Investigation of Accidents on Alabama Bridge Approaches

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As part of a research project to examine bridge accidents in Alabama, an investigation was conducted to ascertain the effects of the approach roadway on bridge accident rate. The objective of this study was to determine whether the accident rate increased near bridges, and if it did, to determine whether the increase could be described by a standard statistical distribution. A sample of approach accidents was prepared by matching county, highway, and milepoint numbers from Alabama's bridge inventory and accident files. This difficult matching process was necessary because state accident-investigation forms do not record structure numbers for bridges that are involved in collisions. More than 24 000 accidents on state-route highways between 1972 and 1979 were used in the study. A unique distribution of accidents was observed at bridge ends. The average accident rate doubled over a 0.35-mile distance at the approach to a structure. This increase could not be identified as any standard statistical distribution, primarily because of investigating officers' preference for recording accidents to the closest one-tenth milepoint. Tenth-milepoint locations dominated the data and masked the true distribution. An examination of accident codes revealed that many Alabama bridge accidents are apparently investigated incompletely, identified improperly, recorded erroneously, or ignored due to limited space on the investigation forms.

A survey of the nation's 564 000 bridges shows that 100 000 structures are seriously deficient (1). Various estimates have indicated that at least 50 000 bridges need widening or replacing (2,3). Such statistics lead to a staggering estimate of the cost of correcting all bridge deficiencies. The 1980 Surface Transportation Act established funding at more than a billion dollars per year for bridge rehabilitation and replacement but, even at such an accelerated rate, it may take 25 years to cure the problem (4).

In Alabama, literally hundreds of bridges are candidates for federal funds. But, from its share of the billion federal dollars allocated to the states, Alabama can afford to replace only a few. The problem is to choose the most dangerous bridges so that they can be replaced first.

OBJECTIVES

This report documents one phase of a bridge accident investigation, an examination of the contribution of approach roadways to bridge accidents. One-way and two-way traffic structures on Alabama state-route highways were included in the study. Underpasses and culverts (with earth cover) were not identified as bridges.

Specifically, this portion of the research was designed to answer questions such as

1. Does the roadway accident rate increase near bridges?
2. If such an increase occurs, can it be described by a statistical distribution?
3. Should approach accidents be included in hazardous bridge studies? and
4. Can a statistical distribution be used to define how much of the approach roadway should be considered?

BACKGROUND

Bridges are inherently more dangerous than the roadways on which they are located. Mitchie generalized that bridges are 50 times more hazardous than roadways (1). He used 1975 data to compare the ratio of fatal ran-off-road, hit-fixed-object type of collisions to gross roadway mileage (5,6). He then found a similar ratio for fatal bridge or bridge-barrier accidents to cumulative bridge mileage. The bridge fatal accident rate was found to be 50 times larger. Although specific inferences should not be drawn from such a generalized analysis, it does serve to demonstrate the drastic increase in the potential for accidents caused by the structures.

Prediction of Bridge Accidents

Two procedures have been suggested as ways to predict accidents: (a) observations of driver behaviors and (b) analysis of historical accident data. Bridges are known to exert an influence on the behavior of drivers as they approach and to cause both lateral displacements and changes in speed. The lateral movement case has been recognized and studied for some time (7-9). Typically, these studies involve observation of a vehicle's lateral position at some distance from a bridge, then a second observation near the structure. The movement of the vehicle toward or away from the centerline has been shown to be a general indicator of how dangerous drivers perceive the bridge to be. Unfortunately, no strong correlation has been identified between lateral movement and bridge width, nor has the relation between lateral movement and accident rate been quantified. A logical assumption would be that these movements could cause an increase in traffic accidents on bridge approaches.

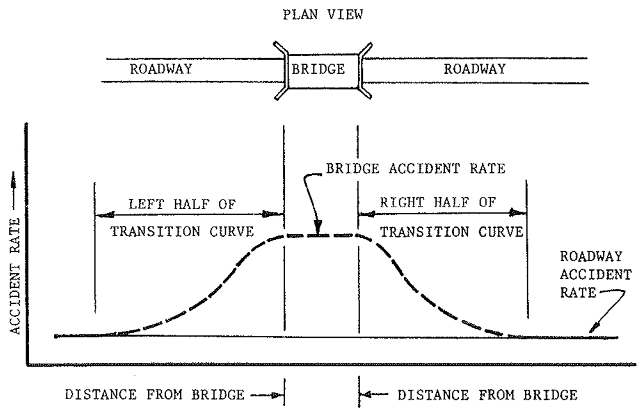
The second method of predicting bridge accidents is by use of historical accident data. In recent years, researchers have examined accident records rigorously in an attempt to isolate those factors most significant in causing bridge accidents. Bridge width, approach-roadway width, sight distance, traffic volumes, alignment, approach barrier, bridge rail, traffic control devices, approach speeds, and pavement surface conditions have all been shown to contribute to accidents. The complex interaction of the multiple contributing factors has made it difficult to define a single method to realistically predict bridge accidents. There has been a general agreement on major factors such as the primary importance of relative structure width and traffic volumes; however, the majority of factors that influence bridge accidents has not been quantitatively defined. At least four of the research projects used accidents on bridge approaches during their studies (8,10-12). Lengths of 500-1200 ft were most commonly used in these projects.

The examination of literature showed that bridges have higher accident rates than the roads on which they are located, that vehicles frequently shift lateral position as they approach structures, and that previous researchers have used various approach distances in analysis of bridge accidents.

Accident Rate Transition

The exact role of the bridge approach (and departure) has not been previously defined. The accident rate does not change abruptly at the beginning of the structure. Rather, a transition must occur as vehicles approach the more dangerous location. A logical assumption would be that the increase in accidents would follow some statistical pattern, such as the normal distribution shown in Figure 1. The figure illustrates that a normal curve may be split at the mean value and one-half placed on each

Figure 1. Suggested accident rate for transition curve.



end of the bridge to form a smooth transition. The mean value for the distribution would be the rate of bridge accidents, although it is possible that approach accidents might occur more often than collisions on the structure. The tail of the distribution would approach the roadway accident rate. The area under the curve would represent the excess accidents (beyond the roadway rate) caused by the bridge structure. Knowledge of the existence, magnitude, and character of the statistical distribution of accidents on bridge approaches would lead to vastly increased accuracy in bridge studies.

STUDY PROCEDURE

To carry out the study, it was first necessary to identify approach collisions. A computer program was prepared to compare accident milepoints and bridge-end milepoints. The program gathered data from the Alabama bridge inventory file, including highway number, county number, milepoint of bridge beginning, and bridge length. The highway, county, and milepoint numbers form a unique designation in the Alabama numbering system. This combination was compared with the highway, county, and milepoint numbers on accident records to match accidents to bridges. For purposes of this study, the approach was defined as the direction of increasing milepoints, and the departure was defined as decreasing milepoints.

During the course of a normal accident investigation, Alabama law-enforcement officers are directed to specify the accident location by highway and milepoint. The officer's training requires that such information be recorded to the closest one-hundredth of a mile (13). A comparison of such accurate data for accident milepoints and bridge-end milepoints should produce a good distribution of distances for an analysis of approach accidents. Accident data were used for all state-route highways for the period 1972 through 1979 to ensure a large and meaningful sample.

The milepost-matching procedure was not without problems, however. One of the complicating factors is that an accident that occurs between two closely spaced bridges occurs on the approach to one bridge and on the departure of the other. Establishment of which bridge was the most significant in causing the accident is very difficult. A bridge could cause an erratic maneuver that results in an accident at the following bridge. In that case, existing records would not assign the accident to the correct location. In addition to the previously described data, travel direction, distance between structures, and many other causal factors would have to be examined to see which of the bridges instigated the accident. Even if a method could be selected to review these data and assign locations, the complexity in developing a computer program makes the procedure unattractive. For study purposes, individual accidents were assigned to the nearest bridge-end milepoint.

To identify exact accident locations, the roadway was searched in incremental lengths away from bridge ends. The unit length was selected as 0.05 mile after some initial analyses indicated that such a length was appropriate. The computer would read the bridge data and calculate beginning and ending milepoints for the approach, for the bridge, and for the departure. The program would then search a sample of 24 000 accident records by milepoint to determine how many occurred at the particular bridge. Next, a new bridge record would be input and the process would be repeated. After all bridge records were examined, the total approach, bridge, and departure accidents were output for the incremental approach length under consideration. The program was repeated for several approach lengths up to 0.35 miles to develop the desired distribution of accident distances from bridge ends.

STUDY RESULTS

The computer program was run for 0.05-mile increments seven different times. When the accidents within 0.35 mile of bridge ends had been merged with the appropriate structures, the results were tabulated for analysis. For example, during the initial computer run for a 0.05-mile increment, 696 accidents were found on bridges, 575 were found on approaches, and 477 were found on departures. When the program was executed with an increment of 0.10 mile, 1027 approach accidents and 1024 departure accidents were noted. The additional collisions noted in the second run represented accidents that occurred between 0.05 and 0.10 mile from bridges.

Initial Analysis

The results of the computer analysis are displayed in Table 1 and Figure 2. The sample contained 24 000 accidents that occurred on state routes in Alabama. More than 25 percent (6049 out of 24 000) were found to be within 0.35 mile of a bridge. Of the 6049 matched collisions, 696 occurred on bridges (approximately 3 percent of all accidents). The number that occurred on approaches, 2645, was almost exactly the same as the 2708 that occurred on departures. Assuming that these accidents comprise a normal distribution, the mean location would be 0.004 mile from the departure bridge end, and the standard deviation would be 0.18 mile. Such characteristics seem to reflect the type of distribution assumed by Figure 1.

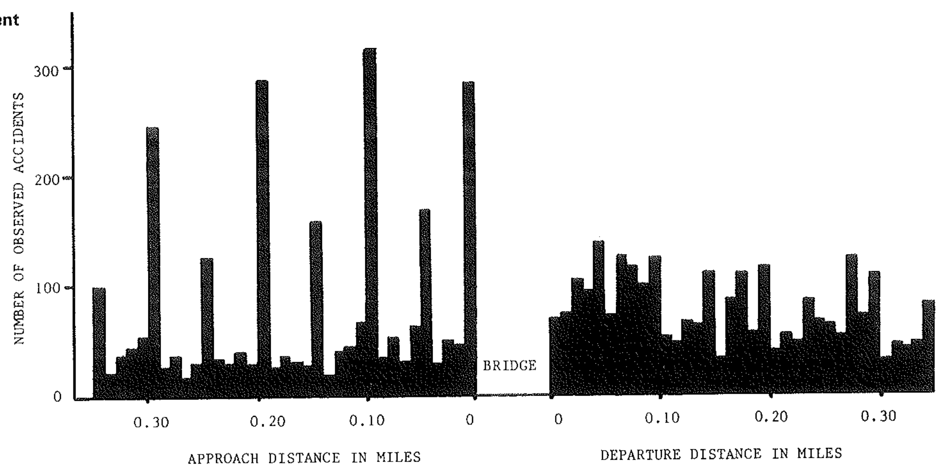
Distribution Patterns

Two things are immediately noticeable about Figure 2. First, the approach accidents follow an unusual and repetitious pattern. This pattern can be traced to an obvious cause. Investigating officers tend to record accident milepoints to the nearest 0.1 mile. This would seem natural since most mileposts are at mile intervals and automobile speedometers measure in tenths of miles. Most officers probably locate the accident milepoint by driving from the milepost to the accident while observing the automobile speedometer. In Figure 2, officers clearly favor use of 0.1-mile distances, and about half as many accidents are recorded in between the tenth-mile locations as officers estimate to the closest 0.05

Table 1. Tabulation of bridge approach and departure accidents.

Distance From Bridge End (mile)	Observed Accidents Approach	Observed Accidents Departure	Distance From Bridge End (mile)	Observed Accidents Approach	Observed Accidents Departure
0.00	135	0	0.19	25	57
0.01	147	70	0.20	290	114
0.02	46	72	0.21	33	38
0.03	50	104	0.22	40	54
0.04	30	94	0.23	30	47
0.05	167	137	0.24	33	83
0.06	33	71	0.25	127	66
0.07	26	127	0.26	29	64
0.08	52	115	0.27	18	53
0.09	33	100	0.28	35	123
0.10	316	123	0.29	27	72
0.11	66	52	0.30	246	109
0.12	44	48	0.31	54	31
0.13	40	65	0.32	44	46
0.14	19	62	0.33	37	42
0.15	154	109	0.34	21	45
0.16	28	44	0.35	101	82
0.17	31	84	Total	2645	2712
0.18	38	109			
Subtotal	1455	1586			

Figure 2. Approach and departure accident distribution.



mile from automobile speedometers. A relatively small number of accidents were recorded to the closest 0.01 mile. This finding imposes a constraint on any statistical inferences drawn from the data.

Approach and Departure Differences

The second thing that draws immediate attention in Figure 2 is the distinct difference in the approach and departure observations. The departure distribution seems to follow the type of random pattern that would be anticipated from accident statistics rather than the tenth-mile pattern so obvious on the approach. This is not the case, however. The departure dispersion was caused by the manner in which the bridge-ending milepoint was calculated. All bridge-beginning stations are recorded in the Alabama bridge inventory file to the nearest tenth mile, as reflected by the approach accident pattern. The computer calculated the bridge-end station from the starting point plus the bridge length. The majority of bridge-ending points thus fall on hundredth-mile stations, instead of tenth-mile stations, like bridge beginning points. If ending stations are calculated to hundredths and accidents are to the tenth, a different pattern could be expected from that of the bridge approach.

The overall distribution of Figure 2, although difficult to analyze, indicates an increase in accidents at bridges. On the approach side, the accidents occurring at each 0.1-mile location, as well as at the midpoints between these locations, increase as the bridge is approached. A similar, although not as obvious, arrangement may be discerned from a study of the departure side.

Larger Class Intervals

The use of 0.01-mile increments tended to confuse rather than simplify the analysis. For that reason, the data were grouped into 0.05 mile units to aid in the interpretation. Figure 3 and the table below represent such a grouping.

Study Interval Miles From Bridge End	Adjusted No. of Bridge Accidents Approach	Departure
0.000-0.050	575	477
0.051-0.100	460	536
0.101-0.150	323	336
0.151-0.200	412	408
0.201-0.250	263	288
0.251-0.300	355	421
0.301-0.350	257	242
Total	2645	2708

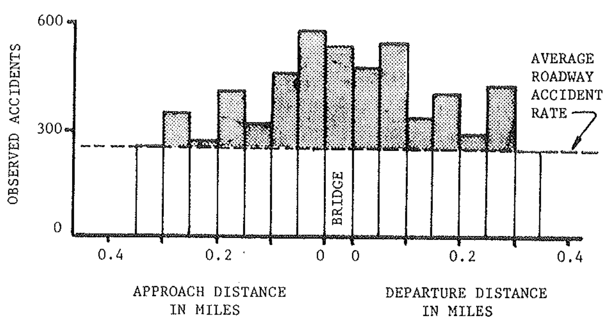
The preponderance of accidents recorded at the one-tenth points is still evident even when the data are grouped. The symmetrical pattern of Figure 3, with every other bar raised, clearly reflects the officer's preference for tenth milepoints. The number of accidents on bridges and the average bridge length in the sample were used to calculate the rate for accidents that occur on the structure, which is shown by the dotted line on the figure. The dotted line agrees nicely with the adjacent approach and departure rates. The number of accidents decreases as distance from the bridge end increases. This is the anticipated result and represents the transition from the bridge rate to the roadway rate. The type of transition is not intuitively obvious from either Figure 3 or the table above. A chi-square test was performed on the hypothesis that the data were taken from a population that has a normal distribution. The hypothesis was rejected. A similar test indicated that the distribution was not linear.

Control Group

In order to further examine the approach and departure distribution and to estimate the number of accidents that would have occurred at study sites if bridges had not been present, a control distribution was established. An equivalent amount of randomly selected highway, county, and milepoint numbers was designated as theoretical bridges and were computer matched against the original sample of accident records. Two things were accomplished: (a) a control distribution was obtained for comparison with the bridge accident distribution, and (b) an average roadway accident rate was obtained for randomly selected sites. Table 2 contains the random control site results. The tenth-point accidents are even more pronounced than the bridge-site accident distribution. This suggests that officers are slightly more prone to pinpoint the location of bridge accidents than roadway accidents. Collisions are not grouped around the control sites as are bridge-approach accidents. Thus, the control site distribution accomplishes the first objective by demonstrating the uniqueness of the bridge approach distribution.

Although the same number of bridges were used for the control group, the randomly generated highway-county-milepost numbers did not always correspond to hazardous locations on Alabama highways. This produced a smaller sample size for merging of control site bridges with accident data.

Figure 3. Excess accidents caused by bridges.



THE SHADED AREA INDICATES "EXCESS" ACCIDENTS CAUSED BY BRIDGES.

Excess Accidents Caused by Bridges

A better analysis of bridge approach and departure accidents might be to examine only those locations where the accident rate is higher than the average roadway rate. Since the roadway rate was determined through the control group, the excess accidents caused by bridges could be identified.

The excess accidents associated with bridges do not seem to fall into any conventional distribution. The table below lists the number of accidents in each distance interval around bridges.

Study Interval (miles from bridge end)	Excess Observed Accidents	
	Approach	Departure
0.000-0.050	321	223
0.051-0.100	206	282
0.101-0.150	69	82
0.151-0.200	158	154
0.201-0.250	9	34
0.251-0.300	101	167
0.301-0.350	3	0
Total	867	942

The mean accident location was 0.013 mile on the departure side and the standard deviation was 0.147 mile. These values are very close to the values for the initial distribution. For the distance class used, the one-tenth point collisions continued to dominate. Two attempts were made to overcome the tenth-milepoint bias of the data and identify the actual distribution.

Smoothed Distribution

The initial effort involved smoothing the sample by distributing the one-tenth point accidents to adjacent intervals. The logic behind the smoothing was that officers recorded the locations as the closest tenth point, but an accident so recorded would have an equal probability of actually oc-

Table 2. Accidents at control site.

Distance From Bridge End (mile)	Observed Accidents		Distance From Bridge End (mile)	Observed Accidents	
	Approach	Departure		Approach	Departure
0.01	4	10	0.16	5	8
0.02	2	7	0.17	0	19
0.03	1	4	0.18	3	11
0.04	1	9	0.19	1	31
0.05	9	0	0.20	174	29
0.06	1	8	0.21	1	1
0.07	1	10	0.22	0	5
0.08	3	16	0.23	3	4
0.09	2	39	0.24	0	7
0.10	215	25	0.25	16	13
0.11	2	1	0.26	2	8
0.12	0	2	0.27	0	6
0.13	2	4	0.28	0	11
0.14	2	12	0.29	1	7
0.15	21	12	0.30	3	28
Subtotal	266	159	Total	475	347

Figure 4. Grouped accidents.

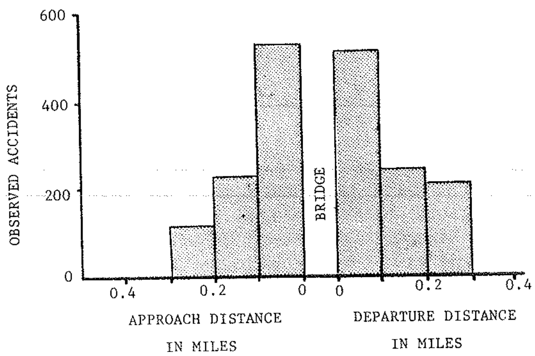


Table 3. Accident codes for approach accidents.

Alabama Accident Code	Frequency	Percentage
No entry	146	22.2
Inattention	121	18.4
Run off road	6	0.9
Run off road and overturn	1	0.2
Before overturning	42	6.4
Skidding	38	5.8
Other collision	227	34.2
Passing	25	3.8
Avoiding other vehicle	9	1.4
Before vehicle submerging	3	0.5
Hit bridge rail	44	6.7
Hit bridge abutment	34	5.2
Hit culvert or headwall	4	0.6
Hit embankment or ditch	18	2.7
Hit guardrail	19	2.9
Hit median barrier	3	0.5
Hit other object	19	2.9
Hit animal	29	4.2
All other codes		9.7

curring at any of the adjacent hundredth points on either side of the one-tenth point. The technique used to distribute the data focused on the difference in the number of observations in a particular interval and the observations in the intervals on either side. The tenth point had a weight of 0.5 and the adjacent intervals had weights of 0.25 each for distributing the extra tenth-point accidents. The smoothed accidents are shown in the table below. The total departure accidents, total approach accidents, mean accident location (0.013 mile from departure end of bridge) and standard deviation (0.149 mile) are almost identical to the distribution prior to smoothing.

Study Interval (miles from bridge end)	Smoothed Accidents	
	Approach	Departure
0.000-0.500	283	243
0.051-0.100	201	217
0.101-0.150	126	150
0.151-0.200	98	106
0.201-0.250	69	97
0.251-0.300	53	92
0.301-0.350	37	42
Total	867	947

The smoothed accident tabulation was tested to see if it conformed to a recognizable statistical distribution. The chi-square test was applied at a 95 percent confidence level to the hypothesis that the sample came from a normally distributed population. The hypothesis was convincingly rejected, primarily due to the large irregularity near the outer edge of the observed accident distribution. The sample was also compared with Poisson, Erlang, and binomial distributions with the same result. Finally, the approach and departure tabulations were each compared with the Poisson and a negative exponential population. The comparisons were again rejected, although the negative exponential distribution came closer to matching the sample than did any previous distribution.

Larger Data Intervals

An alternative to smoothing the data is the use of larger increments for the frequency tabulation. This was done by using a 0.10-mile grouping. The results are shown in the table below and Figure 4.

Study Interval (miles from bridge end)	Observed Grouped Accidents	
	Approach	Departure
0.000-0.101	527	505
0.101-0.200	227	236
0.201-0.300	118	201
Total	864	942

The large increase in collisions at the bridge ends is immediately obvious from the figure. The first 0.10 mile dominates the drawing. It also appears that the figure could be reasonably approximated by a statistical distribution. The chi-square test was used to investigate the normal, Poisson, Erlang, and negative exponential distributions. All comparisons were rejected, as had been the case for previous attempts to identify the data sample as a standard statistical distribution.

TYPES OF ACCIDENTS

An additional investigation was conducted to see whether the character of accidents changed from bridge approach to departure. The descriptive codes on Alabama accident reports, collision diagrams, and explanatory reports were used to compare accidents at the three locations (13,14). The approach and departure collisions were virtually identical in nature, as would be expected. Approximately 10 percent of these accidents were identified as types that might be associated with bridges. Examples are hit bridge rail, hit bridge abutment, before vehicle submerged, and hit headwall. A categorical grouping of approach accident codes is shown in Table 3. About 6 percent of the accidents that occurred between the bridge approach beginning and ending milepoints were coded as hit bridge rail or hit bridge abutment. This is 50 percent as large as the number of corresponding type accidents for bridges. An additional 5 percent of the table was coded such that bridge accidents were implied; however, the vast majority of the collision codes was either noncommital or suggested something other than bridge accidents. In comparison with approach accidents, there were slightly fewer entries for the following codes for bridge accidents: no entry, hit tree, hit pole, inattention, and during passing.

That most bridge accidents are apparently not identified as such is significant. Many collisions caused by bridges are probably not identified by officers due to the single data entry point on the investigation forms. A complex accident may have several causes, or a sequence of events may precede the wreck. The investigating officers choose and record only one. Officers apparently do not place great emphasis on identifying the events that surround an accident, since one-fourth of the forms had blank entries. Other reasons for the discrepancy between the number of bridge-associated accidents and the corresponding coded descriptions could be erroneous data code entries, misidentified milepoints, and incomplete investigations.

CONCLUSIONS

During the investigation of the effects of bridge approaches on accident rate, 24 000 accidents that occurred in Alabama between 1972 and 1979 were compared by highway, county, and milepoint for 960 bridges. The most significant findings were as follows:

1. Researchers have previously recognized that bridge approaches cause an alteration of driver behavior through modification of vehicle lateral placement and speed. Other researchers have used various a roach distances during bridge accident analyses. None of the previous research had identified a quantifiable relationship between approaches and accident rates.
2. Although Alabama investigation forms provide for the recording of accident locations to the closest hundredth of a mile, officers record them to 0.1-mile points on more than half of the cases. Around bridges the tendency to measure them more closely (to the 0.01 mile) is increased.
3. The recording of accident location data to the closest 0.1 mile tempers the significance of any statistical analysis applied to such data.
4. There is an inherent difficulty in assigning an Alabama accident to the correct structure where bridges are in close proximity due to overlapping approaches and departures.
5. One-quarter of the traffic accidents in Alabama occur within 0.33 mile of a bridge.
6. An analysis of nonbridge control sites indicated that there is a unique distribution of accidents for bridge approaches and departures.
7. There is a definite transitional increase in accidents on bridge approaches and departures. The maximum rate occurs at the bridge abutment and is more than twice the rate of the adjacent roadway.
8. The increase in accidents apparently reaches 0.35 miles from bridge ends. The precise beginning of the transitional pattern could not be identified due to the complexity of approach and departure overlap.
9. The grouped tabulation of approach distances (see Figure 3) could not be identified as any standard statistical distribution. Normal, Poisson, Erlang, negative exponential, binominal, and linear distributions were rejected. A negative exponential distribution came closest to matching the data. The exact distribution was masked by the tenth-milepoint predominance, extensive overlap of approaches and departures at the tail of the distribution, and inability to establish the absolute base accident rate for the roadway. The distribution could not be identified in spite of repeated frequency groupings and smoothing attempts.
10. The character of accidents that occurred on approaches is virtually identical to that of accidents that occurred on departures. The nature of collisions on the structure is slightly different from that of approaches and departures, with a greater emphasis on hit bridge rail and hit bridge abutment types of accidents.
11. For accidents that occurred on bridge structures as identified by milepoint, only 12 percent are directly labeled as bridge hits by the data coded on accident investigation forms.
12. Many bridge accidents are apparently incompletely investigated, not properly identified, erroneously recorded, mislocated, or ignored due to limited room for identifying information on accident investigation forms.

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