Using Accident Records To Prioritize Roadside Obstacle Improvements in New Mexico

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ABSTRACT

This paper contains a description of a process for identifying sections of rural New Mexico Interstate, primary, and secondary highways with significant fixed-object accident experience. Data bases for the analysis are the computerized accident record and roadway inventory systems for the 3-fiscal-year period from 1980 to 1982. The rate quality control method is used as the statistical technique to identify those sections of roadway that are most in need of examination. Accident and inventory information are combined to calculate critical accident rates for sections of roadway on each of the three systems. Calculated critical rates are then compared with the actual rates on each section, and a listing of sections arranged by criticality (the difference between the actual and critical rates) is obtained. This listing is used by New Mexico State Highway Department personnel to prioritize locations for implementing safety improvements. The procedure is applicable to the analysis of other subsets of accidents as well. Data quality is critical for the proper application of the technique; factors other than accident experience, in addition, must be considered in the cost-effective development of accident reduction countermeasures.

National statistics (1) indicate that over 63 percent of fatal traffic accidents involve only a single vehicle. Even when pedestrian and pedalcycle accidents are excluded, single-vehicle accidents still account for over one-half of all traffic fatalities. The most frequently cited "first harmful event" for single-vehicle fatal accidents on a national level is collision with a fixed object (48 percent of all single-vehicle fatalities), followed by collisions with pedestrians and pedalcyclists (29 percent) and overturning accidents (17 percent). Rural highways, which account for 44 percent of the nationwide total vehicle miles of travel (VMT), account for 56 percent of the single-vehicle fatal accidents. Despite the emphasis on clear roadsides for Interstate highways, occupant fatalities in single-vehicle accidents remain the largest component of the fatality toll on these facilities.

Traffic accident data in New Mexico reflect many of the national trends. In 1983, for example, 69 percent of New Mexico's fatal accidents were of the single-vehicle type, while for the 3-fiscal-year period from 1980 to 1982, over 58 percent of the nonpedestrian fatal accidents involved a single vehicle (2). Because of the rural nature of New Mexico, 70 percent of fatal accidents occurred in rural areas, even though less than 60 percent of the state's VMT take place in these areas.

Other New Mexico Traffic accident characteristics deviate from national norms. New Mexico's fatal accident rate is consistently one of the highest in the nation, while the percent of fatal accidents involving multiple vehicles is among the lowest. Fatal overturning accidents, for example, are overrepresented, probably because of the relatively uncluttered roadside terrain in many parts of the state (3). On the other hand, fixed-object accidents occur somewhat less frequently than expected. The sum of these two accident classes could generally be described as run-off-the-road accidents. Fixed-object accidents in 1982 accounted for 14 percent of the state's total accidents and 12 percent of its fatalities. Because of the relative ease with which fixed-object countermeasures may be implemented, a study was undertaken in New Mexico to establish a manageable set of hazardous locations and to develop improvement priorities.

The purpose of this paper is to report on a procedure for ranking in priority order rural fixed-object accident site improvements in New Mexico. Although the general aspects of the procedure are not unique (4), certain features of its application are examined in greater detail. The computerized accident record and roadway inventory systems are combined to identify roadway sections with critical fixed-object accident rates. Computerized data are supplemented by the use of hard-copy accident reports, photologs, and individual site visits. Although rural Interstate segments were initially examined from the records system, principal emphasis for improvements is given to rural federal-aid primary (FAP) and federal-aid secondary (FAS) facilities in the state. Fixed-object accidents involving guardrails, moreover, are not considered because they were the subject of a previous study (5).

Subsequent sections of this paper contain descriptions of fixed-object accident experience in the state, discussions on the application of the rate quality control procedure for identifying critical fixed-object accident locations, and an outline of other considerations in the ranking in priority order of improvement sites. While the specific examples developed in this paper apply to rural, single-vehicle accidents in New Mexico, the general principles are applicable to other significant subsets of traffic accidents.

FIXED-OBJECT ACCIDENT CHARACTERISTICS

Computerized accident records show that during the 3-fiscal-year period from 1980 to 1982, approximately 143,000 accidents were reported in New Mexico. Other accidents, particularly those involving a single vehicle, no doubt occurred but are not in the record system for several reasons (6). These reported accidents were distributed by accident class as indicated in Table 1. The data show that fixed-object accidents are an important, although not major, portion of New Mexico's accident experience.

TABLE 1 Accidents by Class for Fiscal Years 1980-1982

	Total Accidents		Fatal Accidents	
Accident Class	No.	Percentage	No.	Percentage
Other vehicle	87,773	61.3	450	30.2
Fixed object	20,014	14.0	181	12.1
Overturning	11,526	8.1	492	33.0
Pedestrian/pedalcyclist	3,073	2.1	297	19.9
Other	20,776	14.5	72	4.8
Total	143,162	100.0	1,492	100.0

TABLE 2 Single-Vehicle, Fixed-Object Accidents by Location and Severity

Location	Fatal	Injury	PDO	Total	Severity Index
Rural	108	2,164	4,200	6,472	0.35
Urban	71	3,279	9,877	13,227	0.25
Total	179	5,443	14,077	19,699	0.28

Note: Severity index = (fatal + injury)/total.

Further analysis found that the 20,014 fixed-object accidents shown in Table 1 include 315 accidents involving two or more vehicles. The remaining 19,699 single-vehicle, fixed-object (SVFO) accidents are distributed by location and severity as shown in Table 2. Although two-thirds of the SVFO accidents occur in urban areas, over 60 percent of the fatal crashes and almost 40 percent of the injury accidents are in rural locations. The severity index (the ratio of fatal plus injury accidents to total accidents) is thus considerably higher for rural areas undoubtedly because of higher speeds, different types of fixed objects, and the probable underreporting of some rural, single-vehicle, property-damage-only (PDO) accidents.

The 6,472 rural SVFO accidents include many that occurred on nonfederal-aid roads, such as other state, county, Indian reservation, and U.S. Forest Service roads. The exclusion of accidents on these other roads as well as fixed-object accidents involving guardrails (6) provided a sample of 3,432 nonguardrail SVFO accidents on New Mexico Interstate, FAP, and FAS systems during the 3-year period. It is this set of accidents (approximately 2 percent of New Mexico's total accident experience) that is examined in greater detail in this paper.

Figure 1 shows the process used to select the accidents of interest, beginning with a computer tape of all New Mexico traffic accidents for the 3-year period and ending with a set of 3,432 nonguardrail SVFO accidents on rural federal-aid highways. Although the average severity index (0.38) for these accidents on the Interstate system is identical to those for the FAP and FAS systems, the systems clearly differ in their roadway and roadside design characteristics. Previous research has documented substantial variation in severity indices as a function of the type of object struck (3). An alternate technique for assessing the severity of impact with a particular object type is to weight the average NHTSA costs for fatal, injury, and PDO accidents by the probability of these severity levels. The probabilities can be estimated by the observed relative proportions of impacts with a specific object type that result in a fatal, injury, or PDO accident. Because of the subjective aspects of the NHTSA costs and the lack of homogeneity of objects within a particular category, the results of this analysis are relative rather than absolute. The average cost for all accidents examined in this project was $8,800. The severity indices and estimated costs of crashes involving various object types are given in Table 3.

The absence of trees and utility poles along New Mexico's rural Interstate is reflected by the proportions of crashes involving these fixed objects. Culverts, medians, and traffic signs, on the other hand, comprise a larger percentage of Interstate than FAP and FAS crashes. Fences (right-of-way fences on the Interstate) and embankments (in reality, consisting of both cut and fill slopes) are struck with similar frequencies on both systems. The category "other" includes barricades and construction material and equipment; these fixed-object types constitute a slightly larger portion of the accident experience on the Interstate system.

The average cost values exhibit substantially more variation than the severity indices. To a certain extent, this cost analysis procedure emphasizes those objects that are more likely to result in a fatality. However, caution must be exercised in using small accident samples where one or two fatalities can dramatically alter the average costs.

Other characteristics of rural SVFO accidents are summarized in Table 4. In general, these accidents occur on curves more often than on tangent sections and are more common on downgrades and during hours

TABLE 3 Fixed-Object Accident Type by Road System for New Mexico for Fiscal Years 1980-1982

	Interstate			FAP and FAS		
Fixed Object Type	Percentage	Severity Index	Cost ($)	Percentage	Severity Index	Cost ($)
Culvert	15	0.47	13,800	8	0.48	8,700
Embankment	16	0.41	12,600	18	0.47	10,300
Bridge	4	0.39	4,600	2	0.45	14,100
Tree	2	0.50	19,800	12	0.44	15,900
Utility pole	1	0.45	5,400	5	0.40	9,400
Ditch	6	0.30	8,700	11	0.37	8,400
Median or curb	6	0.48	10,700	1	0.24	3,000
Guard posts	4	0.18	2,400	2	0.27	3,400
Fence	21	0.32	6,300	23	0.32	3,900
Traffic sign	7	0.15	11,400	4	0.38	7,800
Other	18	0.43	14,900	14	0.37	7,100

Note: Severity index (SI) = (fatal + injury)/total; FAP and FAS = federal-aid primary and secondary, respectively.

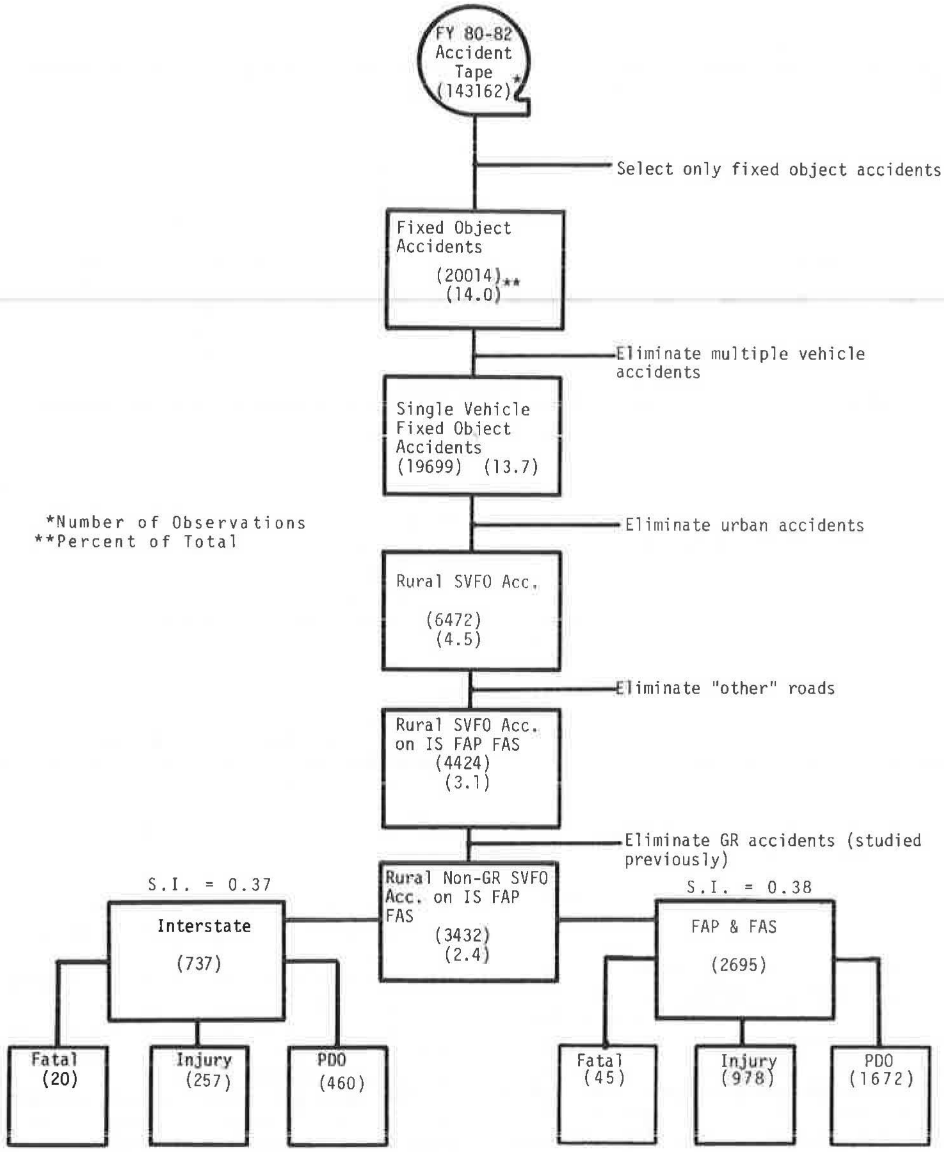

FIGURE 1 Accident selection procedure.

TABLE 4 Characteristics of Rural, Nonguardrail SVFO Accidents for New Mexico for Fiscal Years 1980-1982

	Interstate (%)	FAP and FAS (%)
Weather		
Clear	84	84
Rainy	16	16
Horizontal alignment		
Straight	88	65
Curve	12	35
Vertical alignment		
Level	76	66
Grade	24	34
Lighting		
Day	51	40
Night	49	60

of darkness. The results are consistent with those reported in the technical literature and the findings of previous studies of run-off-the-road accidents in New Mexico (3,5).

IDENTIFICATION OF CRITICAL LOCATIONS

Discussion in the previous section centered on the characteristics of nonguardrail, single-vehicle fixed-object accidents on New Mexico's rural Interstate, primary, and secondary roadway systems. Although this information is perhaps interesting from an aggregate statistical standpoint, it is of little use in identifying hazardous locations since specific objects on moderate volume rural highways are rarely struck more than once and, because exposure, in terms of volumes and section lengths, is not specifically taken into account.

The technical literature (7) discusses a number of techniques for the identification of hazardous locations. According to one survey (8), the most commonly used procedure is based on the number of accidents, followed by techniques using accident rates and crash severity. The shortcomings of relying primarily on the number of accidents are well documented. Although rate-based techniques incorporate exposure, thus eliminating one problem, they induce artificially high rates when only a few accidents are combined with low exposure. If reasonably complete and reliable data are available, this deficiency in the identification of hazardous locations may be overcome through the use of quality-control, statistical techniques, commonly known as rate quality control methods (4,9). Approximately 15 states make some use of this technique in the process of identifying hazardous locations (10).

Subsequent sections of this paper contain discussions on the application of the rate quality control method to the identification of rural, fixed-object accident locations in need of remedial action. The technique itself is discussed first; application of the technique to rural federal-aid highways in New Mexico is then considered.

THE RATE QUALITY CONTROL METHOD

The rate quality control method calculates a critical accident rate (RC) for each section of roadway. The value of RC is a function of the systemwide accident rate (RA), the amount of VMT on the section (m), and a factor (k) based on the desired level of statistical significance. The relationship is

$$RC = RA + \{k[(RA/m)^{1/2}]\} + 0.5/m \quad (1)$$

The term RA/m is an estimate of the variance of the accident rates, while 0.5/m is a continuity correction. Agencies using this technique for the general identification of hazardous locations reportedly use a variety of levels of significance (α) ranging from 0.005 to 0.05, and possibly higher. The choice of α establishes the value k in the equation, with lower values of α corresponding to higher values of k and resulting in a shorter list of hazardous locations. Higher values of α reduce the likelihood that a truly hazardous location will be overlooked, but the larger list of locations generated in this process will include many sites that are not actually hazardous. Under conditions of financial and personnel constraints, it may be appropriate to select a value of α that will result in a manageable list of locations warranting further study. Using a normal distribution table, the choice of α = 0.05 yields a value for k of 1.645, and Equation 1 reduces to

$$RC = RA + \{1.645[(RA/m)^{1/2}]\} + 0.5\ m \quad (2)$$

where

- RC = section rural nonguardrail, fixed-object critical accident rate (accidents per million VMT on the section),
- RA = systemwide rural nonguardrail, fixed-object accident rate (total SVFO accidents per total travel, not the average of individual section rates), and
- m = million VMT on the section.

The critical rate is obviously greater than the systemwide accident rate. It decreases with increasing travel on the individual study sections. If the amount of travel and the SVFO accident experience on a section are known, the actual section rate can be calculated and compared with its critical rate. Within the limitations imposed by the quality of the traffic accident and travel data, sections where the actual rate exceeds the calculated critical rate are said to be hazardous at the 5 percent level of significance.

APPLICATION OF THE RATE QUALITY CONTROL TECHNIQUE

Application of the foregoing technique for establishing roadside obstacle improvement priorities in New Mexico involves identifying sections of rural Interstate, primary, and secondary highways with higher-than-critical, fixed-object accident experience. The initial step involves combining the computerized accident record and roadway inventory data files to determine the RA for each of the three roadway systems. The next step involves using these data files to calculate and compare the actual and critical rates on each roadway section. Sections are then ranked according to their criticality, that is, the difference between the actual section rate and the critical rate for that section. The process is shown in Figure 2 and is described in the following paragraph.

The critical, fixed-object accident rate calculation begins by selecting from the accident file those accidents of interest, in this case, rural single-vehicle, nonguardrail, fixed-object accidents on the Interstate, primary, and secondary systems. The total travel by system for the 3-year study period is estimated by using the individual section lengths and annual average daily traffic counts (ADTs) in the inventory file. The average rates are then calculated for each system.

There are a number of techniques for establishing individual roadway sections. Ideally, sections should be homogeneous with respect to roadway design and development, traffic volume, and speed. While short section (<0.5 mi) are more likely to be homogeneous, they also have limited accident experience. The New Mexico roadway inventory establishes sections principally on the basis of the construction contracts under which they were built. Thus, the sections vary in length, but are reasonably consistent in design and operational features. The inventory contains 305, 1,237, and 1,028 sections on the rural Interstate, primary, and secondary systems, respectively. Inventory sections average 3 mi in length, but there is considerable variation among individual sections. To facilitate the analysis and reduce the number of individual roadway sections to be considered, the traffic volumes of adjacent sections were compared. If ADTs on adjacent sections differed by less than 100 vehicles per day (vpd), the sections were combined. This process reduced the total number of study sections from 2,570 to 967.

Determination of critical accident rates on these sections is accomplished by first calculating the VMT on each section (the product of ADT, section length, and the 1,096 days in the 3-year period). A critical accident rate is then calculated using VMT and the previously calculated accident rate for the roadway system. Those sections on which the actual rate exceeds the critical rate are flagged and ranked according to the difference between the two rates.

PROGRAM RESULTS

Calculated systemwide SVFO accident rates for the Interstate, primary, and secondary systems are 0.114, 0.187, and 0.344 accidents per million VMT, respectively. As expected, the Interstate rate is relatively low (one fixed-object accident for each 8.8 million VMT) while the secondary rate is three times higher (one fixed-object accident for each 2.9 million VMT). Use of these systemwide rates results in the following critical rate calculations at the 5 percent level of significance for individual sections on each of the three systems:

$$RC = 0.114 + \{0.555[(1/m)^{1/2}]\} + 0.5/m \text{ (IS)} \quad (3)$$

$$RC = 0.187 + \{0.711[(1/m)^{1/2}]\} + 0.5/m \text{ (PR)} \quad (4)$$

$$RC = 0.344 + \{0.965[(1/m)^{1/2}]\} + 0.5/m \text{ (SE)} \quad (5)$$

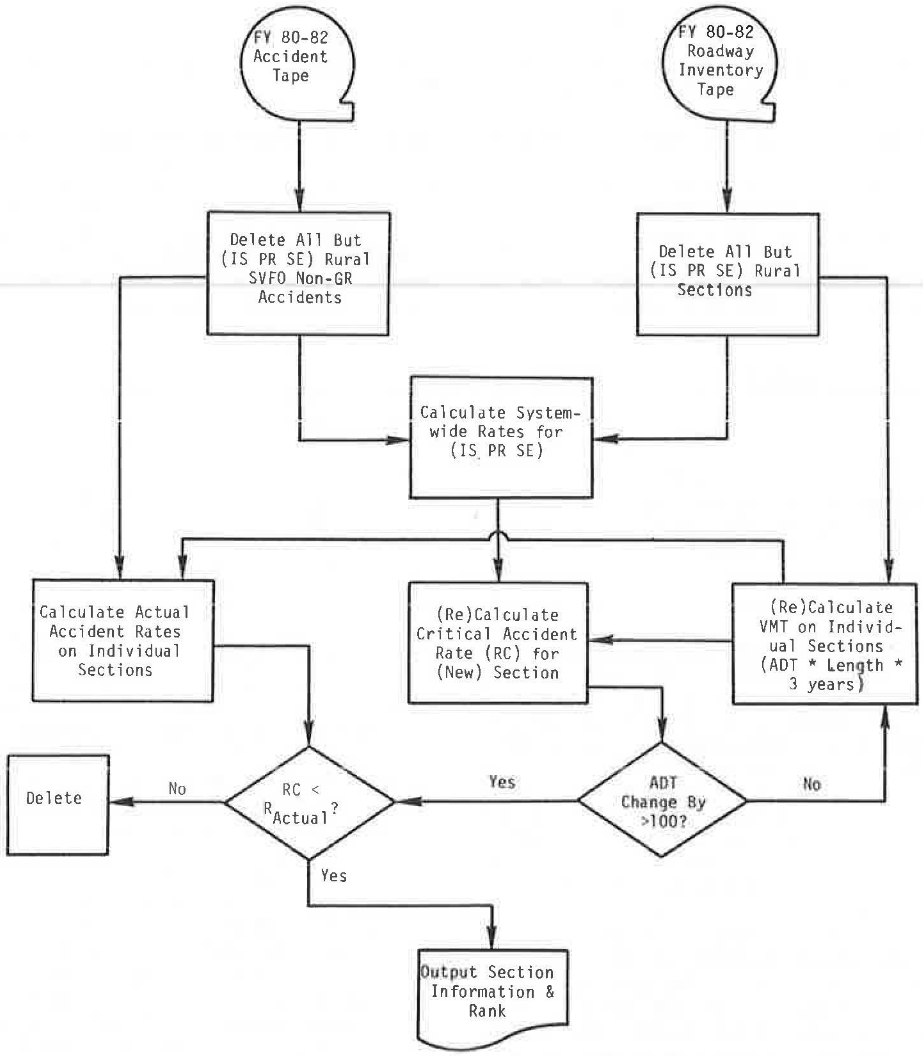

FIGURE 2 Calculation of critical fixed-object accident rates for New Mexico for fiscal years 1980-1982.

where IS is Interstate system, PR is primary system, and SE is secondary system.

For the purposes of this analysis, the value of m is the number of million VMT on a section during the 3-year study period. The critical rate relationships given in the preceding equations are plotted by roadway system in Figures 3, 4, and 5. Observed accident rates above the plot are critical at a level of significance of $\alpha = 0.05$. The abscissa of each figure is actually the ADT on a section exactly 1 mi long. It may also be interpreted as the daily VMT on a section with a length other than 1 mi. For example, to apply Figure 4 to a 3-mi roadway section with an ADT of 5,000, the figure is entered at 15,000 on the abscissa. Although the principles underlying the development of these figures have general applicability, the actual figures are only valid for the 3-year study period on rural New Mexico highways.

The application of this procedure identified a total of 14 Interstate, 47 primary, and 59 secondary sections that had actual accident rates higher than the critical rates. In other words, between 10 and 14 percent of the sections on these routes were judged to be hazardous. An example of the output information showing the five most critical sections on the FAS system is shown in Table 5.

The information listed in Table 5 shows the administrative route number on which the section is located, the beginning and ending mileposts of the critical section, the number of SVFO accidents on

TABLE 5 Fixed-Object Accidents on Rural New Mexico Secondary Roads

Administrative Route No.	Beginning Milepost	Ending Milepost	No. of Accidents	Daily VMT	Rate per Million VMT	
					Actual	Critical
1303	0.0	10.6	13	531.0	22.36	2.47
1120	0.0	1.5	4	274.5	13.31	3.77
1362	0.0	0.4	6	699.5	7.83	2.10
1226	12.9	14.4	3	362.9	7.55	3.13
1316	8.1	9.0	2	238.4	7.66	4.15

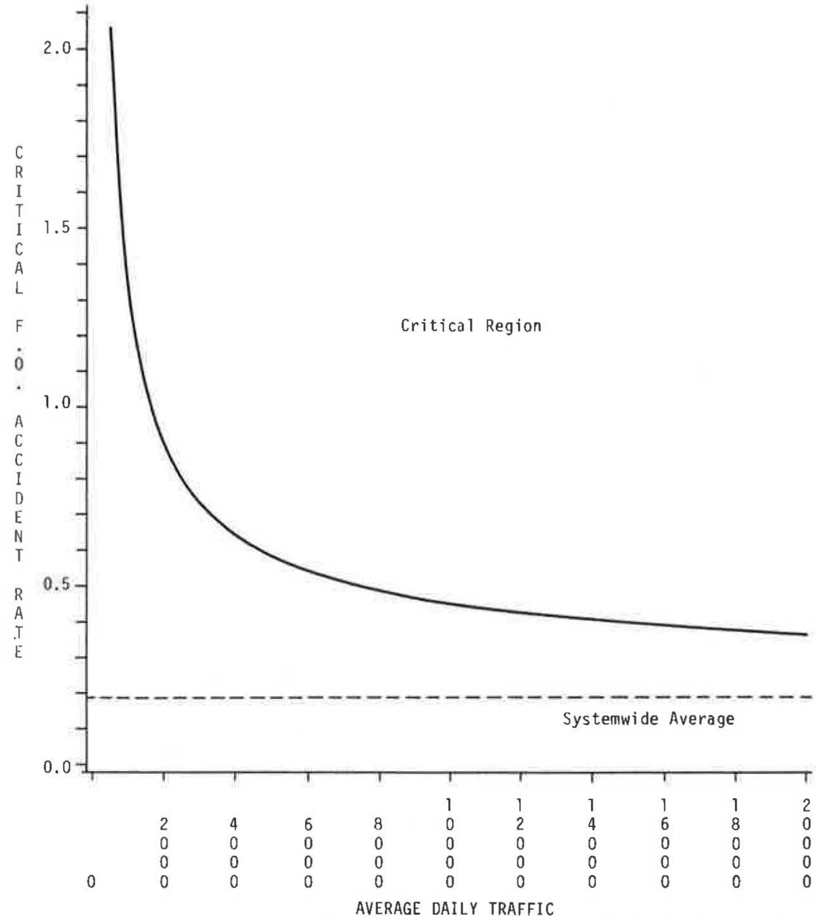

FIGURE 3 Critical fixed-object accident rates for rural New Mexico Interstates for fiscal years 1980-1982.

the section during a 3-year period, the daily VMT on the section, and the actual and critical accident rates on the section. The sections are ranked by criticality, that is, the difference between the actual and critical accident rates for the section. Although it is not obvious from the abbreviated listing in Table 5, a slightly different ranking is obtained if the sections are arranged in decreasing order by the ratio of actual to critical accident rates.

Listings such as that shown in Table 5 can be used by New Mexico State Highway Department engineers for establishing priorities for those sections of various roadway systems in the state that appear to warrant more attention in the amelioration of fixed-object accident hazards. To be useful, however, the list must be restricted to a manageable number of sections that can be examined in greater detail. The 120 highway sections identified by this process were judged to be too many to be accommodated within the constraints of this program. One logical approach for shortening the list is to use a smaller value of α. This has the effect of increasing the value of k in the critical rate equation, thus increasing the value of RC and reducing the number of critical sections. A principal shortcoming of this approach is that 20 percent of the sections, including several short sections near the top of the list, had only 2 or 3 accidents during the 3-year period. Although these sections may truly be critical, it is also quite possible that the miscoding of a single accident's location by as little as 0.1 mi could alter the section's classification from hazardous to safe. A preliminary attempt to restrict the number of study sections involved the use of cutoff values, expressed as number of accidents per mile (1.2 for the FAP, 1.7 for the FAS). Although this effort eliminated a few short sections with low travel and 2 or 3 accidents, its principal effect was to eliminate longer sections. A separate analysis of construction and project planning records also revealed that several sections had recently been reconstructed, and these sections were dropped from further analysis.

OTHER CONSIDERATIONS

Although the use of computerized accident record and roadway inventory data files provides an excellent guide for identifying roadway sections with high fixed-object accident experience, in reality, several additional steps are necessary before accident countermeasures may be implemented. Because it is often difficult to determine with certainty from computerized records whether the same objects are being struck repeatedly, the next logical step in the process must be a review of hard-copy accident reports for roadway sections of interest. This process uncovered a number of instances in which the accident locations were miscoded. Because roadside improvements are typically made at spot locations rather than overextended sections, a more thorough review of identified sections is necessary before countermeasures may be implemented. As a first step in this process, photolog reviews of the critical sections were undertaken to identify specific objects along the roadside that may warrant attention. This effort

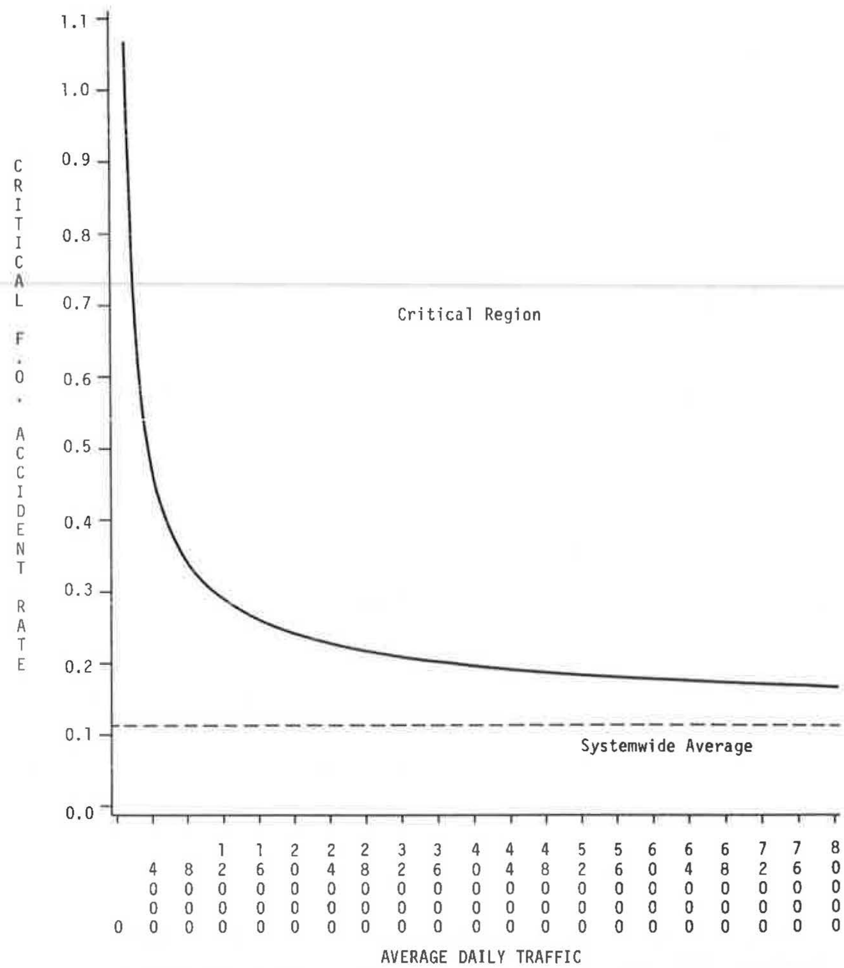

FIGURE 4 Critical fixed-object accident rates for rural New Mexico primary systems for fiscal years 1980-1982.

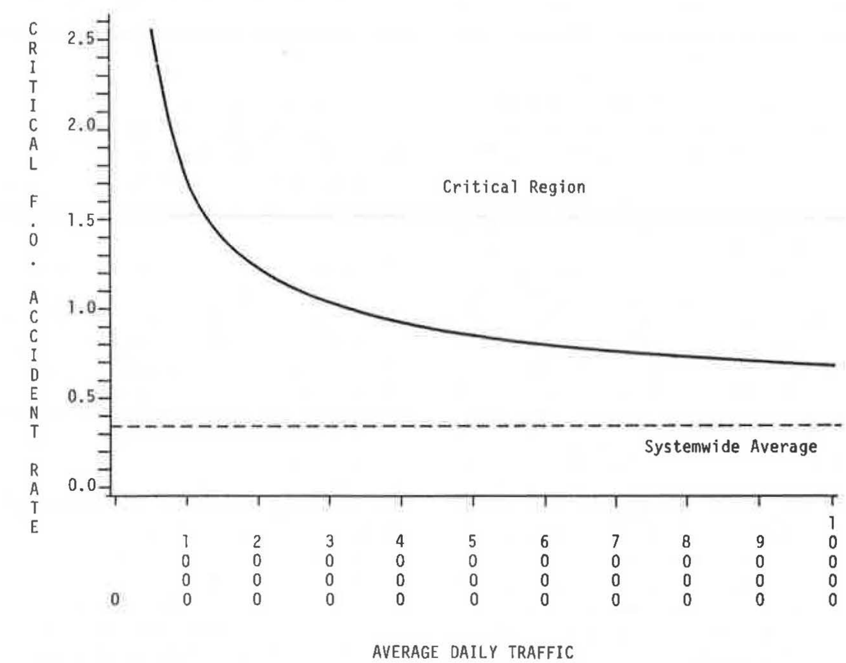

FIGURE 5 Critical fixed-object accident rates for rural New Mexico secondary systems for fiscal years 1980-1982.

was quite helpful, although certain types of roadside fixed-objects (ditches, culverts) were not readily discernible on some photologs. Finally, field reviews of critical sites are essential in identifying locations where improvements are to be made and in establishing the proper type of remedial action.

SUMMARY AND CONCLUSIONS

An attempt has been made to describe New Mexico's rural single-vehicle, fixed-object accident experience and to develop a procedure, using the rate quality control method, of identifying roadway sections that have unexpectedly high fixed-object accident rates. Although this procedure has been applied here to a particular accident type, it should be realized that the process is applicable to most accident subsets with sufficient sample size. The process has, in fact, also been used to examine single-vehicle, run-off-the-road accidents on New Mexico's secondary system (6).

However, several concerns regarding the use of this procedure should be recognized. First, there may be roadway sections that have accident rates just below critical; changing the statistical level of significance, then, will affect the number of sections identified as critical. Second, it would appear from an examination of the New Mexico data that the locational information in the roadway inventory file is superior to that in the accident record system; incorrect milepost coding of an accident location could thus affect the rate for that section. Third, it is entirely possible that a completely different group of sections would be identified as critical if other accident subsets were considered. A comprehensive program of roadside safety in the state should thus recognize the importance of these other accident types. Finally, it should be realized that past accident experience is not the only reliable indicator of hazard. Past accidents cannot be eliminated; with proper evaluation and development of countermeasures, however, the number of future accidents may be reduced.

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REFERENCES

1. Fatal Accident Reporting System 1982. National Center for Statistics and Analysis, NHTSA, Washington, D.C.
2. New Mexico Traffic Accident Data 1982. Traffic Safety Bureau, New Mexico Transportation Department, Albuquerque, April 1983.
3. J.W. Hall and P. Zador. A Survey of Single Vehicle Fatal Rollover Crash Sites in New Mexico. In Transportation Research Record 819, TRB, National Research Council, Washington, D.C., 1981, pp. 1-7.
4. J.A. Deacon. Identification of Hazardous Rural Highway Locations. In Transportation Research Record 543, TRB, National Research Council, Washington, D.C., 1975, pp. 16-33.
5. J.W. Hall. Guardrail Installation and Improvement Priorities. In Transportation Research Record 868, TRB, National Research Council, Washington, D.C., 1982, pp. 47-53.
6. J.W. Hall and J.D. Brogan. Engineering Use of Accident Records. Report FHWA-NMDOT-84-1, FHWA, U.S. Department of Transportation, May 1984.
7. F.M. Council. Accident Research Manual. Report FHWA-RD-80-016. FHWA, U.S. Department of Transportation, 1980.
8. The 1983 Annual Report on Highway Safety Improvement Programs. Office of Highway Safety, FHWA, U.S. Department of Transportation, 1983.
9. Evaluation of Criteria for Safety Improvements on the Highway. Roy Jorgensen & Associates, Gaithersburg, Md., 1966.
10. J.C. Laughlin. Methods for Evaluating Highway Safety Improvements. NCHRP 162. TRB, National Research Council, Washington, D.C., 1975 150 pp.

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