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A HIGH-ACCIDENT SPOT-IMPROVEMENT PROGRAM

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INFORMATIVE ABSTRACT

As a result of an extensive before-and-after accident study, the high-accident location, spot-improvement program in Kentucky, although not a costly program, was found to have significantly decreased the number of motor vehicle accidents. Favorable benefit-cost ratios indicated that the cost of the program has represented a good investment in comparison with the resultant savings in accident costs. The spot-improvement program had little effect on average accident severity as measured by a severity index. Detailed analysis of available accident data showed that, for studies of the type reported, the 12-month period immediately prior to the date of identification of a high-accident location is not a reliable period for representing the actual long-term "before" accident experience. A much more acceptable period is the 12 months beginning 2 years in advance of the date of identification. Further analysis also showed that a route segment of 0.1 mile (0.16 km) is not of sufficient length for properly identifying high-accident locations or for accumulating accident statistics to support a before-and-after study. Since only slightly more than five percent of the identified high-accident locations were judged to warrant improvement, the procedure used in Kentucky for identifying high-accident locations, namely, those having three or more accidents at a 0.1-mile (0.16-km) location during a 12-month period, was found to be inefficient.

Keywords: High-accident locations, Safety, Accident study, Cost-benefit ratio, Severity index, Benefit-cost analysis, Statistical analysis

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INTRODUCTION

In an attempt to reduce the large number of motor vehicle accidents occurring annually throughout the United States, many safety improvement programs have been initiated. One such program, in operation within the Kentucky Bureau of Highways since 1968, involves minor safety improvements at rural high-accident locations. To date, the program has been of limited extent, generally entailing total annual expenditures of $100,000 to $150,000. Improvements made under this program consist of installation or modification of traffic control devices and minor construction and corrective maintenance. Direct expenditures have averaged about $500 per project.

This program has been in effect for over 6 years, and a large number of spot improvements have been made. The primary purpose of this study was to determine the overall effectiveness of the spot-improvement program in Kentucky. It is supported by one of the recommendations of the Special AASHTO Committee on Traffic Safety *(12)*; that is, to make follow-up studies for evaluating the effectiveness of corrective measures undertaken in spot-improvement programs.

Spot-Improvement Program in Kentucky

The spot-improvement program in Kentucky has operated in the following manner. Each month, a computer printout identifies all 0.1-mile (0.16-km) locations where three or more accidents have occurred during the previous 12-month period. The source of this list is a statewide accident file maintained by the Department of Justice and containing a record of each accident investigated and reported by state police. Unfortunately, Kentucky has not had uniform accident reporting on a statewide basis; thus, only state-police-reported accidents are available for use in this program. The accidents in most urban areas are not investigated by state police and, therefore, urban locations have generally been excluded from the spot-improvement program. State police report the location of each accident to the nearest 0.1 mile (0.16 km) along a route from a suitable reference point. Accidents occurring on the minor roadways at intersections are assigned to the major roadways.

The monthly list of high-accident locations together with copies of all accident reports for these locations are screened by highway engineers in the central office and the districts to determine which locations should be investigated in the field. Field inspections are not made at locations where, in the opinion of the engineers, the 12-month accident history is unrelated to correctable site deficiencies. Locations which have been investigated previously and corrected to the point of major reconstruction are not normally revisited. At the present time, approximately ten percent of the locations in the monthly computer list are investigated in the field.

Each location warranting a field inspection is assigned to a investigative team. This team, composed of traffic engineers, maintenance engineers, and police personnel, investigates the location and formulates its recommendations. Recommended improvements are then implemented through the spot-improvement program.

A subsequent study *(18)* has resulted in a change in the method of identifying hazardous locations on rural highways. The new procedure combines a Number Method, EPDO Method, Rate-Quality Control Method, and objective input from citizens and state police. This procedure is used to identify hazardous spots 0.3 mile (0.48 km) long and sections 1 and 3 miles (1.61 and 4.83 km) long which should be investigated in the field.

Evaluations Conducted by Other States

While spot-improvement programs vary widely from state to state, their effectiveness in improving highway safety has generally been established. Evaluations of program effectiveness are based primarily on a study of the before and after accident experiences at the improved locations. Most commonly, the before and after periods are of either 1-year *(9, 13)* or 2-years *(5, 6)* duration. In any event, it is imperative that the before and after periods encompass identical calendar months so as to minimize the influence of fluctuations in accident patterns associated with seasonal influences *(8)*. Preferably each of the paired periods is an integer-multiple of 12 months.

Methods for evaluating the effectiveness of a program or of an individual improvement are somewhat diverse. One measure of effectiveness is the change in the accident pattern from the before to the after period. Percentage changes in the total number of accidents and in the total accident rate have both been used. To evaluate changes in accident severity, some investigators have relied on the percentage change in the number or rate of fatal and(or) injury accidents *(4, 7, 9)* while others have evaluated changes in a severity index *(1, 8)*. The chi-square test *(8, 9)* and the Poisson test *(1)* are useful in determining the statistical significance of the findings. Another common measure of effectiveness is the benefit-cost ratio or the difference between benefits and costs *(7, 8)*. Such a measure is useful in ascertaining if the cost of the program is a good investment in relation to savings resulting from accident reduction. Finally, several states have added depth to their evaluations by classifying improvements by type and evaluating separately the effectiveness of each type *(4, 7, 8)*.

STUDY PROCEDURES

The spot-improvement program in Kentucky was evaluated using the following three measures of effectiveness:

1. change in the number of accidents between the before and after periods,
2. benefit-cost ratio, and
3. change in the severity index between the before and after periods.

Appropriate statistical tests *(1, 14)* were used to determine the significance of the results obtained with the first and third measures.

For each location, before and after periods were identified by a single reference date. For locations where an improvement was made, the reference date was taken as the improvement completion date. Where no improvement had been recommended, the reference date was taken as the date of field investigation.

Separate evaluations were made for two different before-and-after periods. In the first case, data obtained during the first year before the reference date were compared with those obtained during the first year after the reference date. Accident data were available for 578 such locations, including all locations investigated between January 1, 1968, and June 30, 1971, whether or not improvements had been recommended by the field teams. In the second case, data obtained during the second year before the reference date (a 12-month period) were compared with those obtained during the first year after the reference date. The purpose of this evaluation was primarily to reflect the long-term accident experience in the before period. Accident data were available for 302 such locations, including all locations investigated between January 1, 1969, and June 30, 1971.

Each high-accident location had been identified to the nearest 0.1 mile (0.16 km) along a particular route. A complete analysis was performed including only these accidents that had been reported as occurring in that exact 0.1-mile (0.16-km) interval. In recognition of accident reporting errors and the broader range of influence of many high-accident locations, a second complete analysis was performed including all accidents reported as occurring within a 0.3-mile (0.48-km) interval centered on the 0.1-mile (0.16-km) location.

To calculate benefit-cost ratios, both costs and benefits had to be estimated. The costs were defined to include both the direct cost of any improvements and the administrative costs ($500 per location investigated). Where no improvements had been recommended by the field team, the benefit was assumed to be zero. Where improvements had been made, the benefit was defined as the difference in accident costs between the 12-month before and after periods.

Two different methods were used to determine accident costs. In the more conservative method, only direct costs were used. Components of direct costs include property damage, medical costs, loss-of-use-of-vehicle costs, value of work time lost, legal costs, and other such items. The following direct accident costs were used in this study: $9,880 for a fatal accident, $4,570 for an A-type injury accident (visible signs of injury, such as bleeding or distorted member, or had to be carried from the scene), $2,635 for a B-type injury accident (other visible signs of injury such as bruises, abrasions, swelling, and limping), $1,525 for a C-type injury accident (no visible sign of injury but occupant complained of pain or was momentarily unconscious), and $585 for a property damage accident. These values were based on Illinois data *(3)* suitably adapted to Kentucky conditions *(2, 16)* and updated by means of appropriate economic indicators *(14, 15)*. In the second method, total accident costs, including both direct and indirect components, were used. The indirect component of accident cost consists mainly of losses of future earnings. The following total accident costs for 1970, as determined by the National Safety Council *(17)*, were used in this study: $45,000 for each fatality, $2,700 for each non-fatal injury, and $400 for each property damage accident. The direct cost of a property damage accident as used in this study exceeds the total cost as derived by the National Safety Council. This results from the fact that basically all property damage accidents used in the direct-cost calculations were rural accidents while the National Safety Council costs are based on a more uniform distribution of rural and urban accidents. The costs of rural accidents generally exceed those of urban accidents.

Finally, the severity index (SI), used herein to reflect an important measure of effectiveness, indicates the average severity of accidents and is computed by dividing the number of equivalent property-damage-only (EPDO) accidents by the total number of accidents. The number of EPDO accidents is a total in which fatal and injury accidents are weighted according to accident costs and relative frequency of occurrence. The following relationship was developed for use in this study *(2)*:

$$EPDO = 9.5\ (K + A) + 3.5\ (B + C) + PDO \qquad (1)$$

in which EPDO = number of equivalent property-damage-only accidents, K = number of fatal accidents, A = number of A-type injury accidents (accidents in which an A-type injury is the most severe sustained), B = number of B-type injury accidents, C = number of C-type injury accidents, and PDO = number of property-damage-only accidents.

RESULTS

Table 1 summarizes locations investigated under the spot-improvement program during the period from January 1, 1968, through June 30, 1971. A total of 578 locations were investigated during this period. Also, 35 investigations were made at locations which had been previously studied. A majority of these field investigations (60 percent) resulted in the recommendation and completion of improvements. Table 2 summarizes the safety measures and the types of improvements used at the 349 improved locations. An average of 2.1 corrections or adjustments were made at each location.

1-Year Before-and-After Comparisons

Table 3 summarizes accident data for those locations where improvements were recommended and completed under the spot-improvement program. The numbers and types of accidents are given for the 1-year periods immediately preceding and immediately following the dates of completion of the improvements. The numbers of accidents of all types were greatly reduced in the after period. The reduction in total number of accidents was found to be 43 percent and 59 percent for 0.3-mile (0.48-km) and 0.1-mile (0.16-km) segments, respectively. Even greater reductions in the number of fatalities were observed -- 55 percent and 70 percent for the 0.3-mile (0.48-km) and 0.1-mile (0.16-km) segments, respectively. These accident reductions were found to be statistically significant at the 0.05 level using the chi-square test. Thus, on the basis of 1-year before and 1-year after comparisons, the spot-improvement program was shown to have been highly effective in reducing the number of accidents. It was also found, as had been anticipated, that the percentage reductions in accidents were greater for the 0.1-mile (0.16-km) segments than for the 0.3-mile (0.48-km) segments. As the distance interval increases, the influence of a hazardous site or location generally diminishes.

The entire program, including not only those locations where improvements were completed but also locations where improvements were not recommended by the investigative teams, was evaluated by the benefit-cost technique, as summarized in Table 4. All ratios are much greater than 1.0 -- regarded as the minimum value needed to economically justify the spot-improvement program. This is especially significant since the benefits in these calculations accrued in the short period of 1 year following completion of the improvement. As expected, the benefit-cost ratios were greater for the 0.3-mile (0.48-km) segments than for the 0.1-mile (0.16-km) segments and for the total accident cost procedure than for the direct accident cost procedure.

Changes in accident severity were analyzed by means of the previously-defined severity index. Average accident severity decreases as the index decreases. Table 5 indicates that only a very slight reduction in average accident severity, which was found to be statistically insignificant, resulted from these improvements. Table 5 also shows that a small reduction in the percentage of fatal accidents did occur; this was offset in the severity-index calculations by a small increase in the percentage of non-fatal, injury accidents. It appears, therefore, that the spot-improvement program had a disappointingly minor effect on accident severity.

Severity indices were also computed for data reported by other states. Equation 1 was used in these computations assuming that 30 percent of the reported injury accidents were of the A-type, a percentage representative of rural conditions in Kentucky. In Wisconsin, the average severity index for 136 projects in the 1967 Highway Safety Project decreased from 2.74 to 2.53 *(4)*. In California, the average severity index for 259 spot-improvement projects costing about $4,700,000 decreased from 2.70 to 2.58 *(13)*. In Virginia, the average severity index for 382 safety projects completed in 1968 and costing about $30,000,000 decreased from 2.28 to 2.06 *(7)*. Finally, in Ohio, the average severity index for 27 projects completed under the 1970 Traffic Safety Program decreased quite significantly from 3.12 to 2.49 *(9)*.

Why the safety improvement programs in other states resulted in more significant reductions in average accident severity than the spot-improvement program in Kentucky is a matter for conjecture only. Perhaps it is due in part to the fact that, as a whole, improvements in Kentucky were much less extensive and much less costly than those in other states. What is more important, however, is that the program in Kentucky did result in significant reductions in all types of accidents with a most favorable benefit-cost performance.

Peak-Year Effect in High-Accident Site Investigations

Locations identified as high-accident sites based on accident experience for a relatively short time period such as 1 year may be truly hazardous locations reflecting physical attributes and traffic characteristics at these locations or they may be simply locations which, due to a series of conditions and circumstances that may be termed random events, had an unusually severe and unrepresentative accident experience during that period. Fortunately, the randomness inherent in accident data can be adequately treated by considering the number of accidents per unit of time on highway sections of reasonably comparable characteristics to follow a Poisson distribution *(11)*. Thus, accident occurrences may be described by

$$P\ (N = x) = e^{-a}a^{x}/x!, \tag{2}$$

in which P (N = x) = probability that the number of accidents (N) occurring at a particular location during a given time period is equal to x and a = expected number of accidents at that same location during the same period of time. If m is the number of vehicle miles (vehicle kilometers) of travel observed for the location during the given period and λ is the expected accident rate expressed in terms of accidents per vehicle mile (vehicle kilometer) of travel, then

$$a = \lambda m. \tag{3}$$

Figure 1, which was constructed assuming a Poisson distribution, provides a useful demonstration of the effects of accident randomness on the identification of high-accident locations. Assume, for example, that the criterion for identifying a high-accident location is three accidents in a given time period (N = 3). If the expected number of accidents for a given category of locations is two, then approximately 32 percent of such locations will be classified as high-accident locations, a clear case of mistaken identity. If the expected number of accidents is four, then approximately 76 percent of the locations will be classified as high-accident locations. The remaining 24 percent will be incorrectly identified as low-accident locations. To conclude, then, any list of "so-called" high-accident locations identified from accident statistics compiled within a short period of time will invariably include some locations which are actually low-accident locations and exclude others which are actually high-accident locations.

In this study, all locations experienced a relatively large number of accidents in the year immediately prior to their identification as high-accident locations; otherwise, they would not have been so identified. Thus, the method of selection tends to define the "before" year as a peak accident year. If the peaks were the result of spurious or random occurrences, the number of accidents should tend to re-normalize in the "after" year. To evaluate this "peaking" effect, the combined accident history of the unimproved locations was compared to that of the improved locations. Figure 2 shows the total number of accidents over a 4-year period at 99 locations identified as high-accident locations but for which the investigative teams recommended no improvements be made. For both the 0.3-mile (0.48-km) and 0.1-mile (0.16-km) segments, it is obvious that the number of accidents which occurred during the 1-year period immediately prior to the reference date is abnormally high as a result of randomness in the accident data and the method for identifying high-accident locations. This is of crucial importance since a conventional before-and-after comparison of these locations would yield the obviously incorrect conclusion that significant benefits had been derived even at locations where no improvements had been made! It is also especially important to note that the second-year before accident data is similar to the first- and second-year after data and, therefore, must be considered as more representative of the long-term accident experience than the first-year before data.

Figure 3 is a similar presentation for 109 improved locations. Here, too, the first-year before shows many more accidents than the other years studied. The important difference between Figures 2 and 3 is that, for improved locations, the second-year before accidents significantly exceeded in number both the first- and the second-year after accidents -- indicating the real value of the safety improvements.

The phenomenon demonstrated in Figures 2 and 3 can be explained through further use of the Poisson distribution. The probability distribution of accidents for locations that have been identified as high-accident locations can be assumed to be a truncated Poisson distribution. Figure 4 shows the expected number of accidents for such high-accident locations as a function of both the criterion for identification (N) and the stable accident experience. For example, if the expected number of accidents in the original population is three, the expected number of accidents for all locations having three or more accidents -- that is, the so-called high-accident locations -- is 4.15.

Figure 4 provides a ready, convenient explanation of the phenomenon of Figures 2 and 3. Assume that the long-term accident experience for the 99 no-improvement-recommended locations of Figure 2 is the average of the second-year before and first- and second-year after data -- that is, 1.45 accidents per 0.1-mile (0.16-km) location. From Figure 4, the expected number of accidents in the first-year before, that is, for all such locations having three or more accidents, is 3.45 accidents per location or 342 accidents for all 99 locations. This compares quite favorably with the 346 accidents that were observed. A similar analysis is useful in explaining that portion of Figure 3 pertaining to 0.1-mile (0.16-km) segments. If the second-year before accident experience is representative of the stable, long-term before experience, 382 accidents would be expected in the first-year before data. This compares favorably with the 362 accidents that were observed.

The conclusion is obvious: accident data obtained for "high-accident" locations during the 12-month period immediately prior to their identification are not reliable indicators of the actual long-term before accident experience. A much more reliable indicator of the before-improvement accident experience is the second-year before accident data.

Modified Before-and-After Evaluations

The peak-year effect in high-accident site investigations could be eliminated if the evaluation considered only those accidents that the improvement was designed to eliminate. This would mean that each accident report would have to be studied in detail to eliminate those due to random events. Attempting to obtain the accident reports and then studying them in detail would be a tremendous task. The following method of evaluation was performed in lieu of that time-consuming process.

Considerations of the "peaking" effect led to the adoption of a modified procedure for evaluating the effectiveness of the spot-improvement program. In this analysis, the before period was represented by the second year before the reference date; and, as before, the after period was represented by the first year after the reference date. A total of 168 improved locations were thus available for evaluation, each of which had a reference date between January 1, 1969, and June 30, 1971. There were also 134 investigations during this time period which resulted in no improvements being recommended. The same procedures were used in evaluating this modified accident data set as were used in the initial evaluation.

Table 6 summarizes accident data for those locations where improvements were recommended and completed. The numbers and types of accidents are given for the second year preceding and the first year following the dates of completion of the improvements. The total numbers of accidents were reduced by the rather large amounts of 25 percent and 31 percent for the 0.3-mile (0.48-km) and 0.1-mile (0.16-km) segments, respectively. These reductions were found to be statistically significant at the 0.05 level using the chi-square test. Using the method of paired comparisons *(10)*, the reduction was statistically significant at a level of 0.005. The percentage reductions in fatal accidents were only slightly greater than the percentage reductions in the total number of all accidents. Also, as observed in the original evaluation, percentage reductions in accidents were greater for the 0.1-mile (0.16-km) segments than the 0.3-mile (0.48-km) segments.

Benefit-cost ratios, computed using the same procedure as before, are shown in Table 7. Ratios representing both accident cost procedures were greater than 1.0 for the 0.3-mile (0.48-km) segments. A benefit-cost ratio less than 1.0 was observed only for direct costs for the 0.1-mile (0.16-km) segments; it would be greater than 1.0 if the time period to justify the improvement costs were extended to approximately 18 months, certainly a justifiable extension.

Table 8 shows there were no significant changes in accident severity between the before and after periods, which agrees with the conclusion from the prior analysis. Percentages of the various types of accidents also demonstrate few significant changes in the before and after accident severity.

In conclusion, the results of the modified evaluation are thought to be more representative of actual conditions than the original evaluation. They provide conclusive documentation of the significant accident reductions occasioned by the spot-improvement program in Kentucky as well as the economic viability of this program.

Length of Segments

All prior evaluations have been duplicated for both 0.1-mile (0.16-km) and 0.3-mile (0.48-km) segments. While the primary conclusions of this study are insensitive to segment length, its importance both in identifying high-accident sites and in evaluating spot improvements should be emphasized. Three significant factors must be realized. First, error in accurately reporting the location of an accident is inevitable due to field conditions surrounding an accident investigation and the fact that field reference markers are usually placed no more frequently than one per mile (1.6 kilometers). Second, the area of influence of a particular hazardous site often extends considerably beyond 0.1 mile (0.16 km). Third, accidents are fortunately rare occurrences and their historical patterns reflect the apparent randomness in these events.

A brief example is useful for illustrating the effect of randomness. It is assumed that the set of locations under consideration experiences reasonably consistent traffic volumes and that a high-accident location has been defined to be one which has 30 or more accidents during a given time period per mile (18.6 per kilometer). This corresponds to an accident rate of about 10 accidents per million vehicle miles (6.2 accidents per million vehicle kilometers) for traffic volumes averaging about 8,000 vehicles per day. It is further assumed that accident patterns can be adequately described by a Poisson distribution. Figure 5 shows the effect that varying segment lengths have on the probability that a particular location is identified as a high-accident location, that is, has 30 or more accidents per mile (18.6 per kilometer). It is desired to select a segment length that maximizes the probability of identifying as high-accident locations those having expected accident rates equal to or greater than 30 accidents per mile (18.6 per kilometer) and to minimize the probability of identifying as high-accident locations those having expected accident rates less than 30 accidents per mile (18.6 per kilometer). Figure 5 demonstrates that this objective can be best realized by selecting a longer segment length. Examine, for example, that curve representative of locations having expected accident rates of 20 accidents per mile (12.4 per kilometer). If the segment length is taken to be 0.1 mile (0.16 km), then the probability of identifying these "safe" locations as being "hazardous" is 0.32. If, on the other hand, the segment length is 0.5 mile (0.80 km), the probability reduces to 0.08, a very desirable reduction indeed. This example serves to illustrate only the probability aspects of the problem and excludes the significant additional effects of reporting errors and range of impact of a hazardous site.

For the purpose of identifying high-accident locations, it is apparent that a segment length in excess of 0.1 mile (0.16 km) is desired. Lengths of 0.3 mile (0.48 km) or even 0.5 mile (0.80 km) should pose no difficulty to the investigative team which can readily isolate any particularly hazardous site within such a limited length. For the purpose of evaluating a spot-improvement program, a segment length in excess of 0.1 mile (0.16 km) is again desired regardless of the length used in the identification program. As verified by the data of this study, selection of a longer length will usually (1) increase the reduction in the total number of accidents, (2) decrease the percentage reduction in accidents, and (3) increase the calculated benefits of the spot improvement to a level better approximating the real benefits.

Type of Improvement

A cursory examination was made of the effectiveness of the spot-improvement program for each of four broad classes of improvements. For this comparison, interstate locations were separated from all other highway types and treated as a separate class. All other locations were divided into three classes, namely, intersections, curves, and tangents.

Table 9 compares the percentage reductions in accidents for the various location classes. Locations on non-interstate tangents and curves exhibited comparable percent reductions in accidents. Significantly smaller reductions were observed for intersection locations, particularly when using the second-year before period to represent the before accident experience. This may be due to the fact that intersections present a more complex accident situation than other locations and are thus more difficult to improve by means of the techniques and resources of a limited spot-improvement program. Percentage reductions in interstate accidents were generally intermediate between those for intersections and those for curves and tangents but were somewhat more variable, perhaps due to the rather small sample size.

The average accident severity was greatest for curves (SI of 3.20) followed by interstate locations (SI of 2.96), intersections (SI of 2.59), and tangents (SI of 2.54). No significant changes in the severity indices were observed between the before and after periods. However, slight reductions were recorded for all classes except intersections. For intersections, the average severity index increased slightly during the after period.

Another study *(15)* compared the accident reduction for various types of improvements (Table 10). In this study, a 0.3-mile (0.48-km) section was used. The before period was the 1-year period before the improvement adjusted by a multiplying factor to account for peak-year effect. The study period was longer, which resulted in an increase (28 percent) in the number of projects considered. The improvements were divided into general improvements, improvements at curves, and improvements at intersections.

There was only one type of improvement which did not result in a reduction in accidents. This involved installing lighting at one location. The installation and upgrading of intersection beacons resulted in a very small accident reduction (2 and 5 percent, respectively). The largest reductions involved installing regulatory signs at intersections (48 percent) and signs and maintenance at curves (47 percent).

CONCLUSIONS

The primary objective of this study was to evaluate the effectiveness of the high-accident location, spot-improvement program in Kentucky. The following represent major conclusions:

1. The spot-improvement program, while not a costly one, has resulted in significant reductions in accident occurrences at high-accident locations in Kentucky.

2. Savings attendant to the reduction in accident costs have more than offset program costs within a short time span following completion of the improvements.

3. Contrary to data reported by other states, average accident severity, as measured by a severity index, was not appreciably reduced as a result of the spot-improvement program.

4. In this type of before-and-after study in which high-accident locations are identified from short-term accident statistics, the 12-month period immediately prior to the identification date cannot be used for the purpose of accumulating accident statistics representative of relatively stable before-improvement conditions. A much better period is the 12-month period beginning 2 years in advance of the identification date.

5. When accidents are located by means of cumulative distance along a route from a fixed reference point, high-accident locations should not be identified in terms of very short segment lengths such as the 0.1-mile (0.16-km) segments used in Kentucky. Neither should such a short segment length be used for evaluating a spot-improvement project or program regardless of the length used for identification of the site. A segment length of 0.3 mile (0.48 km) was found in this study to be considerably superior to a segment length of 0.1 mile (0.16 km).

6. The analysis validated the capabilities of the investigative teams, composed of state police and maintenance and traffic engineers, to discern proper corrective measures through field investigations and office study.

7. The method for identifying high-accident locations, namely, three or more accidents at a 0.1-mile (0.16-km) location during a 12-month period, is an inefficient method for identifying hazardous locations for improvement under the spot-improvement program since only slightly more than five percent of the locations so identified have warranted improvement.

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APPENDIX – NOTATIONS

A	Number of A-type injury accidents
a	Expected number of accidents at a particular location in a given time period
B	Number of B-type injury accidents
C	Number of C-type injury accidents
EPDO	Number of equivalent property-damage-only accidents
K	Number of fatal accidents
m	Number of vehicle miles (vehicle kilometers) of travel
N	Number of accidents at a particular location in a given time period
P	Probability
PDO	Number of equivalent property-damage-only accidents
λ	Expected accident rate in terms of accidents per vehicle miles (vehicle kilometers) of travel

TABLE 1

SUMMARY OF LOCATIONS INVESTIGATED FROM JANUARY 1, 1968, THROUGH JUNE 30, 1971

RESULT OF INVESTIGATION	NUMBER OF LOCATIONS	PERCENTAGE OF LOCATIONS	NUMBER OF INVESTIGATIONS
Improvements Recommended and Completed	349	60.4	336
No Improvements Recommended	207	35.8	225
Improvements Recommended But Not Completed	22	3.8	22
Total	578[a]	100.0	613

[a]A total of 613 investigations were made at these 578 locations.

TABLE 2

SUMMARY OF SAFETY MEASURES AND TYPES OF IMPROVEMENT

SAFETY MEASURE	NUMBER	TYPE OF IMPROVEMENT	NUMBER
Warning Signs	323	Installation	505
Regulatory Signs	91	Refurbishing	85
Guidance Signs	22	Relocation	46
Traffic Signal	10	Upgrading	85
Beacon	21	Removing	27
School Signal	1		
Signal Adjustments	2	Total	748
Roadway Markings	97		
Post Delineators	43		
Channelization	16		
Construction	28		
Shoulder Maintenance	26		
General Maintenance	66		
Lighting	2		
Total	748		

TABLE 3

ACCIDENT SUMMARY FOR LOCATIONS WHERE IMPROVEMENTS WERE MADE

(Reference Date between January 1, 1968, and June 30, 1971)

TYPE OF ACCIDENT OR INJURY	0.3-MILE (0.48-KM) SEGMENTS			0.1-MILE (0.16-KM) SEGMENTS		
	FIRST-YEAR BEFORE PERIOD	FIRST-YEAR AFTER PERIOD	PERCENT REDUCTION	FIRST-YEAR BEFORE PERIOD	FIRST-YEAR AFTER PERIOD	PERCENT REDUCTION
Accidents						
PDO	1382	787	43.1	817	335	59.0
A-Type[a]	277	144	48.0	165	72	56.3
B-Type	187	121	35.3	115	44	61.7
C-Type	182	117	35.7	113	52	54.0
Fatal (K-Type)	52	19	63.5	34	9	73.5
Total	2080	1188	42.9	1244	512	58.8
Injuries						
A-Type	439	225	48.7	285	116	59.3
B-Type	394	253	35.8	250	109	56.4
C-Type	398	242	39.2	249	108	56.6
Total	1231	720	41.5	784	333	57.5
Fatalities	60	27	55.0	37	11	70.3

[a]An injury accident is classified according to the most severe injury to any person involved.

TABLE 4

BENEFIT-COST RATIOS FOR ALL LOCATIONS

(Reference Date between January 1, 1968, and June 30, 1971)

ACCIDENT COST PROCEDURE	0.3-MILE (0.48-KM) SEGMENTS			0.1-MILE (0.16-KM) SEGMENTS		
	BENEFIT[a] ($)	COST[b] ($)	B/C	BENEFIT[a] ($)	COST[b] ($)	B/C
Total Cost of Accidents (Including Indirect Costs)	3,102,700	484,630	6.40	2,580,500	484,630	5.32
Direct Cost of Accidents	1,554,960	484,630	3.21	1,234,090	484,630	2.55

[a]Benefits computed by subtracting the year-after accident costs from the year-before accident costs.

[b]Costs defined as the sum of the costs of improvements ($178,130) and the administrative costs ($306,500 or $500 per investigation).

TABLE 5

ACCIDENT SEVERITY AND ACCIDENT-TYPE DISTRIBUTION
FOR LOCATIONS WHERE IMPROVEMENTS WERE MADE
(Reference Date between January 1, 1968, and June 30, 1971)

	0.3-MILE (0.48-KM) SEGMENTS		0.1-MILE (0.16-KM) SEGMENTS	
	FIRST-YEAR BEFORE PERIOD	FIRST-YEAR AFTER PERIOD	FIRST-YEAR BEFORE PERIOD	FIRST-YEAR AFTER PERIOD
Severity Index	2.79	2.67	2.82	2.81
Percentage of Various Types of Accidents				
PDO	66.4	66.2	65.7	65.4
A-Type	13.3	12.1	13.3	14.0
B-Type	9.0	10.2	9.2	8.6
C-Type	8.8	9.9	9.1	10.2
Fatal	2.5	1.6	2.7	1.8
Total	100.0	100.0	100.0	100.0

TABLE 6

ACCIDENT SUMMARY FOR LOCATIONS WHERE IMPROVEMENTS WERE MADE

(Reference Date between January 1, 1969, and June 30, 1971)

TYPE OF ACCIDENT OR INJURY	0.3-MILE (0.48-KM) SEGMENTS			0.1-MILE (0.16-KM) SEGMENTS		
	SECOND-YEAR BEFORE PERIOD	FIRST-YEAR AFTER PERIOD	PERCENT REDUCTION	SECOND-YEAR BEFORE PERIOD	FIRST-YEAR AFTER PERIOD	PERCENT REDUCTION
Accidents						
PDO	400	300	25.0	200	133	33.5
A-Type[a]	88	68	22.7	49	41	16.3
B-Type	77	48	37.7	35	17	51.4
C-Type	42	39	7.1	21	21	0.0
Fatal	14	10	28.6	8	5	37.5
Total	621	465	25.1	313	217	30.7
Injuries						
A-Type	149	101	32.2	104	56	46.2
B-Type	152	99	34.9	93	43	53.8
C-Type	112	85	24.1	77	40	48.1
Total	413	285	31.0	274	139	49.3
Fatalities	19	16	15.8	9	6	33.3

[a]An injury accident is classified according to the most severe injury to any person involved.

TABLE 7

BENEFIT-COST RATIOS FOR ALL LOCATIONS

(Reference Date between January 1, 1969, and June 30, 1971)

ACCIDENT COST PROCEDURE	0.3-MILE (0.48-KM) SEGMENTS			0.1-MILE (0.16-KM) SEGMENTS		
	BENEFIT[a] ($)	COST[b] ($)	B/C	BENEFIT[a] ($)	COST[b] ($)	B/C
Total Cost of Accidents (Including Direct Costs)	520,600	228,200	2.28	526,300	228,200	2.31
Direct Cost of Accidents	270,410	228,200	1.18	152,825	228,200	0.67[c]

[a]Benefits computed by subtracting the first-year after accident costs from the second-year before accident costs.

[b]Cost of improvements was $77,200 and the administrative cost was $151,000.

[c]In 18 months, this benefit-cost ratio would be greater than one.

TABLE 8

ACCIDENT SEVERITY AND ACCIDENT-TYPE DISTRIBUTION
FOR LOCATIONS WHERE IMPROVEMENTS WERE MADE
(Reference Date between January 1, 1969, and June 30, 1971)

	0.3-MILE (0.48-KM) SEGMENTS		0.1-MILE (0.16-KM) SEGMENTS	
	SECOND-YEAR BEFORE PERIOD	FIRST-YEAR AFTER PERIOD	SECOND-YEAR BEFORE PERIOD	FIRST-YEAR AFTER PERIOD
Severity Index	2.88	2.89	3.00	3.24
Percentage of Various Types of Accidents				
PDO	64.4	64.5	63.9	61.3
A-Type	14.2	14.6	15.7	18.9
B-Type	12.4	10.3	11.2	7.8
C-Type	6.7	8.4	6.7	9.7
Fatal	2.3	2.2	2.5	2.3
Total	100.0	100.0	100.0	100.0

TABLE 9

COMPARISION OF ACCIDENT REDUCTION
BY CLASS OF SITE

LOCATION CATEGORY	NUMBER OF LOCATIONS	0.3-MILE (0.48-KM) SEGMENTS	0.1-MILE (0.16-KM) SEGMENTS
Comparing First-Year Before to First-Year After			
Intersections	203	36	52
Curves	88	52	68
Tangents	42	53	68
Interstates	16	56	64
Comparing Second-Year Before to First-Year After			
Intersections	99	18	28
Curves	40	42	53
Tangents	17	47	40
Interstates	12	35	18

TABLE 10

ACCIDENT REDUCTION BY TYPE OF IMPROVEMENT

	TYPE OF IMPROVEMENT	NUMBER OF PROJECTS	ACCIDENT REDUCTION (PERCENT)
General	Signs and Markings	9	36
	Warning Signs	23	35
	Regulatory Signs	16	22
	Guidance Signs	10	14
	Sign Combinations	16	20
	Markings	8	16
	Sight Distance Improvement	9	28
	Post Delineators	3	25
	Comb. Delineators, Markings Signs, Maintenance	11	22
	Shoulder Improvements	7	23
	Comb. Resurfacing, Patching, Drainage, Deslick, Culvert	22	16
	Rumble Strips	8	29
	Remove Median Crossovers	2	29
	Lighting	1	-58
	Lighting and Rumble Strips	1	17
	Rumble Strips and Beacon	2	32
	Side Road Sign Only	31	19
	Prepare for Sudden Stop Sign Only	19	25
	Side Road Sign and Warning Sign	15	27
Curves	Signing	34	30
	Post Delineators	4	32
	Signs and Delineators	16	28
	Signs and Maintenance	6	47
	Comb. Delineators, Markings, Signs, Maintenance	16	24
	Resurfacing, Patching, Drainage, Deslick, Super, Culvert, Guardrail	22	33
	Re-alignment (Relocate)	3	32
Intersections	Signs and Markings	21	24
	Warning Signs	11	27
	Regulatory Signs	5	48
	Regulatory and Warning Signs	20	16
	Markings	17	16
	Marking, Maintenance, and Signing	9	35
	Channelization – Storage Lane	13	15
	Channelization and Signs	2	37
	Install Beacons	13	2
	Upgrade Beacons	10	5
	Install Signals	10	23
	Upgrade Signals	2	18
	Total Improvements	447	24

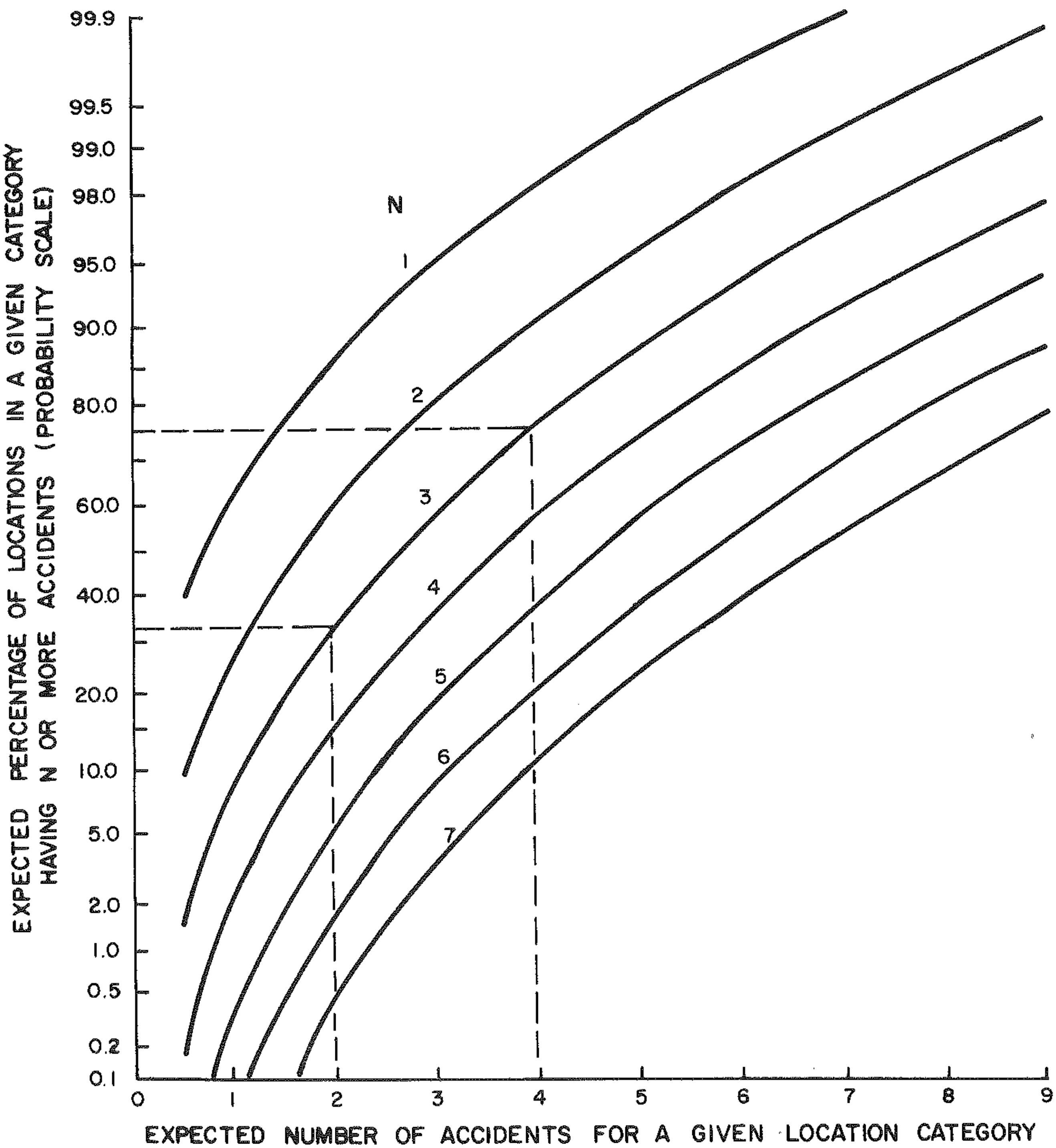


Figure 1. Expected Percentage of Locations to be Classified as "High-Accident" Locations.

Figure 2. Accident History for 99 No-Improvement-Recommended Locations Having Reference Dates between January 1, 1969, and July 30, 1970.

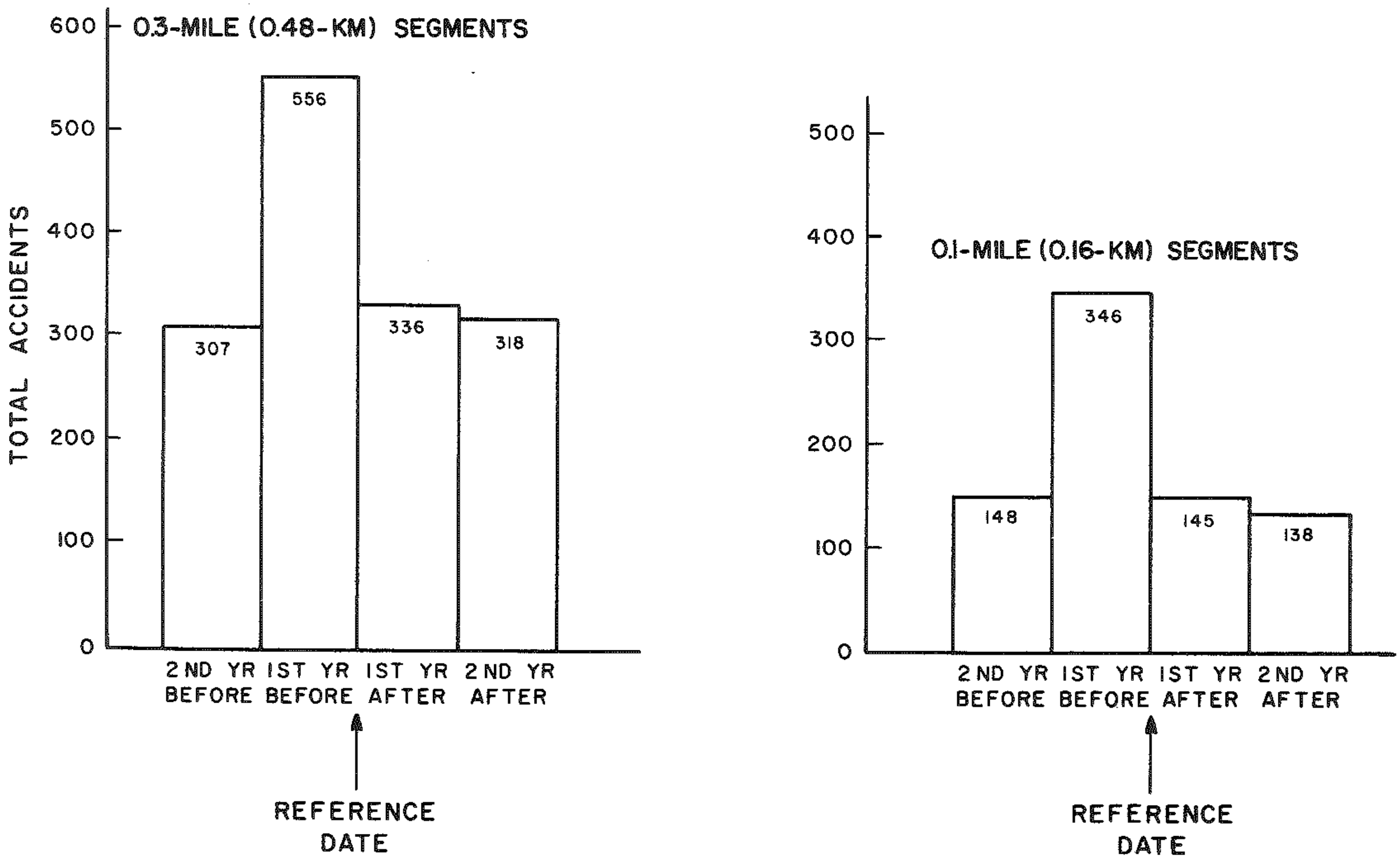


Figure 3. Accident History for 109 Improved Locations Having Reference Dates between January 1, 1969, and July 30, 1970.

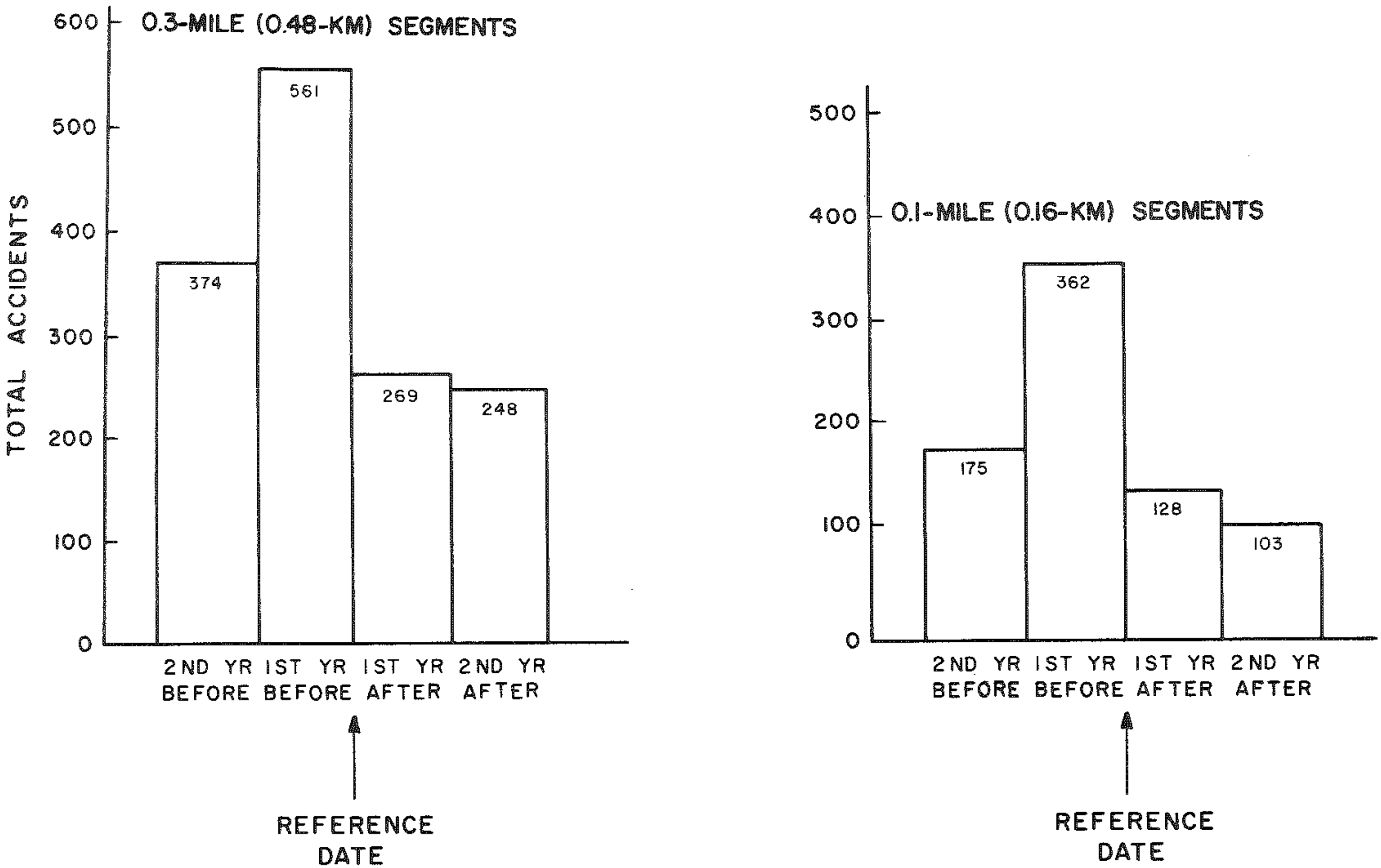
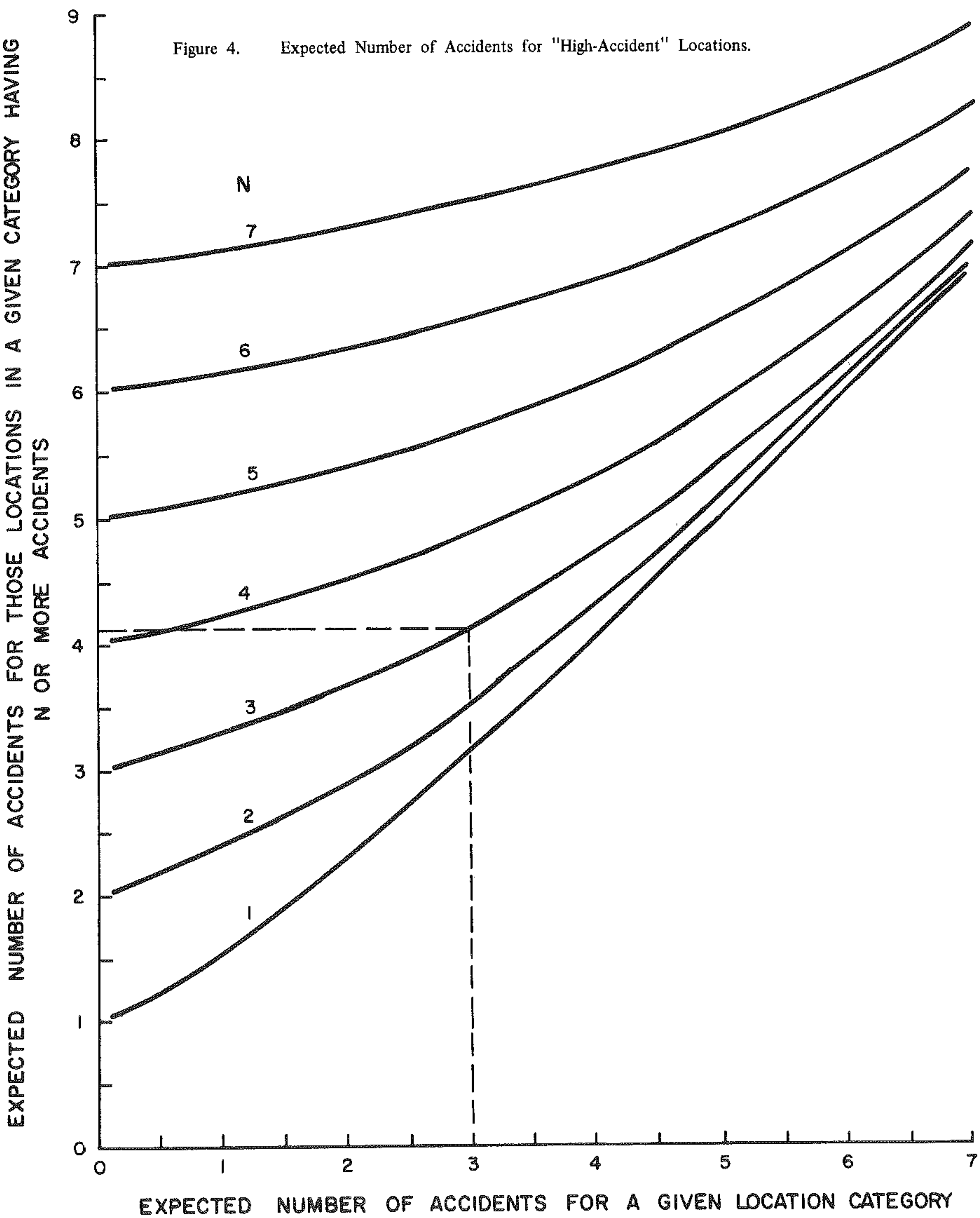


Figure 4. Expected Number of Accidents for "High-Accident" Locations.



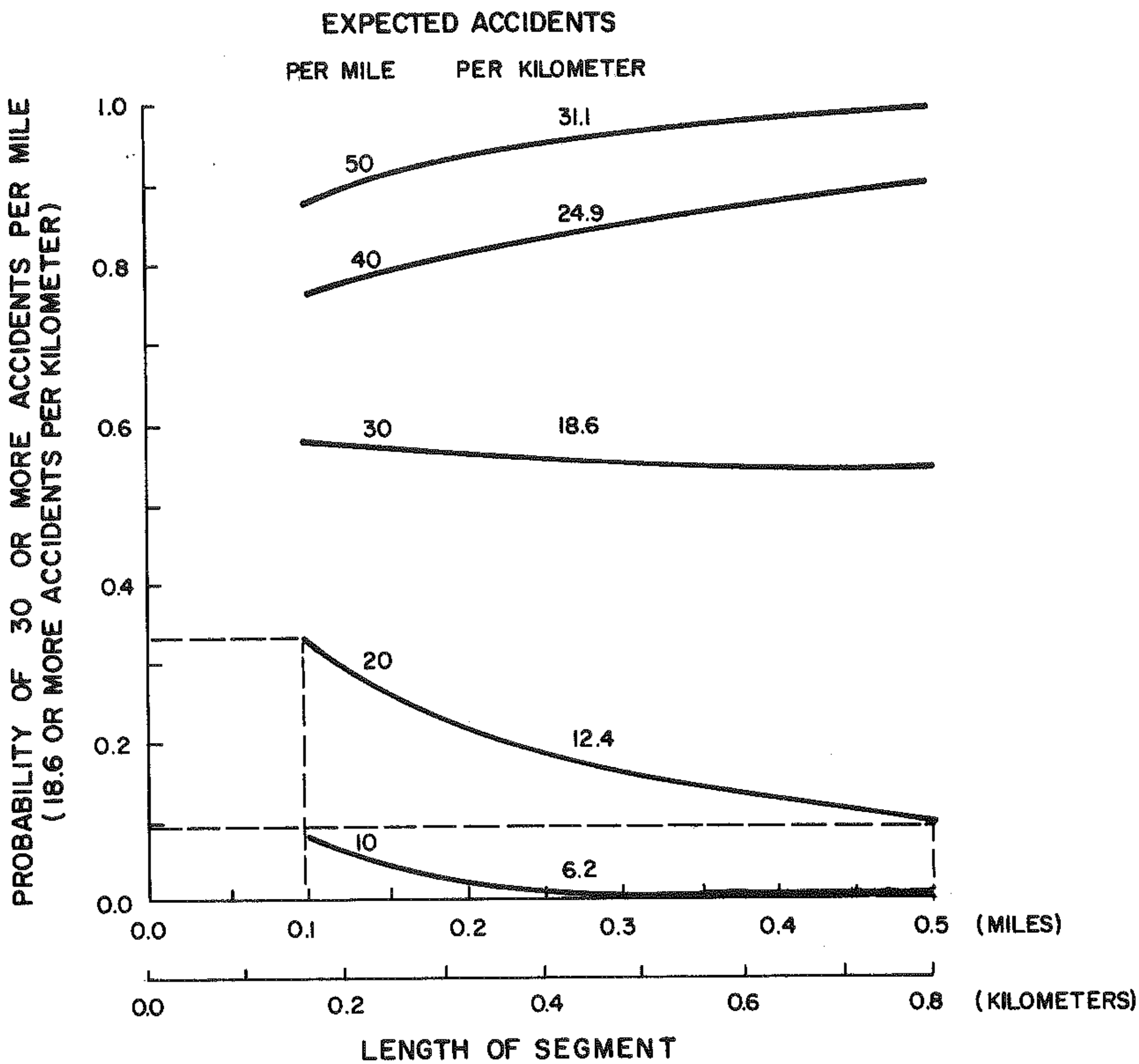


Figure 5. Effect of Segment Length on the Probability of Identifying "High-Accident" Locations.