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16. Abstract

The reduction in accidents through conversion from two-way to one-way operation on freeway frontage roads, excluding a three-month acclimation period, were examined at nine sites. Both accident frequency and accident severity were examined. Study site criteria were: 1) before and after accident data be available; and 2) both of the frontage roads were converted to one-way operation at one point in time.

The findings of this research suggest that an average 20 percent reduction in accident frequency, can be expected by conversion of two-way frontage roads to one-way operation. No significant difference in accident severity was indicated from the data available. Conversion to one-way operation is cost/beneficial for one year frontage road accident frequencies of 35 or more accidents per mile (both frontage roads) with major rechannelization of the ramps or 10 or more accidents per mile where no rechannelization is required, delay is not considered. Report 288-4F discusses the issue in detail. These accident frequencies suggest moderate to high traffic volumes are required to make conversion attractive.

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ACCIDENT ANALYSIS OF THE CONVERSION FROM TWO-WAY TO ONE-WAY FRONTAGE ROAD OPERATION

by

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Research Report 288-3

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

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ABSTRACT

The reduction in accidents through conversion from two-way to one-way operation on freeway frontage roads, excluding a three-month acclimation period, was examined at nine sites. Both accident frequency and accident severity were examined. Study site criteria were: 1) before and after accident data were available; and 2) both of the frontage roads were converted to one-way operation at one point in time.

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KEY WORDS

Service Roads *

Frontage Roads *

Accidents *

Accident Severity

Before and After

Operation

DISCLAIMER

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INTRODUCTION

Some of the frontage roads in Texas have been converted to one-way from two-way operation in the last several years. This conversion has been performed in individual cities either to increase traffic capacity or to reduce potential conflicts (1, 2, 3). Since the passage in 1979 of the Texas law requiring the frontage road traffic to yield the right-of-way to the traffic leaving or about to enter the freeway (4), increased interest in conversion to one-way operation has existed (5).

Although, general requirements and warrants in terms of increased capacity, safety, improved traffic operation and economy are mentioned (1), specific guidelines regarding when, where, and how to convert two-way frontage roads to one-way operation are not available. This study is the first phase of an effort to provide design guidelines concerning the conversion of frontage roads to one-way operation. In this phase of the study, the effect on traffic accidents of conversion from two-way operation to one-way operation has been investigated. In particular, two questions are addressed. First, are traffic accidents significantly different after conversion, and if so, what is the direction and magnitude of the change? Second, is the accident severity different after conversion from two-way to one-way operation?

This report summarizes the findings of the overall accident changes after conversion of frontage roads from two-way to one-way operation.

EXPERIMENTAL DESIGN

The experimental design is the evaluation plan to determine the effects of the conversion from two-way to one-way frontage roads. Two experimental designs appeared to be relevant to this study: One is the "Before-After" design and another is the "Before-After with a Control Site" design.

Some researchers have concluded that overall, the "Before-After" design is a very poor design. Others suggest that, if the control site is not exactly comparable, then the conclusions are more likely to be erroneous than if no control site was used at all (6).

In reality, no two highway sections or sites are either identical or homogeneous. The characteristics of ramp and frontage road geometry, traffic volumes and composition, land use complexity, and traffic control differ more or less from site to site. Thus, the "Before-After" design was selected for use in this study. The weaknesses in the "Before-After" design, such as vulnerability to changes over time, regression toward the mean, and random fluctuation instability (7), are controlled in this study through the selection of sites and analysis methodology.

SITE SELECTION

Survey forms were sent to individual State Department of Highways and Public Transportation Districts to identify frontage road sections changed from two-way to one-way operation in recent years. Sixteen sites were identified which changed during the period from May, 1976, to June, 1980. Two criteria were applied to select sites: first, at least one year of accident data wereavailable before and after the conversion; and second, both frontage roads had to have been converted at one point in time. The second cri-

terion was established due to the difficulty in determining the accident location, since the Texas accident record system does not show on which frontage road the accident actually occurred.

Initial application of both criteria resulted in five sites. Four sites in the city of Abilene had 11 months of accident data for the after condition. This period is considered to be approximately equivalent to one year of accident data, and these four sites, adjusted to reflect one year of data, were added to the data set resulting in a total of nine sites.

The nine sites so selected are frontage roads on both Interstate and U.S. Highways which provide service adjacent to these highways. Table 1 contains the section length of these 9 sites. These sites range from 0.9 mile to 9.5 miles in length.

ACCIDENT DATA COLLECTION

All Texas accident data tapes from 1975 through May, 1981, were obtained from the Accident Analysis Division of Texas Transportation Institute. Accidents that occurred on frontage road sections between the referenced mile points in Table 1 were obtained using the Statistical Analysis System (SAS) (8).

Initially, it was assumed that as many years of accident experience as possible should be used, as this would help in estimating the effects of conversion. However, contrary to this assumption, it is found that there are significant variations in accident frequency between years (See Appendix). A general time trend was observed. From this observation, it is concluded that many years of before data would distort the real effect of the change. Therefore, the maximum period of before data was set as two years. Further, to eliminate the random fluctuation of accident instability, an

equivalent period of before and after data was analyzed. Table 2 shows the exact before and after time periods of each frontage road in the study, as well as its ADT before conversion.

Table 1. Milepoint Boundary of Study Sites.

SDHPT District	Highway Number	Control Section	Beginning Milepoint	Ending Milepoint	Study Site Length (Miles)
18	IH-35E	196 - 2	5.3	8.6	3.3
14	US 81	15 - 13	10.0	13.7	3.7
4	US 87	168 - 1	9.6	14.2	4.6
18	IH 30	9 - 11	25.8	29.1	3.3
12	US 90	271 - 6	0.7	10.2	9.5
8	IH-20	6 - 6	1.2	2.1	0.9
8	IH-20	34 - 1	1.5	4.5	3.0
8	US 83	33 - 6(a)	4.8	6.0	1.2
8	US 83	33 - 6(b)	6.8	8.0	1.2

Table 2. Time Boundary of Study Site Data.

Control Section	Before Period	After Period	Conversion Date	Frontage Road ADT Before Conversion (Before Frontage Roads)
196- 2	1/75 - 12/76	1/78 - 12/79	2/77	11,000
15-13	1/75 - 12/76	1/78 - 12/79	7/77	3,400
168- 9	1/76 - 12/77	1/79 - 12/80	7/78	NA
9-11	1/78 - 12/78	1/80 - 12/80	4/79	NA
271- 6	1/78 - 12/78	1/80 - 12/80	8/79	3,250
6- 6	7/78 - 5/79	7/80 - 5/81	3/80	4,800
34- 1	7/78 - 5/79	7/80 - 5/81	3/80	700
33- 6(a)	7/78 - 5/79	7/80 - 5/81	3/80	3,000
33- 6(b)	7/78 - 5/79	7/80 - 5/81	3/80	10,000

ACCIDENT DATA ANALYSIS

Only nine study sites and seven years of data were available. Therefore, the normality assumption and time series analysis are inappropriate for this study. A non-parametric statistical analysis approach was utilized for the data analysis.

Percentage Change of Accident Frequency

Table 3 presents the number of accidents before and after the conversion from two-way to one-way operation on the frontage roads. The table reveals that five sites out of the nine experienced an accident reduction ranging from 21% to 56%. It also shows that two sites had no change in accident frequency, while two sites indicated some increase. It should also be noted that the reductions tended to be very large, while the increases were rather small. Overall, Table 3 indicates that average accident reduction at nine sites was 21%.

Overall Assessment of Accident Change

It was assumed that there would be an overall effect of the change from two-way to one-way frontage road operation, independent of the sample sites. This effect can be analyzed by a combined investigation of the nine sites.

When normality is assumed, the paired "t" test would be applicable. However, due to the small sample size, a non-parametric test comparable to the "t" test, the Wilcoxon matched-pairs signed rank test (9, 10), was used. Table 4 shows the Wilcoxon test results indicating that there is a statistically significant accident reduction after the change from two-way to one-way frontage operation at the 5% confidence level.

Table 3. Percentage Change in Accident Frequency.

	Sites									
Control-Section	196-2	15-13	168-9	9-11	271-6	6-6	34-1	33-6(a)	33-6(b)	Total
Hwy. No.	IH-36E	US 81	US 81	IH-30	US 90	IH-20	IH-20	US 83	US 83	
District	18	14	4	18	12	8	8	8	8	
Before	91	90	220	16	37	4	47	5	44	554
After	72	74	157	7	39	4	54	5	24	436
% Change	-21	-18	-29	-56	5	0	15	0	-45	-21

Table 4. Results of Wilcoxon Test

Control-Section	196-2	15-13	168-9	9-11	271-6	6-6	34-1	33-6(a)	33-6(b)
Hwy. No.	IH-35E	US 81	US 87	IH-30	US 90	IH-20	IH-20	US 83	US 83
District	18	14	4	18	12	8	8	8	8
Before	91	90	220	16	37	4	47	5	44
After	72	74	157	7	39	4	54	5	24
D_i = After-Before	-19	-16	-63	-9	2	0	7	0	-20
$\lvert D_i \rvert$	19	16	63	9	2	0	7	0	20
Rank of $\lvert D_i \rvert$	5	4	7	3	1	Omit	2	Omit	6
Assign sign of rank	-5	-4	-7	-3	+1	Omit	+2	Omit	-6
Sum of positive (R_+) = 3									

H_0 : The median of before and after difference is greater than or equal to zero,

i.e., D_i = After-Before ≥ 0

H_A : The median of before and after difference is less than zero,i.e.,

$D < 0$

Test Statistic $R_+ = 3$

Critical Region $R_c \leq 4$ (When n=7 and $\alpha = 0.05$)

Therefore, the null hypothesis is rejected and it is concluded that there is a significant reduction in accidents after the conversion to one-way operation.

Overall Assessment of Accident Severity Change

As previously mentioned, another objective of the analysis was to determine whether accident severity was significantly different before and after the operation change from two-way to one-way. The Kolmogorov-Smirnov test (10) was performed to test this hypothesis. The result of this test, presented in Table 5, indicates that there is no significant difference in accident severity before and after the change. That is, the accident severity is expected to be the same regardless of the type of operation.

EVALUATION OF TRAFFIC VOLUME AND ACCIDENTS

The relationship between the level of traffic on the frontage roads and the observed reduction in accidents was examined. Accident rates could not be used, as both intersection accidents and mid-block accidents were included in the data for all sites. In an attempt to provide some insight on the traffic influence into the reduction in observed accident experience, a graph of the ADT on both frontage roads against the percent reduction in reported accidents was prepared. Figure 1 indicates that a trend for the percent reduction to increase as ADT increases does exist. Table 6 provides a least squares fit of the observed data points. The resulting correlation coefficient (r^2) is 0.68. This indicates a definite trend for the percent reduction to increase with volume. The r^2 of 0.68 indicates that only sixty-eight percent of the variation observed is accounted for by the model. The average 20 percent reduction is therefore, from the available data, the best estimate of the accident reduction in converting two-way frontage roads to one-way operation.

Table 5. Results of Kolmogorov-Smirnov Test

Injury classes	Frequency Before	Frequency After	Cumulative Probability Before	Cumulative Probability After	Cumulative Probability Before-After
Non-injury	406	327	0.733	0.750	0.017
Possible Injury	66	50	0.852	0.865	0.013
Non-Incapacitating Injury	63	50	0.966	0.979	0.013
Incapacitating Injury	17	9	0.996	1.000	0.004
Fatal	2	0	1.000	1.000	0
Total	554	436			

H_0: severity Before and After is the same

H_A: severity Before and After is different

Test Statistic $D = \max |S_B - S_A|$

$= 0.017$

Critical Region $D_c \geq 1.36 \dfrac{n_1 + n_2}{n_1 \cdot n_2}$

$\geq 1.36 \dfrac{554 + 436}{554 \cdot 436}$

$\geq .087$

Since $D < D_c$, the null hypothesis is not rejected, and it is concluded that the accident severity before and after the conversion to one-way operation is not statistically different.

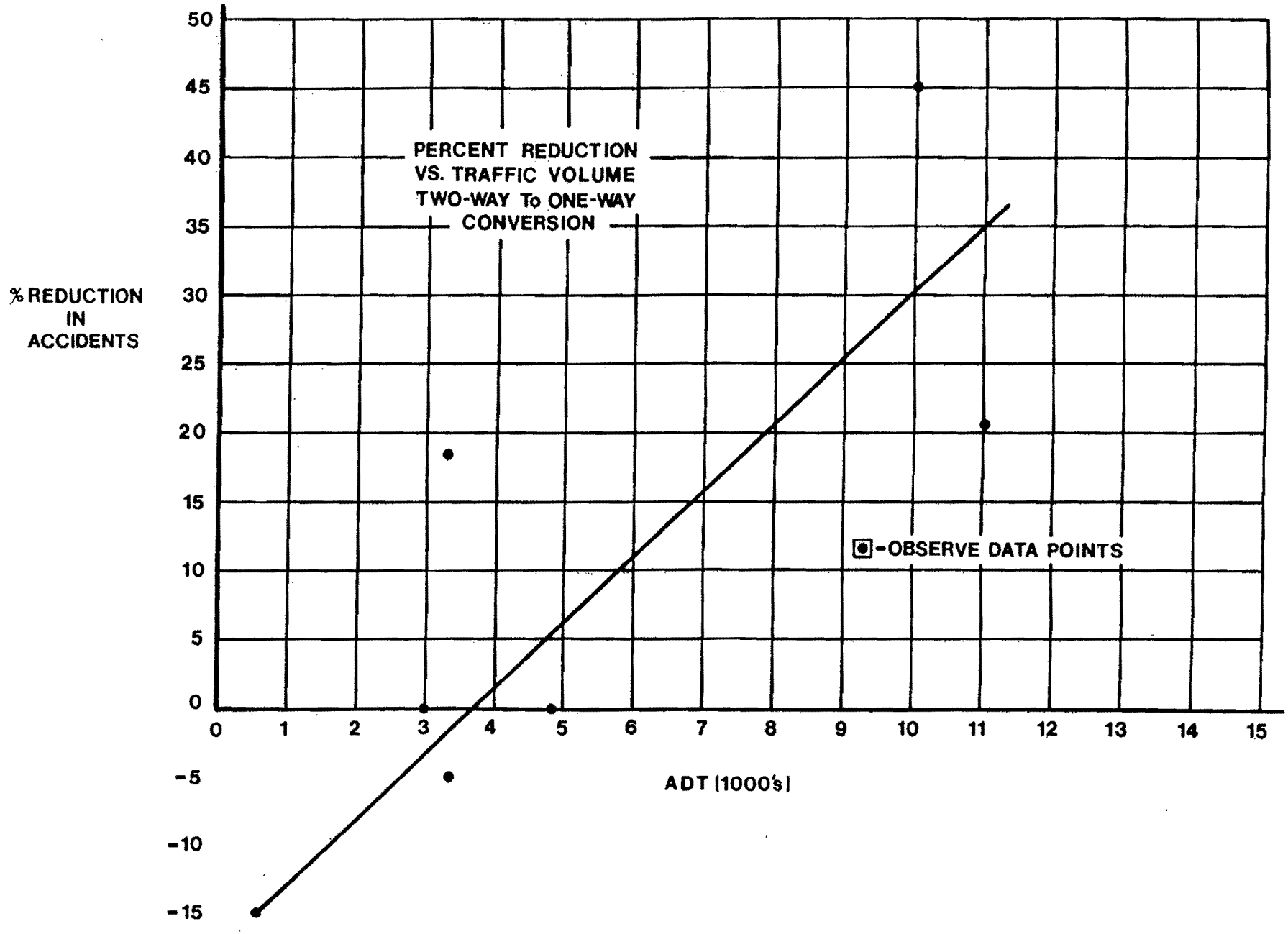

Figure 1. Trend Relationships of ADT's and Accidents

ACCIDENT COST BENEFITS OF CONVERSION TO ONE-WAY OPERATION

The data in Table 5 suggests that 73.3 percent of the frontage accidents are non-injury producing, 11.9 percent produce possible injury, 11.4 percent result in non-incapacitating injury, and 3.4 percent incapacitating injury or fatality. Using this data with an expected 20 percent reduction in accidents as a result of conversion from two-way to one-way operation, the benefit/cost ratio of conversion can be calculated. Table 6 contains the probability of an accident in each accident classification and the associated accident costs, using the accident cost assumptions below. (Figure 2 is developed from Table 6).

Assumptions

Accident Cost	
Non-Injury	$ 1,500/Accident
Possible Injury	$ 8,250/Accident*
Non-Incapacitating Injury Producing	$ 15,000/Accident
Incapacitating Injury	$150,000/Accident

Table 6. Accident Benefits of Conversion

Number of Accidents Before	Expected Reduction in Accidents	Probability of Accident Type				Dollar Value of Accidents Eliminated
		Non-Incap.	Poss. Inj.	Injury	Incap.Inj.	
5	1	0.73	.12	.11	0.03	$ 8,235
10	2	1.47	.24	.23	0.07	$ 18,135
20	4	2.93	.48	.46	0.14	$ 36,255
35	7	5.13	.83	.80	0.24	$ 62,543
50	10	7.33	1.19	1.14	0.34	$ 88,912
100	20	14.66	2.38	2.28	0.68	$177,825

*Assumed to be the average of non-injury and injury accident costs.

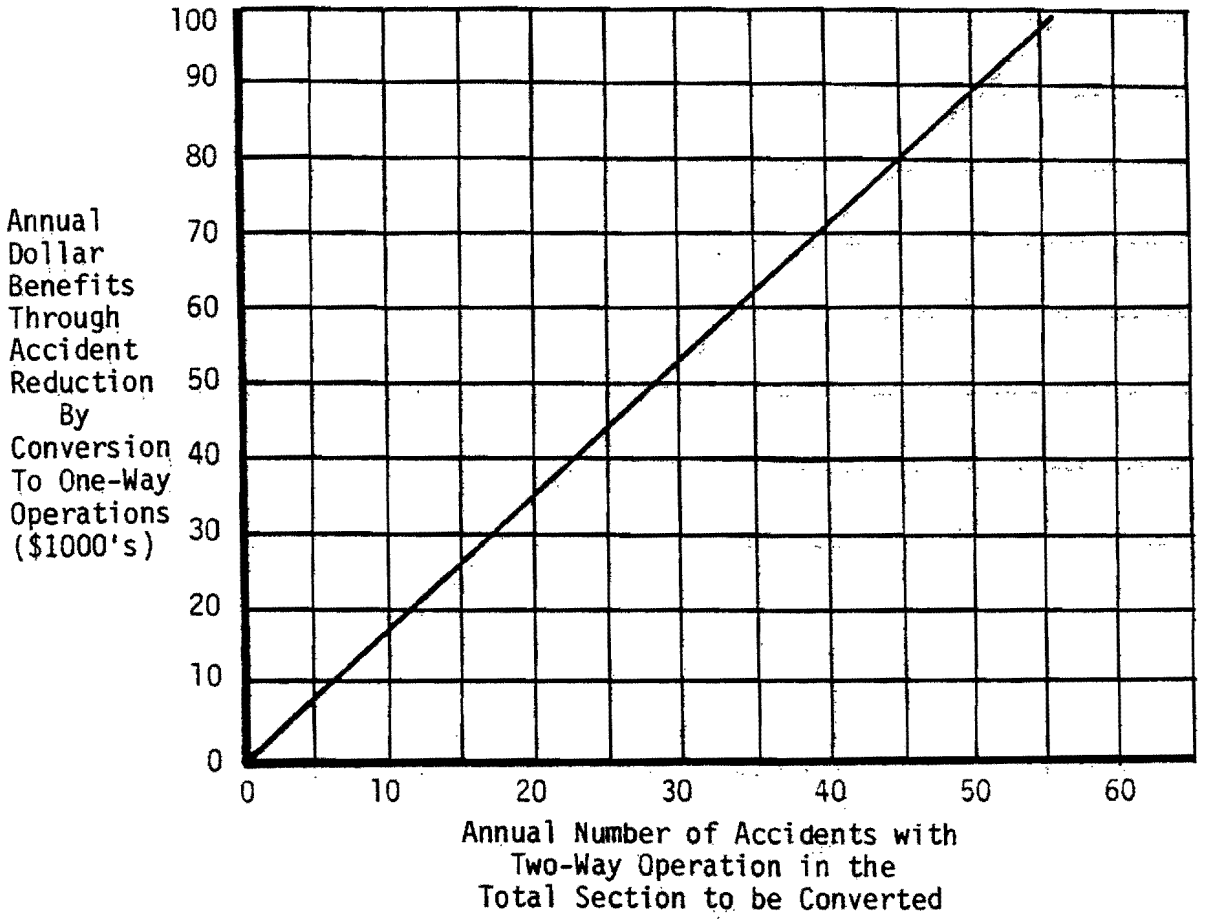

Figure 2. Annual Dollar Benefits Through Accident Reduction After Conversion to One-Way Operation vs. Annual Number of Accidents Before Conversion

The cost of conversion includes remarking, new signs and signals, and ramp geometric modifications. For example, if the remarking cost is set at 5 cents per foot, wrong way signs as $75 each in place, one-way arrows $50 each in place, $5,000 per ramp for rechannelization and allowing 20 percent for incidental costs, the conversion of one-mile of two-way frontage road to one-way operation is estimated as $53,000.

FINDINGS

The findings of this study suggest that:

1) Accidents are expected to be reduced by about 20% by conversion from two-way to one-way frontage road operation.
2) Accident severity is not expected to be significantly different by converting from two-way to one-way frontage roads.
3) Conversion to one-way frontage road operation is cost beneficial within one year when the before accident frequency is 35 or more per mile with major rechannelization of the ramps and 10 or more frontage road accidents per mile if no ramp rechannelization is required and delay is not included in the evaluation. This indicates that moderate to heavy frontage road traffic flows will be necessary in order for the reduction in accidents upon conversion to be statistically significant and cost beneficial.

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APPENDIX
Annual Variation in Accident Frequency

	Sites								
Hwy. No. Dist.	196-2 IH-35E 18	15-13 US 81 14	168-9 US 87 4	9-11 IH-30 18	271-6 US 90 12	6-6 IH-20 8	34-1 IH-20 8	33-6(a) US 83 8	33-6(b) US 83 8
1975	38	43	81	2	7				
						4	7	6	18
1976	53	47	101	7	8				
						1	19	3	21
1977	change*	change	119	7	18				
						1	26	4	26
1978	29	26	change	16	37				
						4	47	5	44
1979	43	48	93	change	change				
						change	change	change	change
1980	54	45	64	7	39				
						4	54	5	24
1981									

*Time of conversion from two-way to one-way operation.