of such geometric deficiencies, other than some limited indication of hazards on off-ramps.

5. There is no information available in the literature on the incidence of truck accidents in no-passing zones. However, a number of recent studies have indicated that on undivided rural roads collisions involving trucks are severe under all conditions.

6. Truck size (length and width) appears to be an intimidating factor in lateral placement of vehicles during passing, as well as longitudinal separation (gap) from the following vehicle. Also, increased traffic turbulences are associated with longer trucks (as evidenced by forced lane changes, gore encroachments, etc.). However, there is no evidence of increased hazard resulting from wider trucks.

7. The current MUTCD practice of marking passing zones designed for automobiles may not be adequate for trucks. The increased eye height of truckers does not compensate for increased truck passing distance.

8. Limited evidence from the literature suggests that both passing lanes and short four-lane sections are likely to provide significant operational benefits on two-lane highways. These operational benefits appear to extend several miles downstream from the treated area. Further, there does not appear to be any indication of a safety problem in the lane-addition or lane-drop transition areas of passing lanes.

9. The use of simulation techniques appears to provide a means of assessing operational impact (on delay, speed, and passing maneuvers) of increased truck traffic as well as altered roadway geometrics (as reflected by various measures of no-passing zones). With the proper calibration of such simulation models it may be possible to quantify some of these operational effects.

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