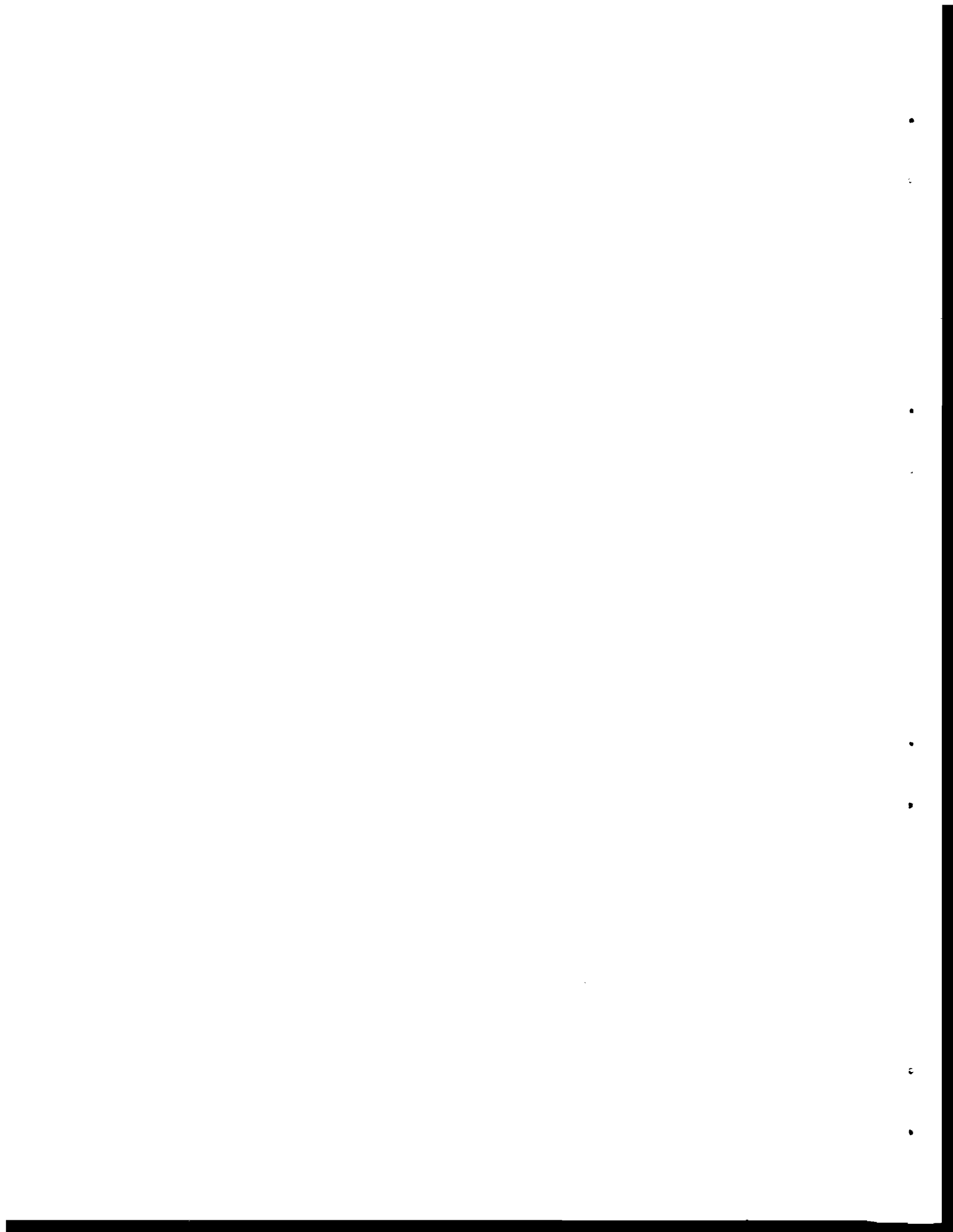


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16. Abstract <p>This report summarizes the findings of an evaluation of the 1979 Texas law (V.C.S., Sec. 73.A.) which requires frontage road traffic to yield right-of-way to freeway ramp traffic. The law was enacted to encourage statewide uniformity in right-of-way assignment at frontage road-ramp intersections. It affected traffic control at approximately 2,700 ramps in Texas and cost nearly \$900,000 to implement.</p> <p>The evaluation revealed that the new law has encouraged uniformity, but also has resulted in safety and operational problems at some locations. It also concluded that the new law violates driver expectancies in certain instances, particularly at "buttonhook" ramps on two-way frontage roads.</p> <p>Based on the research findings, the authors recommend that the law be revised. It is suggested that ramps on two-way frontage roads be excluded from the current policy of mandatory frontage road yield.</p>					
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AN EVALUATION OF THE 1979 TEXAS LAW (V.C.S., Sec. 73.A.)
WHICH REQUIRES FRONTAGE ROAD TRAFFIC TO YIELD
AT FREEWAY RAMPS

by

William R. Stockton
Stephen H. Richards
and
Janet A. Nordstrom

Research Report 288-1

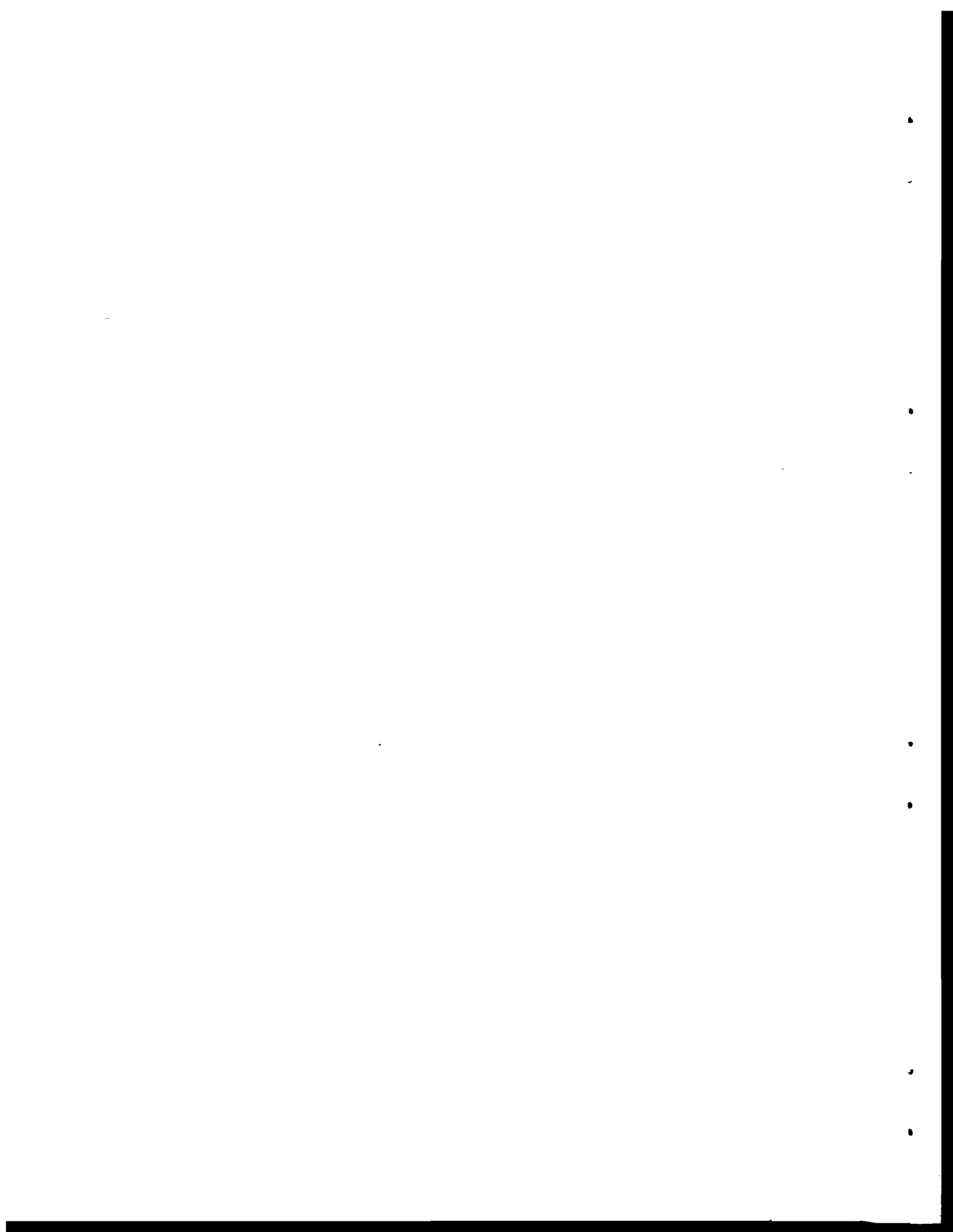
Freeway Ramp and Frontage Road Operation
Research Study 2-8-80-288

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March 1981



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The authors would also like to thank the District personnel from around the State for their valuable assistance. Every District provided much needed information for the research study. Messrs. Jim Williams of D-18T and Harold Cooner of D-8 are acknowledged for their assistance as Study Monitors, and for their constructive reviews of this report.

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

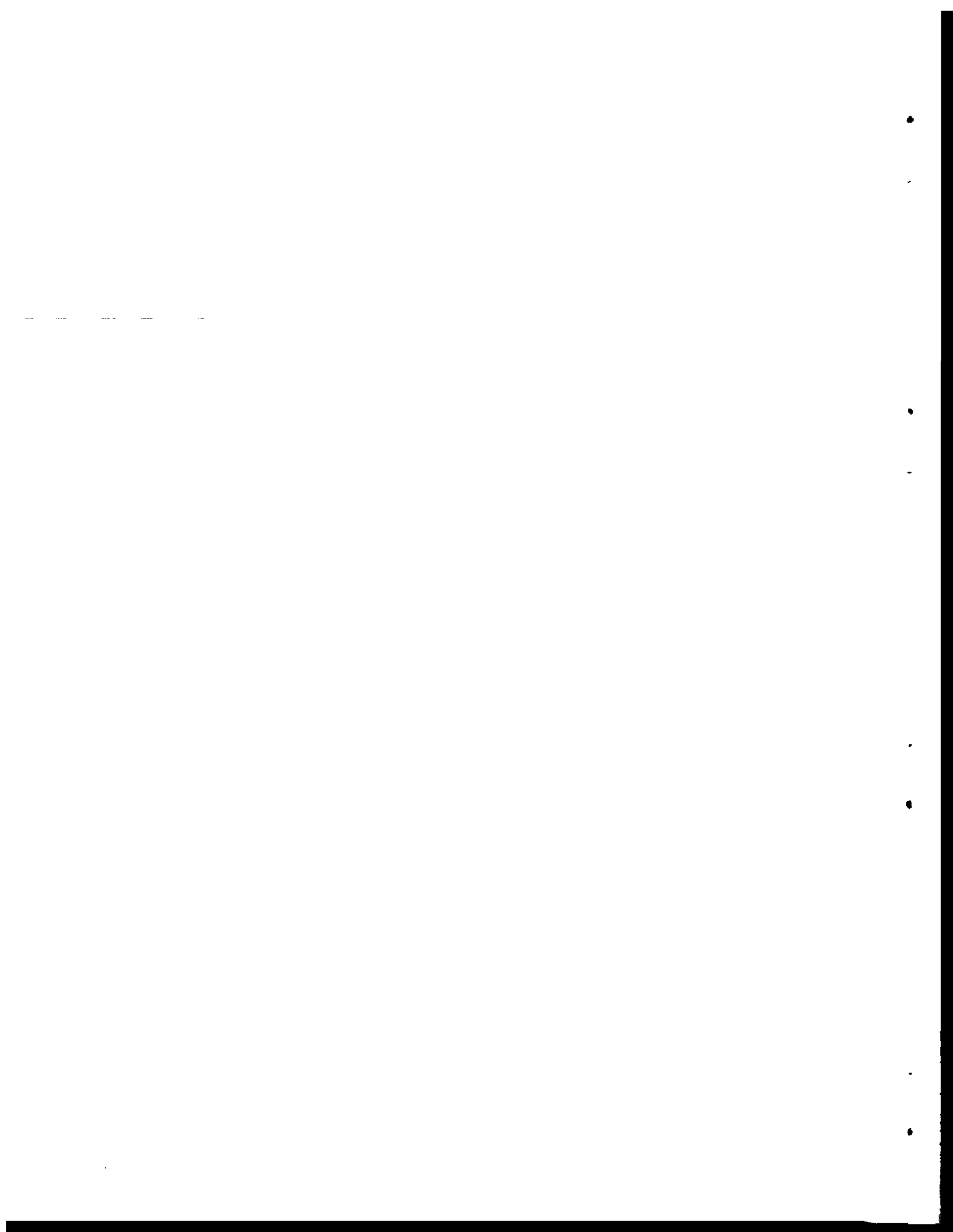
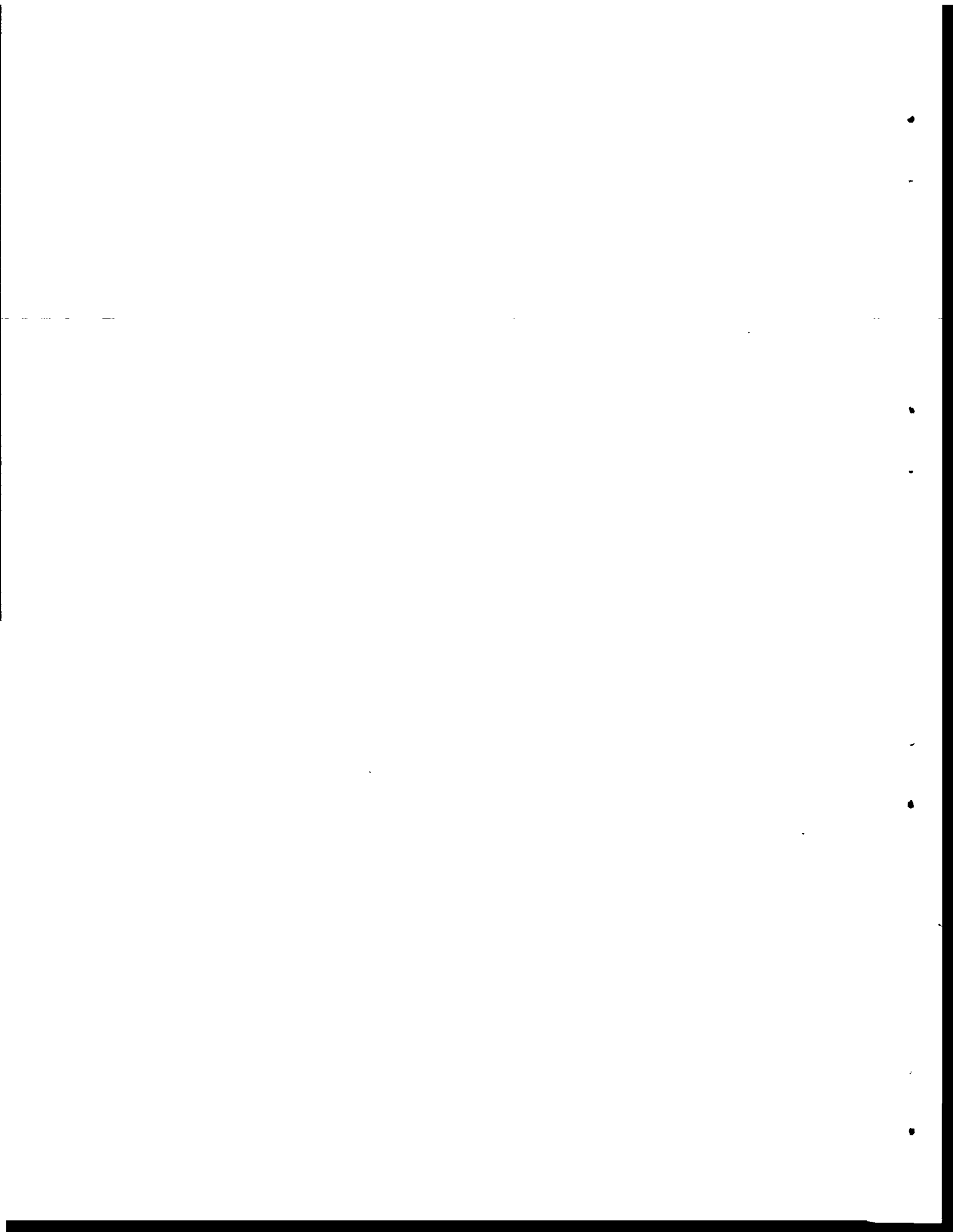


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INTRODUCTION

Texas House Bill 1421 was signed in the summer of 1979 establishing a new law, V.C.S. 6701d, Art. VIII, Sec. 73.A. This law requires drivers on the frontage road of a controlled-access highway to yield right-of-way to drivers using entrance or exit ramps. It also requires the Department (Texas State Department of Highways and Public Transportation) to erect appropriate signs at ramps for right-of-way regulation. Both positive and negative results have stemmed from this legislation. Greater statewide uniformity has been achieved, but isolated traffic operations and safety problems have also resulted, indicating that revision of the law may be needed.

Purpose of the Legislation

HB 1421 was intended to establish statewide uniformity in the control of frontage road/ramp intersections (ramp terminals). Prior to the enactment of this legislation, ramp terminal control was determined based on Department guidelines in effect since January 1974. (See Appendix A.) The Department guidelines recognized that no single "rule-of-thumb" was generally applicable to all types of ramps. Control guidelines were categorized by ramp type and each District could use discretion in the application of the guidelines. Local variations in ramp terminal control, consistent with local driver expectations, developed statewide as a result.

On-Going Study

The Department recognized that an evaluation of the new law was needed in the interest of motorist safety and travel efficiency. The Texas

Transportation Institute (TTI) was engaged to conduct this evaluation as a part of an on-going study of freeway ramp and frontage road operations. This report summarizes the findings of the TTI evaluation.

Literature Review

There is very little literature dealing with right-of-way assignment at frontage road/ramp intersections, primarily because of the limited use of frontage roads nationwide. In regard to right-of-way assignment at exit ramps onto one-way frontage roads, the available literature generally supports the present practice in Texas. Woods, at the Texas Transportation Institute, found that exit ramp capacity is greatest and mainlane blockages are minimized when a free-flow merge (no control) or frontage road yield policy is practiced. Hess determined that a free-flow merge is desirable when frontage road volumes are low and there is adequate spacing between the exit ramp and downstream intersection to accommodate lane changes. Hess concluded that frontage road yield is preferred as exit ramp volumes increase or when lane changing distance is restricted.

Available literature on right-of-way assignment at ramps on two-way frontage roads only partially supports the present practice in Texas. One report by the National Cooperative Highway Research Program recommends that frontage road traffic be required to yield to ramp traffic at braided ramps. At buttonhook ramps, however, it is recommended that ramp traffic stop or yield to frontage road traffic. (Figure 1 illustrates the various ramp types, including buttonhook, braided, slip, and channelized ramps.)

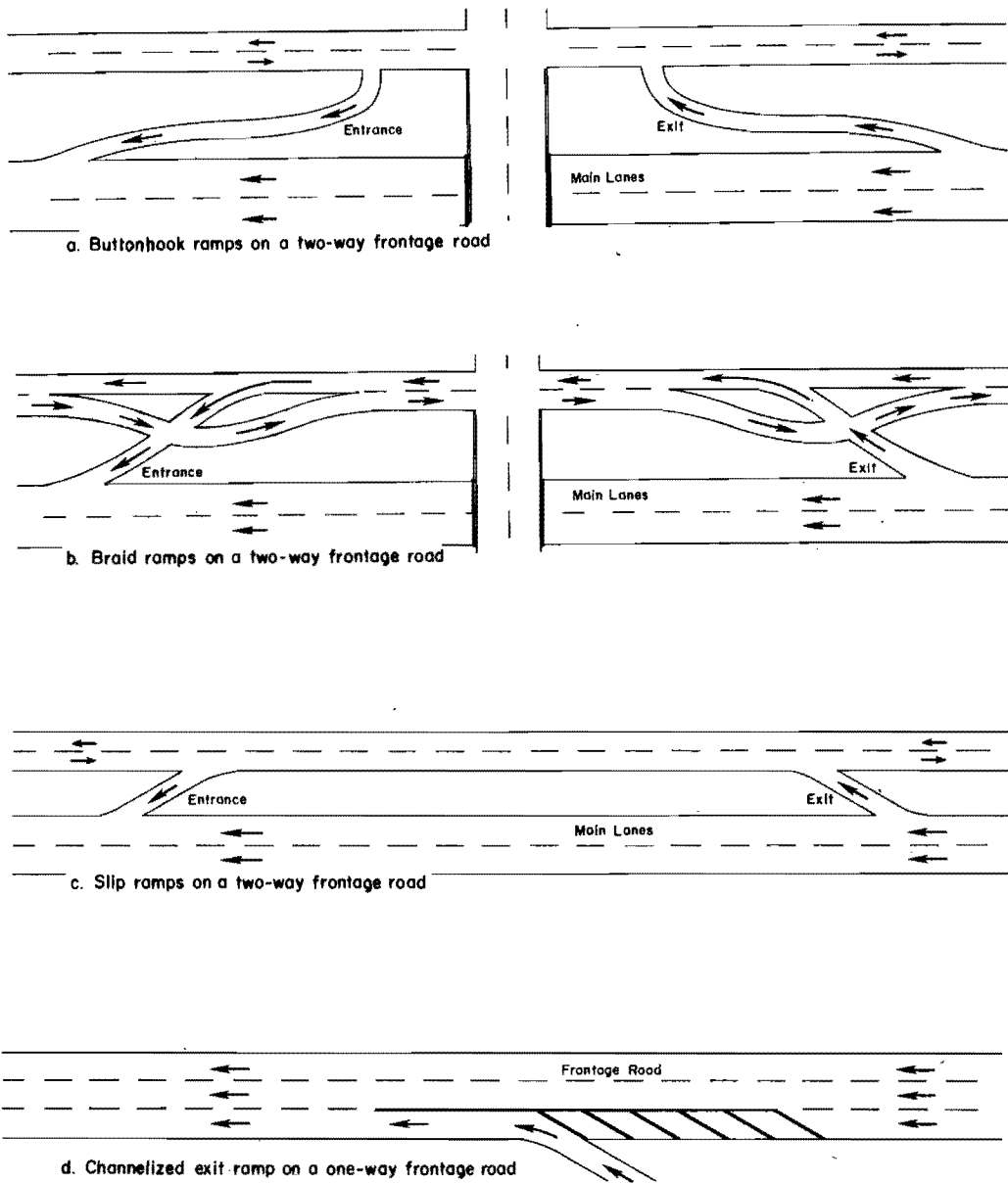
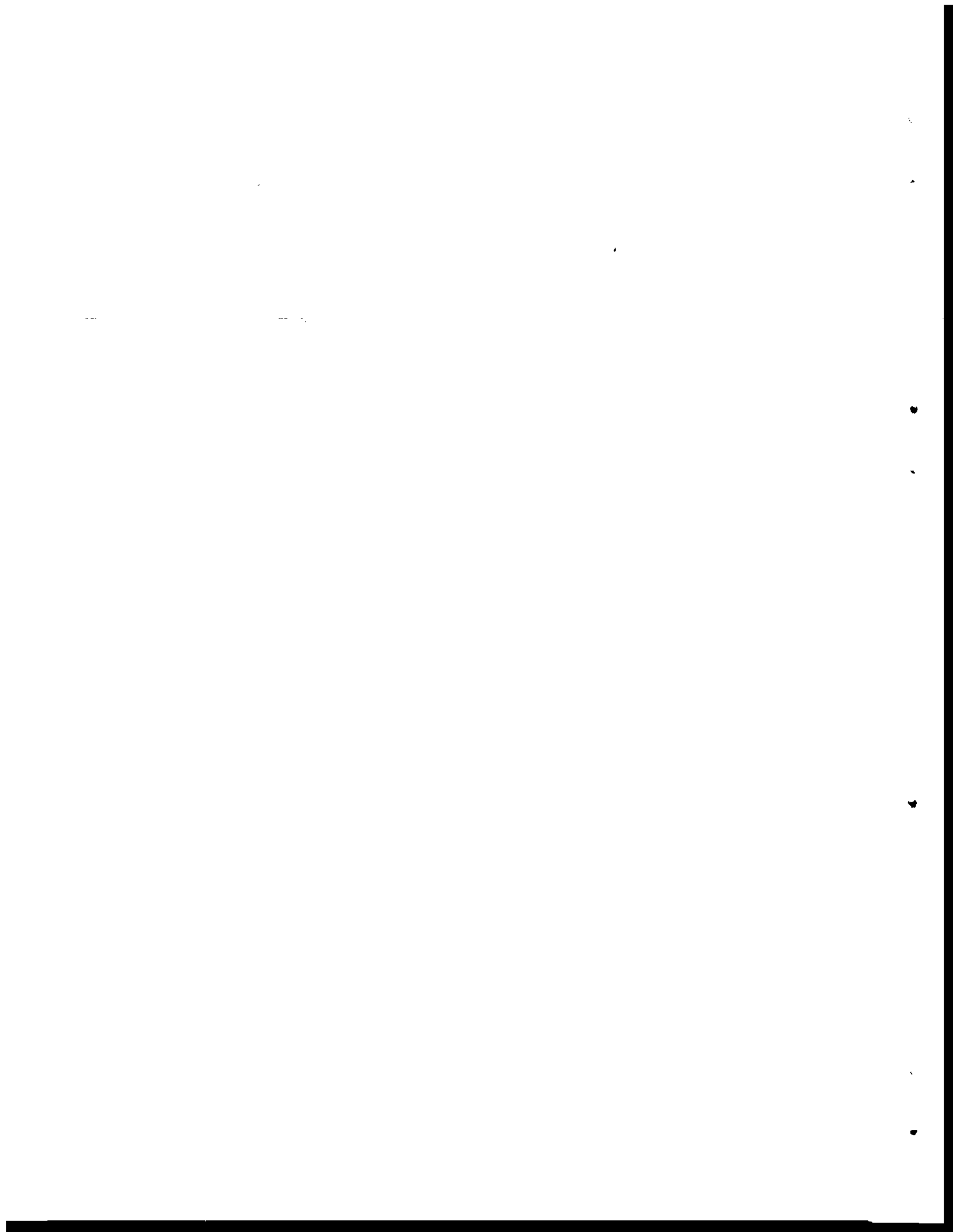


Figure 1. Four Types of Ramp Design in Texas



IMPACTS OF THE NEW LAW

The new law has established statewide uniformity. This uniformity has, in many instances, enhanced safety and traffic operations. However, a few safety and operational deficiencies have been discovered that have had a significant impact on the motoring public, and could warrant some modifications in the law. These deficiencies primarily relate to violations of driver expectancy and reductions in operational efficiency.

The new law allows no discretion on the part of the Department. There are few instances in highway engineering where a single solution can be applied to a variety of problems with equal success. In fact, the *Manual on Uniform Traffic Control Devices (MUTCD)* defines uniformity as providing identical treatments for identical conditions. It further states that "... engineering judgment is essential to the proper use of signs, the same as with other traffic control devices." The validity of this tenet with respect to the new law will be demonstrated in the following discussion.

Legal Conflicts and Driver Expectancy Violations

The provisions of the new law (Sec. 73.A.) create several conflicts with other Texas motor vehicle laws and basic driver expectancies. One of the more critical conflicts involves Sec. 72. *Vehicle Turning Left*. Sec. 72. requires that a driver turning left "... shall yield the right-of-way to any vehicle approaching from the opposite direction which is within the intersection or so close thereto as to constitute an immediate hazard." Sec. 73.A., on the other hand, permits a driver on a two-way frontage road who is turning left onto an entrance ramp to legally turn in front of oncoming traffic. Thus, there is a contradiction in the law and a violation of driver expectancy.

"Driver expectancy" is defined as "a roadway or traffic situation which produces an inclination to respond in a set manner, based on previous experience." Sec. 73.A. violates driver expectancy because it permits the left-turning frontage road driver, who in all other driving situations must yield, to proceed unimpeded. If the ramp terminal signing (STOP or YIELD signs) fails to attract the attention of on-coming traffic, a head-on collision can result.

A contradiction also exists between the provisions of Sec. 73.A. and Sec. 60.(a). The latter provides that a driver may change lanes only after he has "... ascertained that such movement can be made with safety." Sec. 73.A., on the other hand, apparently allows an exit ramp driver to proceed across all the lanes of a one-way frontage road, either to drive in the right lane or to execute a right turn at a downstream intersection. Since all of the roadway cues (straight path, lane lines, etc.) indicate continuous movement on the frontage road, the frontage road driver's expectancy is violated when an exit ramp driver crosses several lanes and cuts in front of him.

Another driver expectancy violation resulting from the new law (Sec. 73.A.) occurs at exit ramps onto two-way frontage roads. A majority of these exit ramps are buttonhook ramps, which require low speed exit maneuvers by ramp traffic. In these cases, ramp design favors, in terms of driver expectancy, right-of-way assignment to the higher speed frontage road traffic. A buttonhook exit ramp is analogous to a "T-type" intersection, where the ramp is the stem and the frontage road is the crossbar of the "T". In normal "T-type" intersection operation, the driver on the stem is required to yield right-of-way. All visual cues (except YIELD or STOP signs) promote a similar type of operation at buttonhook ramps.

Safety

A large majority of the ramp terminals affected by the new law service relatively low traffic volumes. Low volume conditions normally generate very few vehicle conflicts, and therefore, few accidents. For this reason, it is difficult to completely assess the safety impact of the new law in terms of accident numbers.

A detailed analysis of statewide accident trends at ramp terminals showed that accident frequency declined following the implementation of Sec. 73.A. The benefits of this decline were counteracted, however, by a sharp increase in accident severity. Incapacitating injuries resulting from ramp terminal accidents increased 22 percent, while fatal accidents increased 44 percent. These trends indicate that there is an alarming deficiency in the present policies governing ramp terminal control. The exact nature of this deficiency is still under investigation.

Implementation Costs

The Department conservatively estimates that the new law required control changes at approximately 2,700 ramp terminals costing nearly \$900,000. At approximately half of the affected locations, the right-of-way was changed from the frontage road to the ramp by moving existing signs. At approximately 40 percent of the sites, signs had to be installed where no control existed previously. Painted channelization indicating the appropriate maneuvers was installed at the remaining locations (see Figure 1.d.).

These costs reflect only the labor, equipment, and material costs incurred in making the changes. They do not include subsequent expenditures to correct operational or safety problems that arose. An example of these

other expenditures is an additional \$142,000 spent in Abilene to convert some two-way frontage roads to one-way in response to a 220 percent increase in frontage road accidents in the three months following changeover.

Local Impacts

The impact of the new law on the Department's 25 individual Districts has varied considerably. District 2 (Ft. Worth), for example, had to make changes at over 500 affected ramps while District 20 (Beaumont) was already in total compliance with the provision of the new law.

A number of the Districts (e.g., District 20) were using a ramp signing policy consistent with the provisions of Sec. 73.A. prior to 1979. In these Districts, the enactment of the new law has had little or no impact on safety or traffic operations.

In other Districts, however, the new law has had a great impact. Districts where the new law required changes at high volume ramps which generate high conflict rates have experienced the most significant problems. The most prominent example is District 8 (Abilene). In the five-month period following implementation of Sec. 73.A., ramp-related accidents increased 124 percent over the previous five months. The accident problem was mainly on the high-volume frontage road sections in the City of Abilene. All frontage roads in the Abilene District were two-way at the time of the accident study.

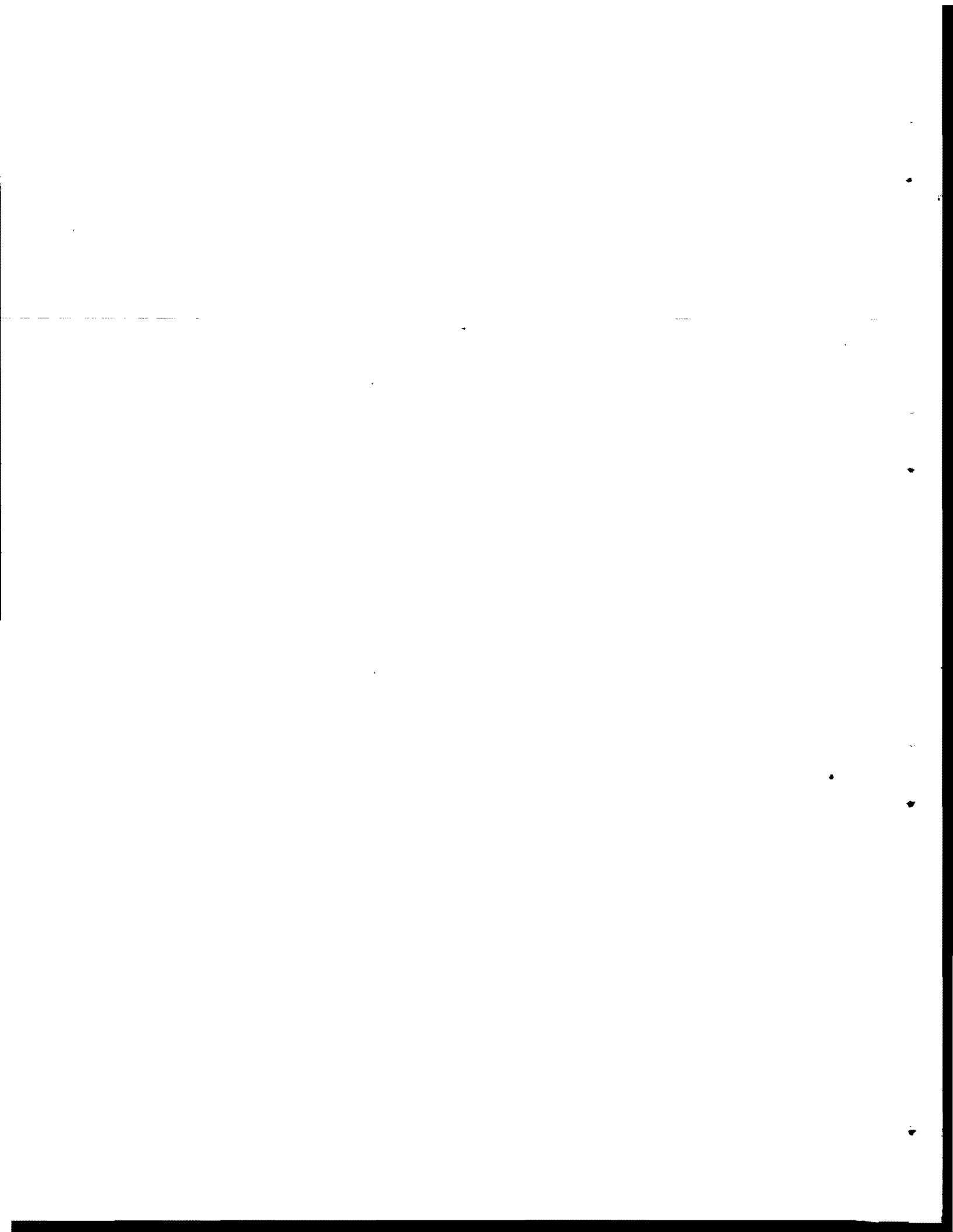
In an effort to respond to the critical safety problem, District 8 has changed from two-way frontage road operation to one-way operation along 16 miles of urban freeway in Abilene. This change, which cost about \$142,000, has significantly reduced accidents, in fact, to a lower rate than experienced prior to the 1979 law change. However, significant operational problems

persist because the entire access network (ramps, frontage roads, and arterial intersections) was designed for two-way frontage road operation.

Other Districts have encountered similar problems of a smaller magnitude. District 10 (Tyler) and District 19 (Atlanta) have experienced problems on high-volume, two-way frontage roads where frontage road drivers are not complying with ramp signing because it violates the drivers' expectancies. District 14 (Austin) reports poor operation at rural two-way frontage road locations, though no accidents have occurred due to the low volumes at the locations.

Some of the remaining Districts have experienced no problems resulting from the new law. The most plausible explanation for this incident-free experience is the absence of high traffic volumes at affected locations. At low-volume locations the potential for vehicle conflicts is so small that only one accident every three or four years would be expected under any control scheme (including no control). As discussed previously, a low accident rate at these sites gives no definitive indication of the success or failure of the new law.

District 1 (Paris) and District 15 (San Antonio) have installed some supplemental pavement markings ("stop bars") at ramps where frequent YIELD violations by frontage road drivers have been observed. In both Districts, the markings have apparently improved compliance. However, the improved compliance could be due to the novelty effect and may be short-lived.



PUBLIC AWARENESS AND ATTITUDE

The majority of the driving public is unaware of any frontage road yield law applicable to ramp terminals. Whether this lack of awareness has an adverse effect on safety or operations is unknown. Some drivers who are familiar with the new law perceive it as a good law; however, they cannot provide specific reasons for this conclusion. Also, many drivers favor a revision of the new law to promote compliance and satisfy driver expectancy requirements

Survey of the General Driving Public

A limited survey of Texas drivers was conducted to assess their awareness of the new law. Less than half of the drivers sampled were aware of the new law or the uniform statewide policy for right-of-way assignment at ramp terminals it creates. This survey also attempted to identify problems and potential solutions related to right-of-way assignment at ramp terminals. Drivers indicated that the failure of frontage road traffic to yield right-of-way was the predominant problem at ramp terminals. Increased public education was suggested as a remedial measure for the apparent driver misunderstanding of or disregard for ramp terminal traffic control.

Survey of Affected Motorists

In addition to the general study cited above, a survey of 471 ramp and frontage road users in Austin and Bryan/College Station was conducted. In this survey, drivers using ramp terminals on two-way frontage roads where the right-of-way had been changed by the new law were asked for their opinions.

These drivers cited failure of frontage road drivers to yield right-of-way to ramp traffic as the most common problem. A number of the drivers reported apparent confusion over right-of-way assignments, which may give some indication of why the right-of-way violations are occurring. Examples of the confusion include: 1) ramp drivers stopping for frontage road traffic and 2) all traffic stopping due to uncertainty over which driver should yield. It should be noted that these are problems perceived by the motorists.

Detailed field observation would be required to determine the actual extent of these problems.

Motorists were asked in the survey to recommend solutions to some of the perceived problems at ramp terminals. Most of their solutions related to improving frontage road traffic compliance to the new law through improved signing, enforcement and publicity.

General awareness of the law was much higher for the affected drivers than it was for the general driving public, as seen in the first survey. In addition, the affected motorists generally perceived the new law as a good law, but one that needs some improvement. More than one-fourth of the drivers surveyed favored a change in the new law. The majority favored some modification of the new law, rather than a reversion to the "no law" status.

In summary, the survey indicated that there is considerable support for a uniform policy on right-of-way at ramp terminals, but that the existing policy does not completely alleviate the motorists' perceived problems. It is unlikely that any traffic law will be satisfactory to all motorists, especially one that restricts one driver in favor of another. Motorists desire a policy, however, that minimizes confusion through consistency with driver expectancies.

DISCUSSION AND RECOMMENDATIONS

There are several primary factors that should be considered in selecting the appropriate right-of-way assignment at ramp terminals--uniformity, safety, operational efficiency, driver expectancy, and implementation cost. All of these factors are related and trade-offs must be made in the selection process.

Ramp Terminals on One-Way Frontage Roads

The new law (mandatory frontage road yield) has apparently had an overall positive effect at ramp terminals on one-way frontage roads. The law promotes operational efficiency at these locations because it encourages control which minimizes the probability of ramp traffic queueing onto the freeway main lanes. Some minor violations of driver expectancy have resulted (e.g., at low-volume ramps), but these violations should be reduced as drivers become more accustomed to the uniform statewide policy. Therefore, it is recommended that the policy of frontage road yield on one-way frontage roads be continued, except for the special case where a separate lane for the exit ramp traffic is available. Where a separate lane is provided, no right-of-way conflict exists and the current policy is not really applicable.

Ramp Terminals on Two-Way Frontage Roads

The effects of the new law at ramp terminals on two-way frontage roads appear to depend on the type of ramp (e.g., buttonhook, slip, etc.). The result is an occurrence of numerous site-specific problems, rather than universal ones.

Frontage road yield may be desirable at braided and channelized exit ramps (see Figure 1c,d) because of the relatively high ramp speeds and geometric similarities to ramps on one-way frontage roads. In addition, frontage road yield does not grossly violate driver expectancies at these exit ramps. On the other hand, frontage road yield severely violates driver expectancies at all types of entrance ramps, and at buttonhook exit ramps which are geometrically similar to "T-type" intersections. Frontage road yield also sacrifices operational efficiency at buttonhook ramps because the high speed traffic on the frontage road is forced to yield to low speed traffic using the ramp.

Recommended Revisions

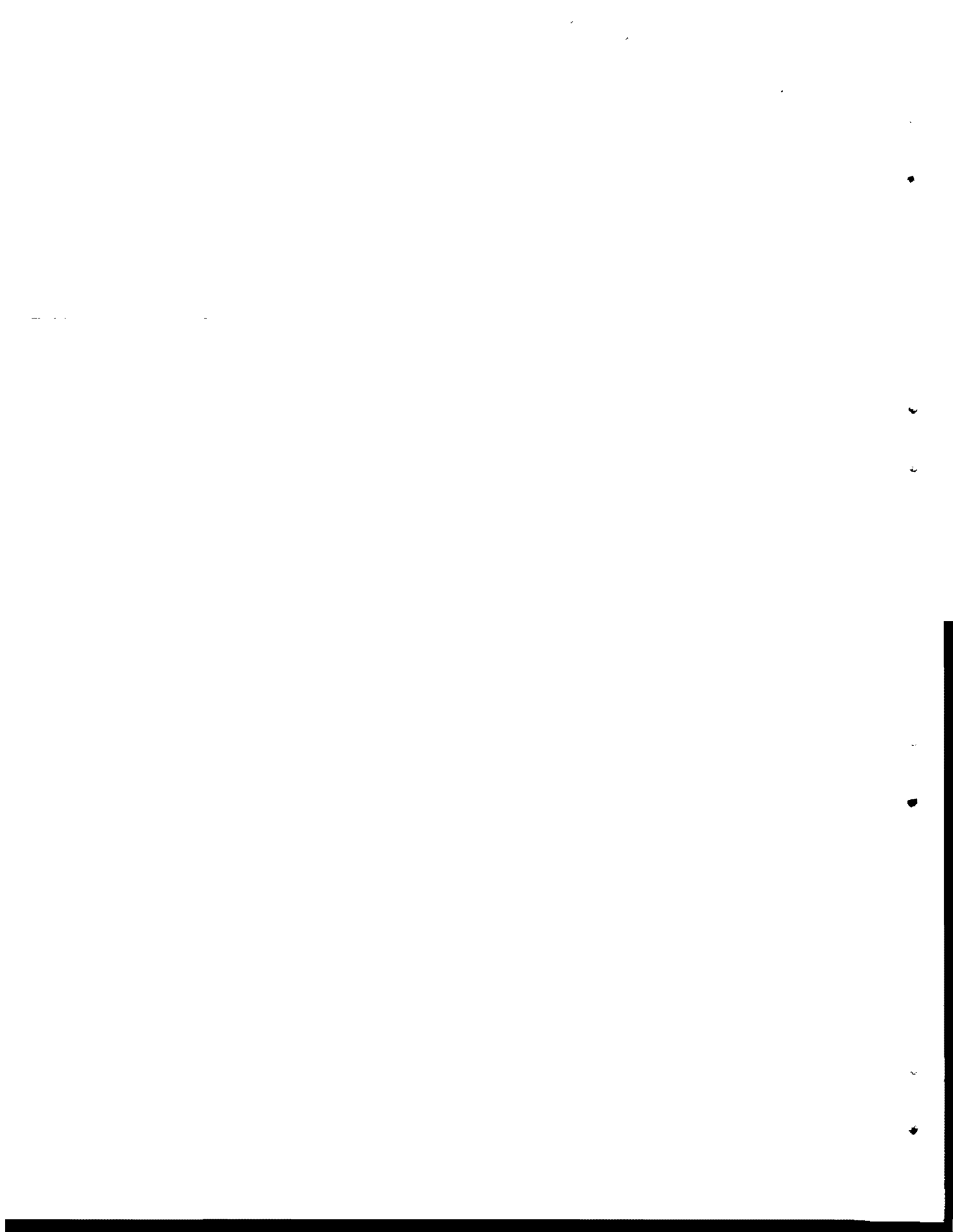
The overall impacts of the new law on uniformity, safety, efficiency, and expectancy at two-way frontage roads are not fully known at this time. However, there is evidence suggesting that, in many cases, the need for uniformity is out-weighed by safety, operational, and driver expectancy requirements. It is therefore recommended that Sec. 73.A. of Vernon's Civil Statutes be amended to address one-way frontage roads only, reading as follows:

Sec. 73.A. VEHICLE ON A CONTROLLED ACCESS HIGHWAY

Section 1. The driver of a vehicle proceeding on an access or frontage road of a controlled-access highway on which frontage road traffic is restricted to movement in only one direction shall yield the right-of-way to a vehicle entering or about to enter the frontage road from the highway, unless a separate lane is available to the entering vehicle, provided that at any location where a traffic and engineering study indicates traffic operations would be adversely affected by this requirement, the Department of Highways and Public Transportation may establish alternate traffic controls by the erection of appropriate traffic control devices.

Section 2. The Department of Highways and Public Transportation shall erect appropriate traffic control devices near the exits of controlled-access highways to advise motorists of the requirements of this Act.

It is further recommended that the Department pursue the full-scale assessment of the factors affecting uniformity, safety, efficiency, and expectancy at ramp terminals on two-way frontage roads. Upon completion of this assessment, any new law needed to promote safety and travel efficiency at ramp terminals on two-way frontage roads should be recommended to the Legislature.



APPENDIX A

COMMISSION

REAGAN HOUSTON, CHAIRMAN
DEWITT C. GREER
CHARLES E. SIMONS

TEXAS HIGHWAY DEPARTMENT
11TH AND BRAZOS
AUSTIN, TEXAS 78701

STATE HIGHWAY ENGINEER
B. L. DEBERRY

January 16, 1974

IN REPLY REFER TO
FILE NO. D-18T

TO: ALL DISTRICT ENGINEERS

SUBJECT: TRAFFIC CONTROL AT THE EXIT RAMP-
FRONTAGE ROAD INTERSECTION

Gentlemen:

In the past, we have been requested to establish guidelines regarding the placement of YIELD signs at the Exit Ramp-Frontage Road Intersection. Numerous comments have been received from various Districts in correspondence about the need for uniformity and much discussion on this subject occurred at the recent Regional Maintenance Conferences.

It has been the position of this office that no single rule of thumb can be uniformly applied to the various designs and thereby result in the most effective traffic control at the exit ramp-frontage road intersection. We do feel, however, that the various designs can be categorized and a desirable control concept for each category could be established. It is our recommendation that the following guidelines be used in the placement of YIELD signs at the Exit Ramp-Frontage Road Intersections:

1. On button-hook exit ramps which intersect two-way frontage roads, we feel it would be best for the ramp traffic to yield. Most button-hook ramps normally require slow speed maneuvers and ramp operation would not be adversely affected by having ramp traffic yield. In addition, since ramp traffic must decelerate anyway in order to negotiate the ramp, this traffic could more readily stop if necessary. The button-hook design also provides ramp traffic with good visibility in both directions along the frontage road.
2. When you have two-way frontage roads with a braided exit ramp, usually a less restrictive exit maneuver is allowed. In these instances, we feel the frontage road traffic should yield. This type ramp-frontage road intersection design usually introduces channelization in the frontage road and drivers are aware they are approaching an intersection and would be more alert for any signing. Frontage road traffic is usually required to decelerate to negotiate the intersection and could, therefore, more readily stop if necessary.

3. Where one-way frontage roads and a slip ramp is used, there are several disadvantages to requiring either the ramp or frontage road traffic to yield. With a YIELD sign for ramp traffic, we require drivers to look in the opposite direction his vehicle is moving in order to determine if he can make a safe maneuver. The traffic a ramp driver must yield to is in a relative position which is least visible to drivers in most vehicles, particularly commercial vehicles. This situation contributes to the incidence of the rear end type accidents on many ramps. When the frontage roads must yield, we in effect require all lanes of traffic on the frontage road to yield to a one lane ramp when only one frontage road lane need be available for exiting traffic. Since a one-way frontage road is usually associated with urban areas where a greater amount of traffic is encountered, the above mentioned disadvantages should be avoided if possible. It is our recommendation that the design illustrated in the attached sketch be used. This would eliminate the necessity for a YIELD sign on either the ramp or frontage road. This type of channelization utilizing only paint stripe has proven very effective in improving operation of this type ramp-frontage road intersection. If this type design cannot be utilized, then we would prefer that where traffic volumes are low on both ramp and frontage road that frontage road traffic yield.


The above comments are offered for your consideration. It is realized that there may be some locations where deviation from the above general guidelines may be necessary. In these instances, an operational analysis of the individual location should be made to determine the location of YIELD signs.

If you have any questions on this matter, please advise.

Sincerely yours

B. L. DeBerry
State Highway Engineer

By:

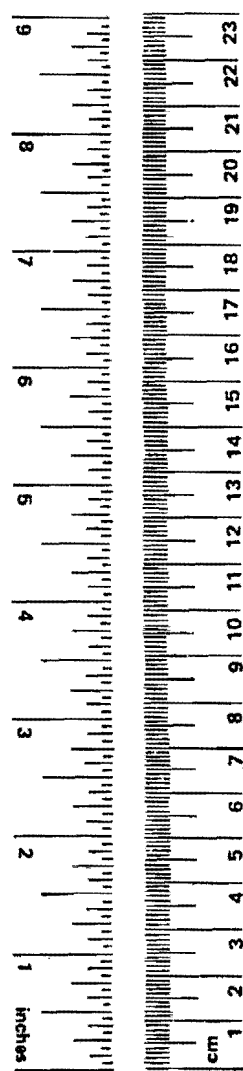

Archie J. Sherrod, Chief Engineer
of Maintenance Operations

EWK:mjb
Attachment

APPENDIX B

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures					Approximate Conversions from Metric Measures			
Symbol	When You Know	Multiply by	To Find	Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH								
in	inches	*2.5	centimeters	cm	mm	millimeters	0.04	inches
ft	feet	30	centimeters	cm	cm	centimeters	0.4	inches
yd	yards	0.9	meters	m	m	meters	3.3	feet
mi	miles	1.6	kilometers	km	km	kilometers	1.1	yards
							0.6	miles
AREA								
in ²	square inches	6.5	square centimeters	cm ²	cm ²	square centimeters	0.16	square inches
ft ²	square feet	0.09	square meters	m ²	m ²	square meters	1.2	square yards
yd ²	square yards	0.8	square meters	m ²	km ²	square kilometers	0.4	square miles
mi ²	square miles	2.6	square kilometers	km ²	ha	hectares (10,000 m ²)	2.5	acres
	acres	0.4	hectares	ha				
MASS (weight)								
oz	ounces	28	grams	g	g	grams	0.035	ounces
lb	pounds	0.45	kilograms	kg	kg	kilograms	2.2	pounds
	short tons	0.9	tonnes	t	t	tonnes (1000 kg)	1.1	short tons
	(2000 lb)							
VOLUME								
tsp	teaspoons	5	milliliters	ml	ml	milliliters	0.03	fluid ounces
Tbsp	tablespoons	15	milliliters	ml	l	liters	2.1	pints
fl oz	fluid ounces	30	milliliters	ml	l	liters	1.06	quarts
c	cups	0.24	liters	l	l	liters	0.26	gallons
pt	pints	0.47	liters	l	m ³	cubic meters	35	cubic feet
qt	quarts	0.95	liters	l	m ³	cubic meters	1.3	cubic yards
gal	gallons	3.8	liters	l				
ft ³	cubic feet	0.03	cubic meters	m ³				
yd ³	cubic yards	0.76	cubic meters	m ³				
TEMPERATURE (exact)								
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C	°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature
								°F



Approximate Conversions from Metric Measures			
Symbol	When You Know	Multiply by	To Find
LENGTH			
mm	millimeters	0.04	inches
cm	centimeters	0.4	inches
m	meters	3.3	feet
m	meters	1.1	yards
km	kilometers	0.6	miles
AREA			
cm ²	square centimeters	0.16	square inches
m ²	square meters	1.2	square yards
km ²	square kilometers	0.4	square miles
ha	hectares (10,000 m ²)	2.5	acres
MASS (weight)			
g	grams	0.035	ounces
kg	kilograms	2.2	pounds
t	tonnes (1000 kg)	1.1	short tons
VOLUME			
ml	milliliters	0.03	fluid ounces
l	liters	2.1	pints
l	liters	1.06	quarts
l	liters	0.26	gallons
m ³	cubic meters	35	cubic feet
m ³	cubic meters	1.3	cubic yards
TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature
			°F

* 1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price \$2.25, SD Catalog No. C13.10:286.

