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DEPARTMENT OF TRANSPORTATION
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May 25, 1973

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S.2.7

MEMORANDUM TO: J. R. Harbison
State Highway Engineer
Chairman, Research Committee

SUBJECT: Research Report 344; "Before-and-After Analysis of Safety Improvements on I 75 in Northern Kentucky;" KYP-56, HPR-1(8), Part III.

Following the Public Hearing by the Congressional Subcommittee at Covington in September 1971, the Research Division was assigned the responsibility for evaluating the safety features installed on the subject section of I 75. The evaluations are contained in the report submitted herewith. The analyses are based on accident statistics. The "before" statistics are from the 1969 calendar year; the "after" period began after the installation of the variable message signs and encompassed a full year also (May 1, 1971, to May 1, 1972). Comparatively, the "after" year's statistics indicate a reduction in accident rates, although the total accidents in the "after" year exceeded those in the "before" year.

The statistics do not indicate which of the features, singly or collectively, effectively reduced accident rates; the most profound statistic found is the elimination of crossing-the-median head-on collisions. Of course, this was the intent and purpose of the concrete barrier. The premise, therefore, was surely valid. However, other statistics indicate more generally that the severity of other accidents increased. Other premises might be tested in the same way if the accident records were more specific. For instance, one of the simplest forms of logic is the syllogism; it consists of a major premise, a minor premise, and a conclusion. For example, a major premise statement might be: Removal of fixed objects from the roadway will eliminate accidents involving fixed objects. The minor premise is: Sign posts are fixed objects. Conclusion: Remove sign posts. The conclusions are obvious if the premises are valid and complete. Guardrails and median barriers are fixed objects too. To include these in the minor premise statement would pose a dilemma.

Last April, I presented a brief paper before the ASCE Highway Division which was entitled: "The Safety Barrier Dilemma." The mere inference that a so-called safety device could also in some way or degree constitute a hazard offended some. Surely, in the case of the median barrier one must be willing to accept the risk of hitting the wall or other vehicles deflected by the wall as a lesser hazard than cross-median collisions even though the probability of involvement may be higher.

A similar type of statistic pertains to the impact attenuating barrier (Fitch-type) installed in the gore area of the 5th Street exit (southbound, south of the Ohio River bridge). It appears that the barrier may have increased the frequency of rear-end collisions at that site because the barrier encroaches into an area which would otherwise serve as recovery zone. The barrier was struck 18 times in the period between November 5, 1970, and April 29, 1972. Seven of these hits occurred before the beginning

of the "after" period (May 1, 1971). No severe injuries resulted from the 18 hits.

The variable message signs usually indicated fog or congested conditions ahead (inbound direction only). Although their effect on drivers remains very intangible, the benefits appear to be significant. There was a 16.1 percent decrease in the northbound accident rate; this compares with only a 1.7 percent reduction in the southbound direction; and, on this basis, it appears that pile-ups were averted by advance warning. Unfortunately, the premises regarding the variable message signs were not discrete. If, for instance, a high increase in inbound accidents had been anticipated, it would be possible now to state that the signs effectively prevented such increase and, additionally, effected a reduction in accident rates. Something appears to have effectively reduced the number of accidents in the half-mile section between Mileposts 190.0 and 190.5.

Improvement of skid resistance will surely reduce the probability of wet-weather accidents. De-slicking treatments have been deferred until a suitable sand asphalt (such as Special Provision 59-B) could be developed and confidently qualified to withstand intense traffic. An expedient trial of this anti-skid material was made on US 31-W (Muldraugh-Tip Top) during the last week of October 1972. After resurfacing, an additional year of accident records should be examined.

As traffic volume continues to rise, the accident toll will contmue to mount. A measure of success may be the mere prevention of an alarming rise in accident rates.

Attention is invited to Robert F. Baker's recent book, The Highway Risk Problem (Wiley-Interscience, 1971), which profoundly implies that certain high risks (probabilities) of accidents cannot be abated.

Only brief mention has been made in the report of the crash cushion (Fitch barrier) at the 5th Street Exit south of the bridge. This and four other barrier sites are the subject of other reports. They are listed below for reference.

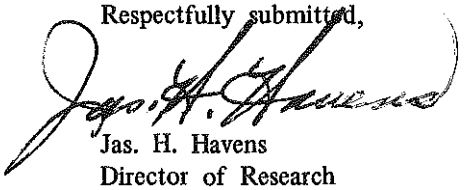
"Impact Energy Absorption Barriers," J. B. Venable; Division of Research, Kentucky Department of Highways, 1964.

"Experimental Installations of Impact-Attenuating Devices;" An Interim Report; B. S. Siria, W. M. Seymour, D. L. Cornette, and J. L. Miller; Division of Research, Kentucky Department of Highways, 1971.

"Energy Absorption Devices," Jas. H. Havens (Report presented to SASHO, Oct. 1, 1972).

"Experimental Installations of Impact-Attenuating Devices;" Final Report; KYHPR-70, HPR-1(8), Part II; Division of Research, Kentucky Department of Highways; February 1973 (No. 359).

Respectfully submitted,



Jas. H. Havens
Director of Research

JHH:dw
attachment
cc: Research Committee

TECHNICAL REPORT STANDARD TITLE PAGE

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Before-and-After Analysis of Safety Improvements on I 75 in Northern Kentucky	January 1973
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Study Title: Before-and-After Analysis of Safety Improvements on I 75 in Northern Kentucky

16. Abstract

In an attempt to evaluate the effectiveness of various safety improvements on approximately five miles of I 75 in northern Kentucky, a before-and-after analysis of accidents was conducted. Safety improvements were: 1) a variable message signing system in the northbound direction; 2) a New Jersey-type median barrier wall; and 3) general improvements such as guardrail end treatments, break-away sign installations, contour grading, etc.

Results indicate the safety improvements were effective in reducing the overall accident rate. Separate analysis also revealed that variable message signs were effective in bringing about a significant reduction in accident rates. There were no fatalities during either of the data collection periods. However, accident severity increased after the improvements. Results were influenced by low skid resistance, continued wear in wheel tracks, and increasing congestion throughout the study section.

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Accident analysis Variable message signs Concrete median barrier wall General safety improvements	

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Research Report
344

BEFORE-AND-AFTER ANALYSIS OF SAFETY IMPROVEMENTS ON I 75 IN NORTHERN KENTUCKY

KYP-56, HPR-1(8), Part III

by

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DEPARTMENT OF TRANSPORTATION
Commonwealth of Kentucky

January 1973

INTRODUCTION

Of the several safety improvements implemented on the Covington segment of I 75, only the variable message signing system was considered by the Department and the Federal Highway Administration to be experimental. Other safety improvements had become more-or-less standards for use as recommended by the "yellow book" *(1)*. The Department forethoughtfully arranged for before-and-after evaluations of not only the variable message signs, because of their innovative and experimental status, but also the New Jersey-type median wall and the various other "hardware" safety features recently implemented. This report presents analyses of accident records on approximately five miles of a six-lane section of I 75 from the Buttermilk Pike interchange in Kenton County (Milepost 187) to the Ohio state line (Milepost 192). Specific safety improvement projects evaluated were: 1) variable message signing within a section bounded by Mileposts 187.5 and 189.5, 2) a New Jersey-type median barrier wall extending from Milepost 187.5 to 191.5, and 3) a general safety improvement project throughout the study section which included upgrading of all guardrail to current safety standards, the extension of existing guardrail to fill in gaps, the installation of buried end-treatments for guardrail, the attachment of guardrail to concrete bridge end railings, the flattening of side slopes, the leveling of gores and removal of existing guardrail in gores where feasible, the installation of breakaway bases on exposed lighting standards, the elimination of butterfly sign supports in gore areas by replacement with new overhead trusses spanning the roadway, and the installation of median guardrail at twin bridges. A brief chronology of antecedent events is given below:

Sept 1962	I 75 opened to traffic
Spring 1963	Landslide brought about lane-closures
Oct 1964 - Dec 1965	Corrective construction for landslides
1967	Double-beam guardrail median barrier installed on hill*
July 1967 - May 1968	Lighting contract**
March 1968 - June 1968	Pedestrian overpass
March 1970 - Nov 1970	Concrete median barrier construction
Oct 1969 - July 1970	General safety improvements
Sept 1970 - March 1971	Variable message signs

*Six cross-median collisions occurred during the first six months of 1968 where the median barrier was not provided.

**Approximately 20 light poles, not equipped with frangible bases, were being struck each year prior thereto.

PROCEDURE

At a meeting of personnel from the Divisions of Traffic and Research, held in February 1971, it was decided that a one-year period of both before and after accidents would be necessary for a reliable evaluation of the aforementioned safety items. The antecedent data, consisting of all 1969 police-reported accidents were collected and summarized as shown in APPENDIX A. Accident rates are presented in APPENDIX B, and a collision diagram is included in APPENDIX C. The after data, consisting of all police reported accidents between May 1, 1971 (the day following final inspection of the variable message signs) and May 1, 1972, were collected and summarized. This summary of corresponding accident rates and a collision diagram are also presented in APPENDICES A, B, and C, respectively. Criteria developed in conjunction with the police agencies responsible for operating the variable message signing system are outlined in APPENDIX D. These criteria define the traffic conditions under which the various messages are to be used. The variable message signs and their locations are shown in Figure 1.

FINDINGS

Accident Summaries

Accident statistics for the calendar year 1969 and for the period May 1, 1971, through May 1, 1972, are presented as before-and-after data, respectively, in APPENDIX A.

From a summary of day of occurrence, Sunday was shown to be the day having the largest number of accidents; there was very little difference between and among the other days of the week. Figure 2 shows the daily variation of before-and-after accident occurrence.

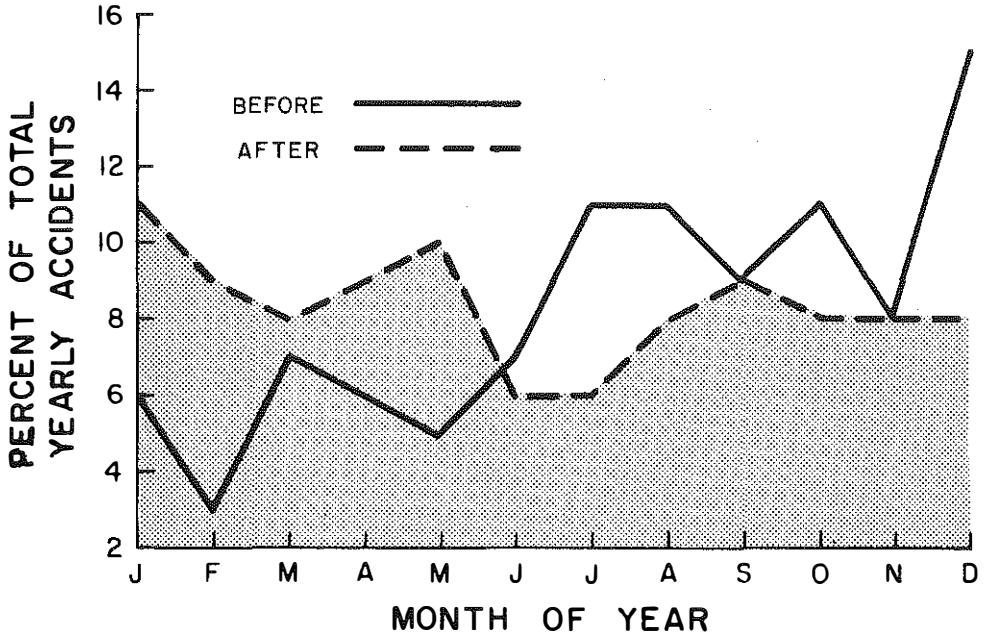

Figure 1. **Monthly Variation of Accidents**

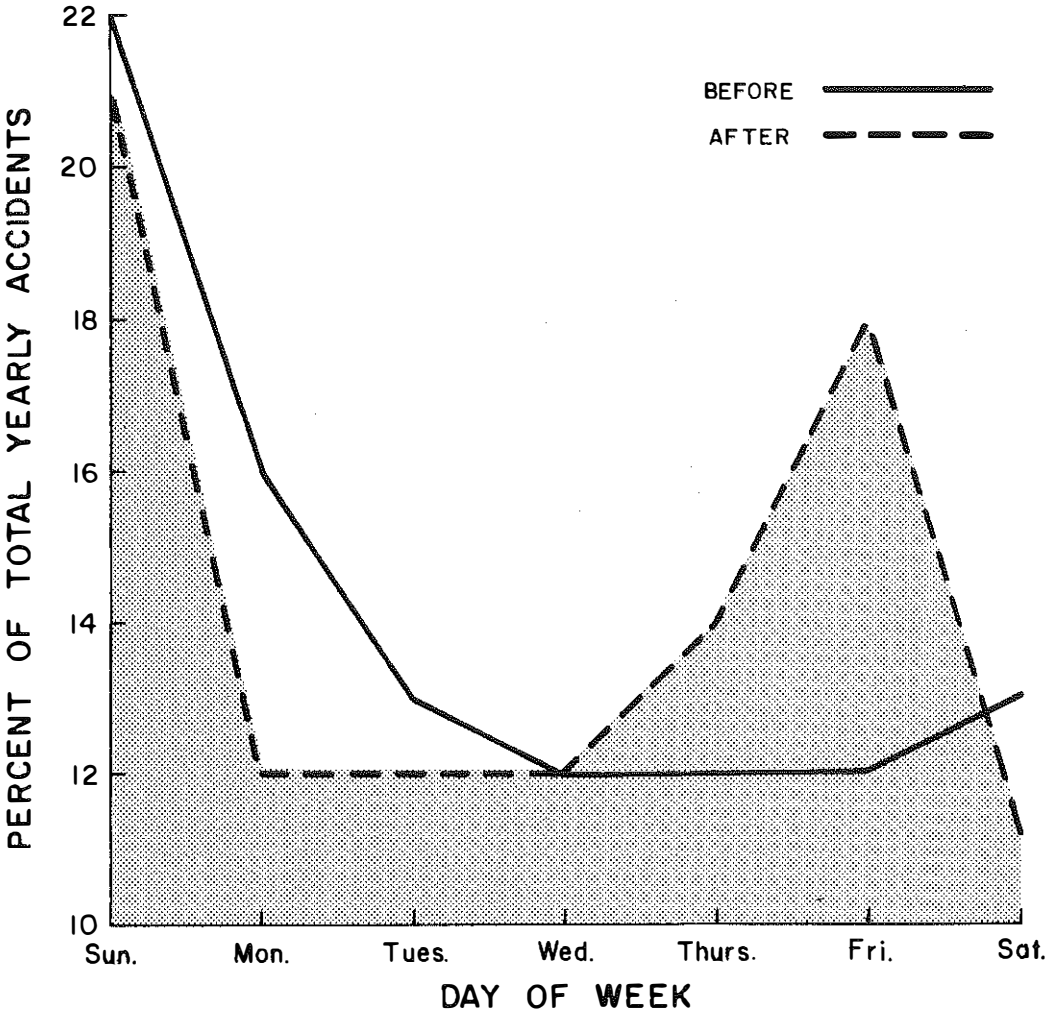

Figure 2. Daily Variation of Accidents

No definitive trend in the monthly occurrence of accidents was discernable; this is indicated in Figure 3. The vehicle in 85 percent of the accidents was a passenger car, and the driver in four of five cases was male. Approximately half of the drivers were 30 years of age or younger. The driver's residence in a third of the cases was Kenton County; about 50 percent of the total were out-of-state drivers.

Of the 416 "before" accidents, there were 149 injuries and no fatalities (Type 'K' injury). Similarly, there were 170 injuries and no fatalities associated with the 455 "after" accidents. Type 'C' injuries (those in which there was no visible injury but the occupant complained of pain or was momentarily unconscious) accounted for 66 percent of the total "before" injuries and 56 percent of the "after" injuries. While the majority of injuries were categorized as Type 'C', a significant percentage of all injuries were Type 'A' and Type 'B'. Type 'A' injuries (those in which there were visible signs of injury such as bleeding, distorted member or had to be carried away from the scene) increased from 17 percent of the "before" injuries to 26 percent of the "after" injuries. Type 'B' injuries (defined as other visible injury such as bruises, abrasions, swelling, limping, etc.) also increased; this time from 17 percent of the "before" injuries to 18 percent of the "after". Table 1 is a summary of before-and-after injuries classified by severity types.

Table 2 is a summary of before-and-after accidents classified by severity types. This summary differs from the preceding table in that each accident is classified by severity type as compared to each injury being classified by severity in Table 2. In addition, property damage only (PDO) accidents were tabulated for the purpose of showing the number of accidents which involved no injuries. As a means of representing the overall severity of all accidents each year, a severity index (SI) was calculated (Table 2). Severity index is defined as the equivalent property damage only (EPDO) divided by the total number of accidents. EPDO, represented by the expression

$$EPDO = 9.5\ (K+A) + 3.5\ (B+C) + PDO,$$

is a means of weighting all accident severity types in terms of PDO accidents.

Severity indices calculated by this method were tested statistically *(2)* and it was determined that there was a significant increase in the overall severity (at the 95 percent confidence level) from "before" to "after" improvements.

It is interesting to note that there were no fatalities during either study period as compared to a fatality rate of 2.3 (fatalities/100 million vehicle miles) reported in a summary of accidents on sections of six-lane interstate highways in 40 states *(3)*. Assuming this rate is applicable to the study section, the expected "before" and "after" fatalities would have been 3 and 4, respectively. From these observations, it would appear as if the study section was relatively safe when considering only fatalities. However, this presumption tends to indicate that the difference between a fatality and a Type 'A' injury is merely a chance happening.

Weather conditions at the time of before-and-after accidents were predominantly clear (70 percent), but a sizeable number (25 percent) occurred during rainy conditions. Rear-end accidents combined with multiple rear-end accidents accounted for 56 percent of all "before" and "after" accidents. Increases in fixed object accidents (54 percent "before" and 73 percent "after") and decreases in head-on collisions (3 percent "before" and 1 percent "after") are probably attributable to the installation of the New Jersey-type median wall. The single head-on collision after the median wall installation was the result of a wrong-way entrance on an access ramp. Table 3 is a summary of all before-and-after accident types.

The most common category of contributing circumstance which led to an accident was that of "following too closely". Next most common was the "others" category which was primarily inattentive driving.

From APPENDIX A in which accident types are classified by road surface and visibility conditions, it is apparent that dry-daylight and wet-daylight conditions account for a majority of all accidents. Dry-daylight and wet-daylight conditions also account for the majority of fixed-object accidents involving collisions with guardrails and the concrete median barrier wall. Practically no difference between before-and-after accidents, except for the replacement of guardrail collisions with median wall collisions, was shown by the summary of dry daylight and wet daylight fixed-object accidents. This difference was expected, since the concrete median wall was a replacement item for the median guardrail.

Accident Rates

Table 4 is a summary of before-and-after accident rates for 5.15 miles of I 75 from the Buttermilk Pike interchange to the Ohio state line. Rates were calculated as accidents per 100 million vehicle miles. In order to incorporate specific characteristics of certain portions of the roadway, the total length of 5.15 miles was subdivided into five sections varying from 0.40 to 1.85 miles in length. Section end-points were chosen at intersections for the purpose of simplifying the procedure for handling mainline and ramp accidents.

TABLE 1

INJURIES CLASSIFIED BY SEVERITY

	K	A	B	C	TOTAL
BEFORE					
Number	0	26	25	98	149
Percent	0.0	17.4	16.8	65.8	100.0
AFTER					
Number	0	44	30	96	170
Percent	0.0	25.9	17.6	56.5	100.0

Type K - Fatal
Type A - Visible signs of injury such as bleeding, distorted member or had to be carried away from the scene.
Type B - Other visible injury such as bruises, abrasions, swelling, limping, etc.
Type C - No visible injury but the occupant complained of pain or was momentarily unconscious

TABLE 2

ACCIDENTS CLASSIFIED BY SEVERITY

	PDO	K	A	B	C	TOTAL	SI*
BEFORE							1.97
Number	309	0	23	21	63	416	
Percent	74.3	0.0	5.5	5.1	15.1	100.0	
AFTER							2.29
Number	317	0	40	33	65	455	
Percent	69.7	0.0	8.8	7.2	14.3	100.0	

*SI (Severity Index) = EPDO/Number of Accidents
where PDO = Property Damage Only
EPDO = Equivalent Property Damage Only
EPDO = 9.5(K + A) + 3.5(B + C) + PDO

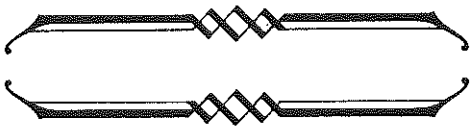

TABLE 3

ACCIDENT TYPES

	BEFORE		AFTER	
	NUMBER	PERCENT	NUMBER	PERCENT
Rear-End	162	38.9	190	41.8
Multiple Rear-End	71	17.1	60	13.2
Oblique or Sideswipe	78	18.8	99	21.8
Fixed Object	54	13.0	73	16.0
Single Vehicle (Overturn)	8	1.9	1	0.2
Head-On	3	0.7	1	0.2
Miscellaneous	40	9.6	31	6.8

TABLE 4

ACCIDENT RATES
(ACCIDENTS/100 MVM)

SECTION BOUNDARIES	BOTH DIRECTIONS					
	MAINLINE AND RAMPS CATEGORIES I AND II			MAINLINE ONLY CATEGORIES III AND IV		
	BEFORE	AFTER	PERCENT DIFFERENCE	BEFORE	AFTER	PERCENT DIFFERENCE
Buttermilk Pike - Dixie Highway Interchange	103	143	38.8	95	134	41.1
Dixie Highway - Kyles Lane Interchange	193	221	14.5	144	197	36.8
Kyles Lane - 12th Street Interchange	392	324	-17.3	360	268	-25.6
12th Street - 5th Street Interchange	373	304	-18.5	345	280	- 18.8
5th Street - Ohio State Line	642	544	-15.3	508	441	- 13.2
Overall Study Section	303	276	8.9	266	238	- 10.5
	NORTHBOUND DIRECTION					
	MAINLINE AND RAMPS CATEGORIES V AND VI			MAINLINE ONLY CATEGORIES VII AND VIII		
Buttermilk Pike - Dixie Highway Interchange	129	177	37.2	107	165	54.2
Dixie Highway - Kyles Lane Interchange	265	254	- 4.2	193	221	14.5
Kyles Lane - 12th Street Interchange	493	377	-23.5	457	336	- 26.5
12th Street - 5th Street Interchange	486	380	-21.8	452	370	- 18.1
5th Street - Ohio State Line	698	523	-25.1	619	427	- 31.1
Overall Study Section	379	318	-16.1	336	286	- 14.9

Further stratification into Categories I through VIII was necessary in order to evaluate the variable message signing system separately from the New Jersey-type median wall and the "hardware" safety improvements. Accident rate Categories I through IV were developed as a means of evaluating all safety improvements while Categories V through VIII were an attempt to isolate the effects of the variable message signing system. APPENDIX B, which is a more detailed summary of accident rates, also includes number of accidents, section lengths, and section annual average daily traffic volumes (AADT).

As a possible means of resolving the high accident characteristics exhibited throughout the study section, friction measurements were made in October 1971 using a skid-test trailer conforming to ASTM E 274-70. These friction measurements, which are listed in Table 5, are also recorded on an aerial photograph along with the "after" collision diagrams in APPENDIX C. Portions of the pavement had Skid Numbers which fell into the "Slippery" range (between 22 and 30). These data, when grouped with the ratio of wet to dry weather accident occurrences, seem to confirm the existence of a skid resistance problem. Based on data from 23 state highway departments *(4)*, the wet-to-dry ratio of 0.269 for the 23 states is considerably less than the ratios of 0.319 "before" and 0.313 "after" improvements.

High accident-frequencies throughout the study section may be related to the wheel-track wear (rut depths) which has caused the coarse aggregates to become exposed, worn flat, and polished. Studded tires have surely contributed to the abrasion of the pavement. Measurements made in June 1972 revealed that rut depths north of Kyles Lane (Milepost 189.0) generally exceeded those south of this interchange. The southbound lanes from the Ohio state line to Kyles Lane, which is upgrade throughout, have somewhat deeper ruts than the northbound lanes. The maximum was 12/32 inch. Table 6 is a summary of the rut-depth measurements throughout the study section.

From Categories I and II in Table 4, overall rates for both directions, including mainline and ramps, indicated a decrease from 303 to 276 accidents/100 million vehicle miles (MVM)) from "before" to "after" improvements. These accident rates do not compare favorably with either a statewide average of 98 on four-lane interstates and parkways *(5)* or with an average of 200 as reported from a summary of accidents on sections of six-lane interstates in 40 states *(3)*. Application of statistical tests *(6)* revealed that this decrease was not significant at the 95-percent confidence level. However, statistical tests at the 90-percent confidence level did reveal a significant decrease. Since no de-slicking treatments have been undertaken, slipperiness has probably increased from those conditions at the time of "before" data collection until "after" data were assembled. Two of the five sections under study, comprising 2.2 miles from Buttermilk Pike to Kyles Lane interchange, did show an increased accident rate. The combined rates for these two sections increased from 146 accidents/100 MVM in 1969 to 180 accidents/MVM in the 1971-1972 data collection period; a 23 percent increase.

Two-directional, before-and-after rates on the mainline only (Categories III and IV) gave results similar to those calculated for both mainline and ramps. The most notable difference was a rate decrease of 25.6 percent on the 1.85-mile section from the Kyles Lane interchange to the 12th Street interchange. Total two-directional rates for the mainline indicated that accidents/100 MVM decreased from 266 "before" to 238 "after." This decrease was significant at the 95-percent confidence level.

Categories V and VI in Table 4 and APPENDIX B are before-and-after rates for both mainline and ramps in the northbound direction only. The overall accident rate for northbound mainline and ramps decreased 16.1 percent during the before-and-after study period. This decrease (from 379 to 318) was statistically significant at the 95-percent confidence level.

Before-and-after rates from Categories VII and VIII were for the northbound direction including mainline sections only. Overall rates for these categories decreased by 14.9 percent. It was also found that the accident-occurrence rate reduction was statistically significant at the 95-percent confidence level.

In summary, it appears that accident rates for the entire section (mainline and ramps in both directions) have decreased at the 95-percent confidence level. Likewise, accident rates in the northbound direction have been reduced and the decrease was statistically significant at the 95-percent confidence level. Accidents occurring in the northbound direction were isolated for the purpose of evaluating the variable message signs and it appears that the system was effective when considering there was no other explanation for the greater accident rate reduction in the northbound than in the southbound direction.

From a report prepared for the "hearing..." in September 1971 *(7)*, accident summaries indicated that there was a steady increase in accident rates between 1967 and 1970 on the section under study. These increases took place despite a stepped up enforcement program which employed a relatively new speed measuring device called VASCAR (visual average speed computer and recorder). Conversations with Kentucky State Police officers who were Post Commanders during the two data collection periods indicated that their

TABLE 5

FRICTION MEASUREMENTS

MILEPOST MARKER	SKID NUMBERS (40 MPH)					
	NORTHBOUND LANES			SOUTHBOUND LANES		
	OUTER	MIDDLE	INNER	INNER	MIDDLE	OUTER
186.5	32	37	39	37	34	30
186.7	32	34	35			
187.0		(37)		36	32	31
187.3	32	36				
187.6	34	33 (34)	34	31	28	31
188.0	31	26	35	30	27	26
188.2	30	32	27	29	32	23
188.5	30	33	38	33	33	
188.9	31	33 (33)	37	35	33	29 (33)
189.0	28	29	30	33	34	29
189.2	29	(35)				28
189.5	31	29	36	37	33 37	27 (35)
189.6						34
189.7		(31)				29
189.8	31					
189.9	29	28	34	33	32 28	27
190.0		28		33		
190.1						
190.2				38		(33)
190.3	26	24	32 31	32		26 (34)
190.4			27		36	
190.5		22				30 (34)
190.6	28	22	31			27
190.7	28	26	27	32	29	29 30
190.8		26			28	
190.9	32 29	27	31	32 69	33	28
191.0	30					
191.1				33		
191.2	33	29	34	33	32	33
191.3		31				(36)
191.4	30	32	31	35	30	28 30
191.5			30			

Tested October 15, 1971; August 10, 1971; and (November 12, 1969).

TABLE 6

RUT DEPTH IN EACH WHEEL PATH
(ALL MEASUREMENTS ARE IN 32NDS OF AN INCH)
DATE OF MEASUREMENTS: JUNE 20, 1972

MILEPOST MARKER	SOUTHBOUND LANES			NORTHBOUND LANES		
	OUTER	MIDDLE	INNER	INNER	MIDDLE	OUTER
187.7	6-7	7-7				
188.0				4-3	7-7	7-4
189.1	6-6	7-5				
189.5	6-4	9-8			6-9	9-9
190.0					7-11	6-6
190.4	12-6	10-10	6-6		7-9	7-2
190.9	6-5	9-7	7-7			
191.1					2-9	6-6
191.3	3-4	7-7				

enforcement efforts were approximately equal. Both officers commented on the reduced fatality rate during the years of enforcement. However, with the increased overall severity rate and small number of fatalities, it would appear that the fatalities were chance happenings.

High Accident Sections

From the before-and-after collision diagrams (APPENDIX C), the four highest accident-frequency sections were isolated. For the purpose of this analysis, the entire study area was divided into sections one-half mile in length. Sections were used rather than discrete locations because it was not possible to isolate high accident-frequency locations along the accident-prone two mile stretch terminating at the Ohio state line. It was found that these four sections comprised only 40 percent of the total study area length, while the percentage of before-and-after accidents represent 62 and 68 percent, respectively. A brief summary of the number and type of accidents on each half-mile section follows. Sections are listed in the order of increasing milepost numbers with the largest number (192.0) ending at the Ohio state line.

1. *Milepost 190.0 to 190.5*

This section includes exit and entrance ramps on the southern end of the Jefferson Avenue - Euclid Avenue - I 75 interchange. There were 86 "before" accidents (21 percent of total in the study area) and 65 "after" accidents (14 percent). Wet-weather accidents decreased (from 33 to 26 percent), and nighttime accidents decreased (from 26 to 17 percent). Very little change was noted in the percentages of rear-end type accidents. Median wall accidents, which accounted for 26 percent of the "after" accidents, contributed an unusually large percentage on this section of roadway. Friction values for this section vary from a Skid Number of 24 to 32. These compare with a minimum friction value of 37 as presented in National Cooperative Highway Research Program Report 37 *(8)*. This minimum value corresponds to the demands for normal driving, cornering, and braking maneuvers by the majority of drivers under normal traffic conditions.

From the beginning of this section (Milepost 190.0) to the Ohio state line (Milepost 192.0), there is a great deal of congestion which probably accounts for the large number of both before and after accidents. There is reason to believe that the variable message signing system is in part responsible for the decrease in percentage of total accidents on this section. The five variable message signs, which were installed in the northbound direction only, are located in a two-and-one-half-mile stretch just prior to this section under discussion.

2. *Milepost 190.5 to 191.0*

This section includes the remainder of the Jefferson Avenue - Euclid Avenue - I 75 interchange and extends northward to 12th Street. The accident trend was just opposite that of the previous section; there was an increase in total accidents from 68 "before" (16 percent of the total) to 86 "after" (19 percent). This accounted for only a three-percent increase as compared to a seven-percent decrease in the preceding section. Probable causes for the large number of accidents on this section are heavy congestion, the presence of a large interchange within the limits, and the low friction levels (range from Skid Number of 22 to 32) in both directions throughout the section. A predominance of rear-end collisions (38 percent of the before and 63 percent of the after accidents) is further evidence of a high degree of congestion. Percentages of wet-weather and nighttime accidents also vary considerably between "before" and "after" periods.

3. *Milepost 191.0 to 191.5*

The 5th Street northbound exit and southbound entrance ramps account for the majority of accidents within this section. There was practically no difference between the percentage of "before" and "after" total accidents (12 and 11 percent, respectively). Congestion was again identifiable as the primary causative factor, because of the large number of accidents classified as rear-end and multiple rear-end (70 percent "before" and 72 percent "after"). Wet weather and nighttime were apparently the cause for some accidents; however, percentages of accidents occurring under these conditions was considerably less than for the other high-accident sections. Wet-weather conditions accounted for 16 percent of the "before" accidents and 21 percent of "after" accidents. Nighttime accidents were also of minor consequence when compared to the time of occurrence of accidents on the other high-accident sections (14 percent "before" and 8 percent "after"). Skid resistance for this section was somewhat higher than for the two previous sections; Skid numbers ranged between 28 and 35.

4. *Milepost 191.5 to 192.0*

Included in this section are the southbound Fifth Street exit and the northbound Fourth Street

entrance ramp to the Brent Spence Bridge. Percentages of total accidents occurring in the section remained the same for the two data collection periods (19 percent "before" and 18 percent "after"). Rear-end and multiple rear-end collisions again accounted for a majority of the accidents (58 percent "before" and 63 percent "after"). "Before" and "after" sideswipe accidents were 16 and 17 percent, respectively. An observation worthy of mention was the occurrence of 12 percent of the "after" accidents with the Fitch-type energy absorbing barrier system. The barrier system had not been installed at the beginning of the "before" data collection period. Wet-weather and nighttime conditions, combined with the ahnost constant state of congestion, resulted in the occurrence of more accidents on this section than any of the other three high-accident sections. Skid-resistance data were not available for this half-mile section.

SUMMARY

A before-after study is usually constrained by the fact that the data base is confined to a few years. In this study, two years of data were collected and analyzed in the form of one year before the improvements were made and one year after. Other before-and-after studies have utilized similar procedures. The following is a summary of observations:

1. No fatalities were recorded in either the "before" or "after" study period as compared to an average of 3.8 during each of the five preceding years.
2. There was a significant increase (95-percent confidence level) in accident severity from "before" to "after" periods.
3. Sunday was by far the most accident-prone day of the week in both "before" and "after" periods.
4. Most of the study sections were frequently in a high state of congestion as evidenced by the fact that rear-end and multiple rear-end accidents accounted for approximately 55 percent of all accidents in both periods.
5. Cross-median accidents were eliminated by installation of the median barrier wall. A single, head-on collision resulted from a wrong-way entrance on a ramp.
6. Accident rates for the mainline and ramps in both directions decreased at the 95-percent confidence level. This indicates that the overall safety improvement program was effective in reducing the accident rate.
7. Accident rates for the mainline and ramps in the northbound direction decreased significantly (95-percent confidence level) between the "before" and "after" periods. This is an indication that the variable message signing system was a contributive factor in producing a greater accident reduction rate in the northbound direction than in the southbound direction.
8. The four highest accident-frequency, one-half-mile sections were those sections just south of the Ohio state line.
9. Limited time-span studies such as this may not be altogether sufficient for evaluating the effectiveness of the overall safety improvements program. While the findings cited here indicate that this particular project was somewhat successful from the standpoint of accident abatement, other investigations may be necessary to evaluate improvements more specifically.

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APPENDIX A

ACCIDENT SUMMARY

Accident statistics for I 75 (both mainline and ramps) from the Beechwood Overpass (MP 187.2) to the Kentucky state line (MP 192) are summarized below. The "before" data consists of 416 police reported accidents that occurred in calender year 1969. The "after" data consists of 455 police reported accidents that occurred in the one-year period following the final inspection of the variable message signs, i.e., May 1, 1971 through May 1, 1972.

I. NUMBER OF ACCIDENTS REPORTED BY EACH POLICE DEPARTMENT

	BEFORE		AFTER	
	NUMBER	PERCENT	NUMBER	PERCENT
Covington Police Department	294	71	273	60
Ft. Mitchell Police Department	49	12	71	16
Ft. Wright Police Department	32	8	57	13
Kentucky State Police	27	6	37	8
Park Hills Police Department	13	3	17	3
Kenton County Police Department	1		0	
TOTAL	416	100	455	100

II. DAY OF WEEK OF THE ACCIDENT

	BEFORE		AFTER	
	NUMBER	PERCENT	NUMBER	PERCENT
Monday	65	16	54	12
Tuesday	55	13	55	12
Wednesday	49	12	53	12
Thursday	52	12	65	14
Friday	48	12	81	18
Saturday	53	13	51	11
Sunday	94	22	96	21

III. MONTH OF YEAR OF THE ACCIDENT

	BEFORE		AFTER	
	NUMBER	PERCENT	NUMBER	PERCENT
January	26	6	49	11
February	14	3	41	9
March	30	7	38	8
April	25	6	41	9
May	21	5	47	10
June	29	7	28	6
July	47	11	26	6
August	45	11	37	8
September	38	9	40	9
October	45	11	35	8
November	32	8	35	8
December	63	15	38	8

IV. TYPE OF *ERRATIC* VEHICLE

	BEFORE		AFTER	
	NUMBER	PERCENT	NUMBER	PERCENT
Passenger	333	85	382	85
Four-Tire Truck (Pickup)	23	6	32	7
Truck (Six or More Tires)	32	8	38	8
Bus	4	1	0	0

V. SEX OF *ERRATIC* DRIVER

	BEFORE		AFTER	
	NUMBER	PERCENT	NUMBER	PERCENT
Male	319	79	356	80
Female	84	21	90	20

VI. AGE OF *ERRATIC* DRIVER

	BEFORE		AFTER	
	NUMBER	PERCENT	NUMBER	PERCENT
16-20	68	19	70	18
21-25	67	18	76	20
26-30	45	12	47	12
31-35	27	7	27	7
36-40	34	9	36	9
41-45	36	10	42	11
46-50	26	7	27	7
51-55	21	6	21	5
56-60	21	6	17	4
61-65	5	1	8	2
over 65	15	4	18	5

VII. ACCIDENT INVOLVEMENT BY RESIDENCE OF *ERRATIC* DRIVER

	BEFORE		AFTER	
	NUMBER	PERCENT	NUMBER	PERCENT
Kenton County	125	32	135	31
Other County in Kentucky	74	19	84	20
Out-of-State	196	49	210	49

VIII. SERIOUSNESS OF INJURY AMONG *ALL* VEHICLE OCCUPANTS

	BEFORE		AFTER	
	NUMBER	PERCENT	NUMBER	PERCENT
Type A	26	17	44	26
Type B	25	17	30	18
Type C	98	66	96	56
Type K	0	0	0	0

Type A - Visible signs of injury, as bleeding, distorted member, or had to be carried from the scene of the accident.
Type B - Other visible injury, as bruises, abrasions, swelling, limping, etc.
Type C - No visible injury but complaint of pain or momentary unconsciousness.
Type K - Fatal

IX. WEATHER CONDITIONS AT TIME OF ACCIDENT

	BEFORE		AFTER	
	NUMBER	PERCENT	NUMBER	PERCENT
Clear	285	70	268	70
Raining	100	25	91	24
Snowing	13	3	13	3
Cloudy	6	1	7	2
Fog	2	1	3	1

X. OFFICER'S OPINION, IF ANY, OF CONTRIBUTING CIRCUMSTANCES

	BEFORE		AFTER	
	NUMBER	PERCENT	NUMBER	PERCENT
Followed Too Closely	63	49	65	47
Speed Too Fast	16	12	6	4
Had Been Drinking	12	9	17	12
Failed to Yield R.O.W.	10	8	8	6
Improper Overtaking	8	6	7	5
All Others (Primarily Inattentive)	20	16	36	26

XI. ACCIDENT TYPES

	BEFORE		AFTER	
	NUMBER	PERCENT	NUMBER	PERCENT
Rear-End	162	39	190	43
Multiple Rear-End	71	17	60	13
Oblique or Sideswipe	78	19	99	22
Fixed Object	54	13	73	16
Single Vehicle (Overturn)	8	2	1	.5
Head-On	3	1	1	.5
Miscellaneous	37	9	22	5

XII. ACCIDENT TYPES CLASSIFIED BY ROAD SURFACE AND LIGHT CONDITIONS

A. REAR-END

ROAD SURFACE CONDITION	LIGHT CONDITION	BEFORE		AFTER	
		NUMBER	PERCENT	NUMBER	PERCENT
DRY	DAYLIGHT	100	62	111	58
DRY	DARK	18	11	24	13
DRY	DAWN OR DUSK	2	1	9	5
WET	DAYLIGHT	28	17	24	13
WET	DARK	9	6	11	6
WET	DAWN OR DUSK	2	1	5	3
SNOWY OR ICY	DAYLIGHT	2	1	3	2
SNOWY OR ICY	DARK	0	0	2	1
SNOWY OR ICY	DAWN OR DUSK	1	1	1	

B. MULTIPLE REAR-END

ROAD SURFACE CONDITION	LIGHT CONDITION	BEFORE		AFTER	
		NUMBER	PERCENT	NUMBER	PERCENT
DRY	DAYLIGHT	48	68	39	65
DRY	DARK	2	3	6	10
DRY	DAWN OR DUSK	2	3	0	0
WET	DAYLIGHT	10	14	6	10
WET	DARK	1	1	3	5
WET	DAWN OR DUSK	5	7	1	2
SNOWY OR ICY	DAYLIGHT	2	3	3	5
SNOWY OR ICY	DARK	0	0	2	3
SNOWY OR ICY	DAWN OR DUSK	1	1	0	0

C. OBLIQUE OR SIDESWIPE

ROAD SURFACE CONDITION	LIGHT CONDITION	BEFORE		AFTER	
		NUMBER	PERCENT	NUMBER	PERCENT
DRY	DAYLIGHT	37	47	59	60
DRY	DARK	22	28	12	12
DRY	DAWN OR DUSK	0	0	3	3
WET	DAYLIGHT	8	10	13	13
WET	DARK	3	4	5	5
WET	DAWN OR DUSK	2	3	3	3
SNOWY OR ICY	DAYLIGHT	2	3	3	3
SNOWY OR ICY	DARK	3	4	1	1
SNOWY OR ICY	DAWN OR DUSK	1	1	0	0

D. FIXED OBJECT

ROAD SURFACE CONDITION	LIGHT CONDITION	OBJECT HIT	BEFORE		AFTER	
			NUMBER	PERCENT	NUMBER	PERCENT
DRY	DAYLIGHT	GUARDRAIL	10	19	2	3
		MEDIAN WALL	0	0	8	11
		LIGHT POLE	3	6	4	5
		MEDIAN G'RAIL	2	4	0	0
		BRIDGE PIER	1	2	0	0
		FITCH BARRIER	0	0	1	1
		MISCELLANEOUS	1	2	6	8
		SUBTOTALS	17	33	21	28
DRY	DARK	GUARDRAIL	4	7	4	5
		MEDIAN WALL	0	0	5	7
		LIGHT POLE	1	2	1	1
		MEDIAN G'RAIL	1	2	0	0
		FITCH BARRIER	0	0	3	4
		SIGN	1	2	1	1
		BRIDGE PIER	1	2	0	0
		MISCELLANEOUS	0	0	4	5
		SUBTOTALS	8	15	18	23
DRY	DAWN OR DUSK	GUARDRAIL	3	6	1	1
		MEDIAN WALL	0	0	1	1
		LIGHT POLE	1	2	0	0
		FITCH BARRIER	0	0	1	1
		BRIDGE RAIL	1	2	0	0
		SUBTOTALS	5	10	3	3
WET	DAYLIGHT	GUARDRAIL	9	17	2	3
		MEDIAN WALL	0	0	9	12
		LIGHT POLE	1	2	0	0
		MEDIAN G'RAIL	2	4	0	0
		BRIDGE RAIL	1	2	0	0
		SUBTOTALS	13	25	11	15
WET	DARK	GUARDRAIL	3	6	5	7
		MEDIAN WALL	0	0	5	7
		MEDIAN G'RAIL	1	2	0	0
		SIGN	1	2	0	0
		FITCH BARRIER	0	0	1	1
		MISCELLANEOUS	2	4	1	1
		SUBTOTALS	7	14	12	16
WET	DAWN	MISCELLANEOUS	0	0	1	1
SNOWY OR ICY	DAYLIGHT	GUARDRAIL	2	4	2	3
		FITCH BARRIER	0	0	1	1
		MEDIAN WALL	0	0	1	1
		MISCELLANEOUS	0	0	1	1
		SUBTOTALS	2	4	5	7
SNOWY OR ICY	DARK	GUARDRAIL	2	4	0	0
		SIGN	0	0	1	1
		LIGHT POLE	0	0	1	1
		SUBTOTALS	2	4	2	2
SNOWY OR ICY	DAWN	LIGHT POLE	0	0	1	1

E. SINGLE VEHICLE (OVERTURN)

ROAD SURFACE CONDITION	LIGHT CONDITION	BEFORE		AFTER	
		NUMBER	PERCENT	NUMBER	PERCENT
DRY	DAYLIGHT	3	38	1	100
DRY	DARK	3	38	0	0
WET	DARK	2	24	0	0

F. HEAD-ON

ROAD SURFACE CONDITION	LIGHT CONDITION	BEFORE		AFTER	
		NUMBER	PERCENT	NUMBER	PERCENT
DRY	DAYLIGHT	0	0	1	100
DRY	DARK	1	33	0	0
WET	DARK	2	67	0	0

G. MISCELLANEOUS ACCIDENT TYPES

ROAD SURFACE CONDITION	LIGHT CONDITION	BEFORE		AFTER	
		NUMBER	PERCENT	NUMBER	PERCENT
DRY	DAYLIGHT	11	30	6	27
DRY	DARK	5	14	5	23
DRY	DAWN OR DUSK	3	8	0	0
WET	DAYLIGHT	11	30	3	14
WET	DARK	5	14	0	0
WET	DAWN	2	5	2	9
ICY	DAYLIGHT	0	0	5	23
ICY	DAWN	0	0	1	5

APPENDIX B

ACCIDENT RATES

ACCIDENTS/ 100 Million Vehicle Miles of Travel = N(100,000,000)/T x L x A

where N = Number of accidents in time period,
T = Time period in days,
L = One-way length of roadway in miles, and
A = Annual average daily traffic for time period.

CATEGORY I. "BEFORE" RATES (1969)
TWO DIRECTIONS, MAINLINE AND RAMPS

SECTION	NUMBER OF ACCIDENTS	LENGTH MILES	AADT	ACCIDENT RATE
Buttermilk Pike - Dixie Highway Interchange	27	1.20	60,000	103
Dixie Highway - Kyles Lane Interchange	48	1.00	68,300	193
Kyles Lane - 12th Street Interchange	194	1.85	73,300	392
12th Street - 5th Street Interchange	66	0.70	69,300	337
5th Street - Ohio State Line	81	0.40	86,300	642

Overall Rate = .233(103) + .194(193) + .359(392) + .136(337) + .078(642) = 303

CATEGORY II. "AFTER" RATES (MAY 1, 1971 - MAY I, 1972)
TWO DIRECTIONS, MAINLINE AND RAMPS

SECTION	NUMBER OF ACCIDENTS	LENGTH MILES	AADT	ACCIDENT RATE
Buttermilk Pike - Dixie Highway Interchange	47	1.20	74,800	143
Dixie Highway - Kyles Lane Interchange	66	1.00	82,000	221
Kyles Lane - 12th Street Interchange	191	1.85	87,200	324
12th Street - 5th Street Interchange	64	0.70	82,400	304
5th Street - Ohio State Line	79	0.40	99,500	554

Overall Rate = .233(143) + .194(221) + .359(324) + .136(304) + .078(544) = 276

CATEGORY III. "BEFORE" RATES (1969)
TWO DIRECTIONS, MAINLINE ONLY

SECTION	NUMBER OF ACCIDENTS	LENGTH MILES	AADT	ACCIDENT RATE
Buttermilk Pike - Dixie Highway Interchange	25	1.20	60,000	95
Dixie Highway - Kyles Lane Interchange	36	1.00	68,300	144
Kyles Lane - 12th Street Interchange	178	1.85	73,300	360
12th Street - 5th Street Interchange	61	.70	69,300	345
5th Street - Ohio State Line	64	.40	86,300	508

Overall Rate = .233(95) + .194(144) + .359(360) + .136(345) + .078(508) = 266

CATEGORY IV. "AFTER" RATES (MAY 1, 1971 - MAY 1, 1972)
TWO DIRECTIONS, MAINLINE ONLY

SECTION	NUMBER OF ACCIDENTS	LENGTH MILES	AADT	ACCIDENT RATE
Buttermilk Pike - Dixie Highway Interchange	44	1.20	74,800	134
Dixie Highway - Kyles Lane Interchange	59	1.00	82,000	197
Kyles Lane - 12th Street Interchange	158	1.85	87,200	268
12th Street - 5th Street Interchange	59	.70	82,400	280
5th Street - Ohio State Line	64	.40	99,500	441

Overall Rate = .233(134) + .194(197) + .359(268) + .136(280) + .078(441) = 238

CATEGORY V. "BEFORE" RATES (1969)
NORTHBOUND DIRECTION ONLY, MAINLINE AND RAMPS

SECTION	NUMBER OF ACCIDENTS	LENGTH MILES	AADT	ACCIDENT RATE
Buttermilk Pike - Dixie Highway Interchange	17	1.20	30,000	129
Dixie Highway - Kyles Lane Interchange	33	1.00	34,150	265
Kyles Lane - 12th Street Interchange	122	1.85	36,650	493
12th Street - 5th Street Interchange	43	.70	34,650	486
5th Street - Ohio State Line	44	.40	43,150	698

Overall Rate = .233(129) + .194(265) + .359(493) + .136(486) + .078(698) = 379

CATEGORY VI. "AFTER" RATES (MAY 1, 1971 - MAY 1, 1972)
NORTHBOUND DIRECTION ONLY, MAINLINE AND RAMPS

SECTION	NUMBER OF ACCIDENTS	LENGTH MILES	AADT	ACCIDENT RATE
Buttermilk Pike - Dixie Highway Interchange	29	1.20	37,400	177
Dixie Highway - Kyles Lane Interchange	38	1.00	41,000	254
Kyles Lane - 12th Street Interchange	111	1.85	43,600	377
12th Street - 5th Street Interchange	40	.70	41,200	380
5th Street - Ohio State Line	38	.40	49,750	523

Overall Rate = .233(177) + .194(254) + .359(377) + .136(380) + .078(523) = 318

CATEGORY VII. "BEFORE" RATES (1969)
NORTHBOUND DIRECTION ONLY, MAINLINE ONLY

SECTION	NUMBER OF ACCIDENTS	LENGTH MILES	AADT	ACCIDENT RATE
Buttermilk Pike - Dixie Highway Interchange	14	1.20	30,000	107
Dixie Highway - Kyles Lane Interchange	24	1.00	34,150	193
Kyles Lane - 12th Street Interchange	113	1.85	36,650	457
12th Street - 5th Street Interchange	40	.70	34,650	452
5th Street - Ohio State Line	39	.40	43,150	619

Overall Rate = .233(107) + .194(193) + .359(457) + .136(452) + .078(619) = 336

CATEGORY VIII. "AFTER" RATE (MAY 1, 1971 - MAY 1, 1972)
NORTHBOUND DIRECTION ONLY, MAINLINE ONLY

SECTION	NUMBER OF ACCIDENTS	LENGTH MILES	AADT	ACCIDENT RATE
Buttermilk Pike - Dixie Highway Interchange	27	1.20	37,400	165
Dixie Highway - Kyles Lane Interchange	33	1.00	41,000	221
Kyles Lane - 12th Street Interchange	99	1.85	43,100	336
12th Street - 5th Street Interchange	39	.70	41,200	370
5th Street - Ohio State Line	31	.40	49,750	427

Overall Rate = .233(165) + .194(221) + .359(336) + .136(370) + .078(427) = 286