Safety Effectiveness of Highway Design Features

Volume I

ACCESS CONTROL

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ACCESS CONTROL

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FOREWORD

In the early 1960's, the highway community became increasingly interested in the safety effects of geometric design. The first attempt to quantify the state of knowledge on this topic was undertaken by the Highway Users Federation for Safety and Mobility (HUFSAM) in 1963 and 1971.

Considerable research on geometrics and safety was then initiated, and in the late 1970's, the Federal Highway Administration (FHWA) provided a consolidated resource for the safety impacts of various geometric and traffic control alternatives. This document, the Synthesis of Safety Research Related to Traffic Control and Roadway Elements, Volumes I and II (FHWA Report Nos. FHWA-TS-82-232 & 233), which updated the earlier HUFSAM reports, served a critical and useful purpose by providing valuable geometric/accident relationships.

This present compendium is the result of the FHWA implementing one of the 23 recommendations contained in Transportation Research Board Special Report 214, "Designing Safer Roads - Practices for Resurfacing, Restoration and Rehabilitation." This report specifically responds to the recommendation, calling for the FHWA to "...develop, distribute, and periodically update a compendium that reports the most probable safety effects of improvements to key highway design features..."

As an initial task, all available United States literature potentially relating a geometric feature with traffic accidents was identified. Resources included the Transportation Research Information Service, libraries at the University of North Carolina and United States Department of Transportation, authors, and the personal documents of the project team. In addition, accident/geometric data bases were identified as possible sources of data which could be used to develop needed relationships.

This identification effort revealed a lack of many new (post-1973) documents for several geometric topic areas. Accordingly, some major pre-1973 reports were included for critical review.

Critical reviews of these reports involved determination of the appropriateness of the study design, the adequacy of the sample size, the application of proper statistical tests and correct interpretation of results. Only information meeting all of these criteria is reported in each volume of this report. These documents are listed in the reference section at the end, and an additional bibliography section is included, covering related research of interest, but not used in this report.

ACCESS CONTROL

INTRODUCTION

In the early days of motor vehicle travel there were no issues or problems associated with access control. Motor vehicles shared unpaved roads with horses, horse drawn vehicles, bicycles, and pedestrians. Even with the advent of paved roads, access to the highways was virtually unlimited since survival in rural society required farm access to the highway to get crops to the railroad and other markets.

As the demographics of society changed and the highway system expanded, conflict arose between the need to move goods and vehicles and access for abutting property owners. Toll roads and turnpikes were introduced to provide needed facilities paid for by the users. Decreased travel time and user costs were the selling points for the turnpikes. This, and the need to collect tolls, required access to these facilities to be completely controlled. Primarily a phenomenon of eastern U.S., the concept of access control was quickly adopted by California and reached it ultimate expression in the Interstate System.

The Interstate System incorporates several eastern toll roads and freeways in other States. In 1960 the Bureau of Public Roads, (predecessor agency to the Federal Highway Administration), in concert with 40 States, undertook a safety evaluation of the Interstate System. This study and others conducted from 1966 until the late 1970's documented the benefits of access control. These studies were complemented by several studies which investigated alternatives for controlling access on noncontrolled access facilities.

Following is a discussion of the relationship between access control and accidents. The information relates both to freeways and nonfreeways. Most reports contain information for both urban and rural areas. City streets are not included. The results of studies which identify measures which can be used to control access on non-freeways are also presented.

SUMMARY OF RESEARCH

Access control, in the reports reviewed, was always defined as some combination of at-grade intersections, business driveways, private driveways, and median crossovers. Illustrations on alternatives to control access are presented later. Following is a discussion of the basic findings which relate access control to the safety of a highway facility.

Access Control and Traffic Flow

Access control on a given facility may range from none to full control of access. Most highways are constructed with no access control. In most cases, volumes are low and roadside development is sparse. However, as travel demand increases adjacent land use also increases, and the ability of the highway to handle the traffic safely decreases. Figure 1 illustrates the generalized relationship between access control and highway functional classification.

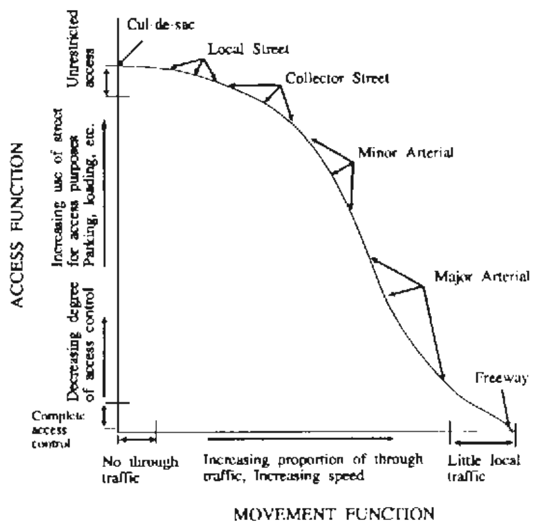

Figure 1. Relationship between control of access and traffic movement.[1]

Access Control and Safety

Traffic engineers recognize that the elimination of unexpected events and the separation of decision points simplifies the driving task. Access control reduces the variety and spacing of events to which the driver must respond. This results in improved traffic operation and reduced accident experience. This effect was highlighted in a report to Congress which utilized data from 30 States and concluded that full control of access was the most important single design factor for accident reduction.[1] The data in table 1 show accident and fatality rates on facilities with full control of access to be 1/2 that of rural highways with no access control and 1/3 that of urban highways of similar design.

In 1959 the Bureau of Public Roads (BPR) and 40 States jointly undertook a study to determine the safety of the Interstate System. In this collaborative effort, the States selected study sites and collected data in accordance with a study design prepared by BPR. The quality control and analysis of the data was completed by BPR.

Table 1. Effect of control of access on accidents and fatalities in urban and rural areas.[1]

	Accident Rates per Million Vehicle Miles			
	Urban		Rural	
Access Control	Total	Fatal	Total	Fatal
Full	1.86	0.02	1.51	0.03
Partial	4.96	0.05	2.11	0.06
None	5.26	0.04	3.32	0.09

Study sites included primary highways existing before the Interstate was built, Interstate highways which either replaced or paralleled a primary highway, and primary highways remaining in operation following the opening of a parallel Interstate highway. The results of this study are documented in several reports, the most comprehensive one being prepared by Fee et al.[2] Table 2 demonstrates the consistently better safety record of the Interstate as compared both to the primary existing before as well as the primary existing after the Interstate opened. The safety benefit of the Interstate System was consistent, although not as dramatic, in urban as well as rural areas.

The study also investigated the types of accidents occurring on the Interstate. As expected, head-on accidents are virtually eliminated and angle collisions greatly reduced. As shown in table 3, single vehicle and rear-end accidents were observed as the

Table 2. Accident, injury, and fatality rates by highway type and type of area.[2]

		Safety Rates per 100 Million Vehicle-miles			
		Existing Highways*			Interstate
		Before	After	Interstate	Corridor
Total Urban:	Accidents	637	601	194	332
	Injuries	259	280	102	162
	Fatalities	3.4	3.4	2.6	2.9
Total Rural:	Accidents	213	230	94	131
	Injuries	137	151	57	83
	Fatalities	7.6	6.8	3.3	4.3

*Travel route which existed prior to building of a "parallel" nearby interstate highway.

predominant type of rural and Interstate accidents respectively.[2]

In addition to the comparative analysis, regression models were developed to determine which element of an Interstate highway contributed most to the increased safety. Models were developed for nine separate categories of highways as follows:

Primary Highways
- Two-lane urban.
- Two-lane rural.
- Four-lane undivided urban.
- Four-lane undivided rural.
- Four-lane divided urban.
- Four-lane divided rural.

Interstate Highways
- Four-lane Interstate urban.
- Four-lane Interstate rural.
- Six or eight-lane Interstate urban.

This modeling exercise indicated a very strong relationship between access control and accident rate. The variables used to measure access control appeared as significant independent variables in *every* noninterstate model developed. These models can be used to project average accident rates on facilities where access points (intersections, driveways) are projected to increase. Figures 2 and 3 show the potential effects of such increases.

In the scenario described above, the increase in roadside development results in an increase in at-grade intersections and in businesses with direct access to the highway. On all types of nonfreeway facilities investigated, this situation always significantly increases accidents. Table 4 shows an increased accident rate on two-lane rural highways as a function of increased access points.

Table 3. Percentage of accident types on rural and urban Interstate and primary highways.[2]

Highway Type	Head-On	Single Veh.	Read-end	Angle	Other
			Rural		
Interstate	2.6%	51.1%	30.7%	4.0%	11.6%
Existing	12.4%	30.1%	40.7%	13.8%	3.0%
			Urban		
Interstate	2.0%	28.9%	59.7%	8.0%	1.4%
Existing	7.3%	10.5%	56.3%	22.2%	3.7%

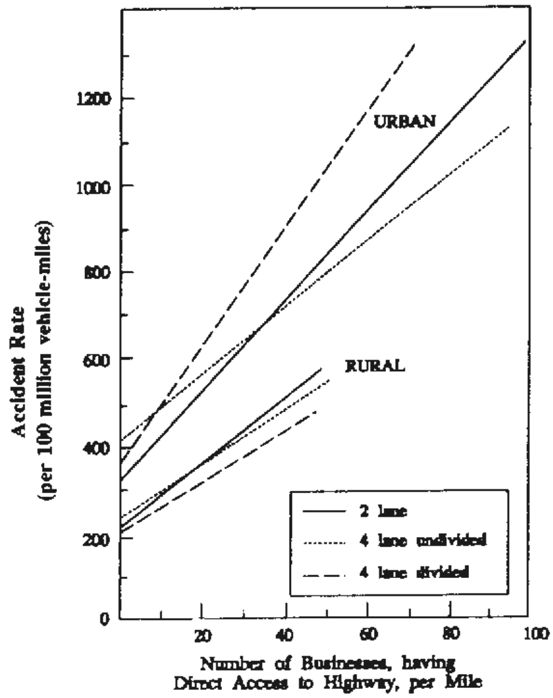

Figure 2. Accident rate on noninterstate highways for selected types of highway by number of businesses per mile.[2]

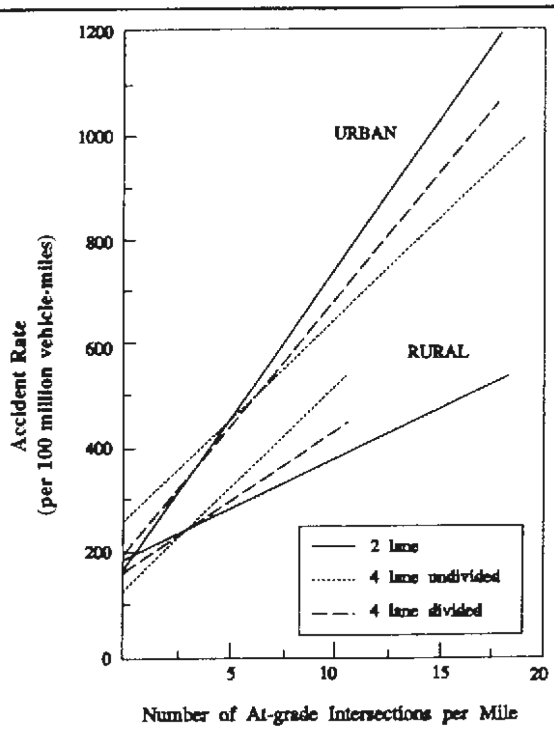

Figure 3. Accident rate on noninterstate highways for selected types of highway by number of at-grade intersections per mile.[2]

Table 4. Accident rate on two-lane rural highways as a function of access points.[2]

Intersections Per Mile	Businesses Per Mile	Accident Rate*
.2	1.0	126
2.0	10.0	270
20.0	100.0	1,718

*Accidents per 100 million vehicle-miles.

Gwynn undertook a similar comparative study of Interstate and primary highways in New Jersey.[1] His investigation concentrated on accident and injury rates. Gwynn's findings are summarized in tables 5 and 6. His results indicate accident and injury rates are 1/5 of those for the parallel highways and the results did not vary significantly from 1958, the year prior to the opening of the Interstate.

Median Openings

Several authors undertook to quantify the relationship between accidents and access control. In a series of studies in North Carolina, Cribbins et al investigated the effects of median openings on accident experience.[3] Using a significant number of homogeneous study sites, Cribbins et al found that traffic volume and various measures of access were the most significant contributors to accidents and that median openings should be kept to a minimum. In all cases, accident rates (defined here as accidents per mile) increased with frequency of access points and signalized openings per mile. Interestingly, the authors conclude that the width of medians did not affect accident rate on multilane highways.

Table 5. Comparison accident and injury rates (Camden County, New Jersey).[3]

	Interstate Route 295	U.S. Route 130	
	(1964)	(1964)	(1958)**
Total Mileage	10.06	10.30	10.30
Average Daily Volume	32,680	33,780	33,800
Accidents (#)	89	539	549
Accident Rate*	0.74	4.24	4.32
Injuries (#)	59	490	429
Injury Rate*	0.49	3.85	3.38

* Accidents per million vehicle miles
** Prior to opening Interstate

Table 6. Comparison accident and injury rates (Morris County, New Jersey).[3]

	Interstate Route 295	U.S. Route 130	
	(1964)	(1964)	(1958)**
Total Mileage	13.27	14.03	14.03
Average Daily Volume	17,130	16,371	17,443
Accidents (#)	73	489	482
Accident Rate*	0.88	5.83	5.40
Injuries (#)	69	411	354
Injury Rate*	0.83	4.90	3.96

* Accidents per million vehicle miles
** Prior to opening Interstate

Of importance in the North Carolina work was the consistent finding that combinations of geometric and traffic characteristics had a more significant impact on accidents than any single variable and Cribbins et al recommended against further research into the effects of single variables.

Cribbins et al also studied in detail the types of accidents which occurred at median openings. From this analysis, they concluded that, whenever possible, storage lanes should be installed at median openings. Use of this countermeasure, properly designed, will significantly reduce the number of accidents at median crossovers.[3]

Roadside Access

Driveways, commercial and private, provide roadside access. Like intersections, the efficiency and safety of driveways depend on traffic volume, geometric design, and traffic control systems. Driveways often carry traffic volumes as high as intersections but are rarely as well controlled or designed. In addition, because driveways in many instances are privately owned, accident data are often incomplete with many accidents going unreported.

Fee et al developed several models for accident rate as a function of traffic volume, length of road section, and access control variables. [2] Figure 2 on page 4 represents the results of the noninterstate models. This graph demonstrates the relationship between accident rate and frequency of commercial driveway access. In all cases accident rate increases as access increases.

McGuirk demonstrated similar results in his study on driveway accidents.[4] He also found a number of interacting variables affecting accidents including number of lanes, commercial driveways, intersections per mile, commercial driveways per mile, driveways per mile and urban area population. McGuirks findings are consistent with the general scenario surrounding growth and roadside development.

Marks, Michael and Petty, and Peterson and Michael documented the accident experience at uncontrolled driveways in California and Indiana.[1] Staffeld attempted to define the relationship between driveway access and accident rate on two-lane highways in Minnesota.[1] Staffeld found that sections having one or more commercial driveways had an average accident rate twice that of sections having only residential driveways. In addition, the accident rate on sections having residential driveways was slightly higher than sections having no driveways. In table 7, Staffeld demonstrates that accident rates tend to increase with both average daily traffic (ADT) and frequency of access. The irregularities in the higher volume groups is a function of small sample size.

Access Control on Nonfreeways

Thirty years of safety research on the effects of geometrics on accidents have produced many findings. Most are not definitive because of problems associated with accident studies and the nonpracticality of controlling the test environment. However, the influence of access control on safety is so strong that the relationship has been established consistently over the years in spite of the difficulties associated with accident studies. One thing is very clear, the most important geometric design element in reducing accidents is access control. It would be ideal to control access on every roadway; ideal but not practical. Thus on those facilities that carry the most traffic, connect major activity centers, and/or are major regional arterials, access should be controlled wherever possible.

Existing noncontrolled access facilities present an interesting challenge. Using information developed by Mulianzzi and Michael, Glennon estimated the number of driveway accidents by access points and ADT as shown in table 8.[5]

Glennon also identified and evaluated numerous other techniques to partially control access on these types of facilities. These techniques were designed to remove or reduce the conflict presented at access points thus allowing the driver to execute an intended maneuver with reduced accident potential. Glennon identified 77 different countermeasures and evaluated many of them using conflicts as the measure of

Table 7. Accident rates related to average daily traffic and access points per mile.[1]

Average Daily Traffic	Access Points Per Mile						
	0-3.9	4-7.9	8-11.9	12-15.9	16-19.9	20-23.9	24-27.9
	Accident Rates (Accidents per Million Vehicle Miles)						
1000-1999	0.70	0.77	1.05	1.36	2.85	2.75	3.17
2000-2999	1.25	1.60	1.63	2.42	1.97	2.40	3.95
3000-3999	1.74	2.03	1.86	1.93	1.50	0.95	2.60
4000-4999	-	0.75	-	1.36	1.80	3.85	2.25

effectiveness. While some controversy exists relative to the use of conflicts vs. accidents, in the time allotted for Glennon's study it would have been impossible to conduct any accident evaluation of the countermeasures. Glennon took particular care to ensure that the data collectors received special training in the collection of conflicts and installed significant quality control techniques to ensure accuracy and repeatability.

Table 8. Annual number of driveway accidents per mile by frequency of access and traffic volumes.[5]

Level of Development (Driveways Per Mile)		Highway ADT (Vehicles Per Day)		
		Low <5,000	Medium 5-15,000	High >15,000
Low	<30	12.6	25.1	37.9
Medium	30 - 60	20.2	39.7	59.8
High	>60	27.7	54.4	81.7

Some of Glennon's countermeasures included techniques which removed the access point, such as closing median openings, frontage road access and driveways with access to both frontage roads and main facilities. Of the techniques which did not remove the access point, Glennon found that separation of the through vehicles from vehicles using the access point would be very beneficial. He recommended extensive use of turning lanes, both acceleration and deceleration, for driveway and nonsignalized intersections. He also recommended use of turning lanes for median openings. It is important to ensure these facilities are properly designed, signed, and marked.

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