Rural Accident Rate Variations with Traffic Volume

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The nature of the relationship between hourly traffic volumes and hourly accident rates on rural highways in New Mexico was examined. The data base consisted of traffic volumes at 44 permanent count stations and 3 years' accident experience on 10-mi roadway sections surrounding these stations. The highest accident rates occurred during hours with the lowest traffic volumes. Over the range of conditions examined, accident rates decreased with increasing traffic volumes and with increasing volume/capacity ratios. However, because of the moderate traffic volumes on these roadways, it was not possible to determine the effect on the accident rate as hourly traffic volumes approach capacity. In rural states such as New Mexico, further study of this issue should focus on higher-volume locations found in urban areas.

For over 50 years, analysts have attempted to identify the relationship between traffic volumes and accident rates. Knowledge of this relationship, coupled with information on the capacity of the highway section, would allow a planner to estimate the safety implications of projected traffic growth and potential improvements in highway capacity. With some notable exceptions, previous research has found that the rate of traffic accidents on sections of roadway, as measured by the number of accidents per million vehicle miles (mvm) of travel, increases with increasing traffic volume. However, the data supporting this relationship are highly scattered and are sensitive to the design and operational features of the highway.

The implications of the existence of a definite relationship between traffic accident rates and the ratio of current or projected traffic volume to capacity (*v/c*) are quite significant. It might be expected, for example, that above some cutoff value, the rate of accidents would intensify with an increase in *v/c* ratios. If this point and the nature of the relationship could be established, then a competent analyst could predict the safety implications of a growth in traffic volume or a change in highway capacity. This ability would be extremely beneficial to an agency attempting to select an optimal program of highway improvements under the constraint of a limited budget. It could also alert engineers and planners that particular roadway sections are approaching conditions that might cause roadway safety to become degraded.

As a practical matter, the relationship between accident rates and *v/c* ratios is inherently difficult to establish. It is generally agreed that the reporting of traffic accidents is not complete, although there may be ways to address this problem (*1*). In addition, the quality of accident data reporting, especially with respect to crash location, is suspect. Furthermore, the reliability of traffic volume data is certainly subject to questioning. In other words, most state data systems are not able to provide accident or volume data in a complete, accurate format, which is necessary for this type of analysis. A study was conducted to determine if the traffic records maintained in New Mexico could be used to identify a tentative relationship between accident rates and *v/c* ratios on rural highways.

BACKGROUND

The occurrence of a traffic accident reflects a shortcoming in one or more components of the driver-vehicle-roadway system. Typically, the correction of problems associated with one of these components is sufficient to keep an accident from occurring. Thus, although many individual factors may contribute to an accident, improvements to highways can have a significant effect in reducing crash experience. It is prudent for a highway agency to operate a program designed to identify and correct locations or situations with unusually high accident experience. Such a program is hampered, however, by the partially random nature of crash occurrence and the quality of available accident data. For this reason, there is considerable interest in surrogate measures, such as *v/c* ratios, that may help in identifying problems.

One of the earliest studies of the relationship between traffic volumes and accident rates was reported in 1937 by Veh (*2*). The study examined the accident rates on sections of two-lane roads in New Jersey and related these rates to the average daily traffic (ADT). Veh (*2*) concluded the following:

> It is interesting to note the rather definite relationship between daily traffic volume and the number of accidents per million vehicle-miles. In other words, as the average daily traffic increases, accident experience, on a million vehicle-mile basis, likewise increases to approximately 7,000 vehicles per day, which is considered by many authorities to be the capacity of a two-lane highway. Beyond that point, primarily because of congestion and the resultant decrease in speed and flexibility of movement during heavy traffic hours, there is a gradual decrease in the accident rate, despite the increase in traffic.

Although Veh (*2*) does not document the original data set used in the analysis, he does present a graph of the relationship between accident rates and ADT. Figure 1 shows Veh's data along with his best-fit line, which shows the relationship between the two variables. The data dispersion in Figure 1 is a reasonable representation of the amount of scatter reported subsequently by other researchers.

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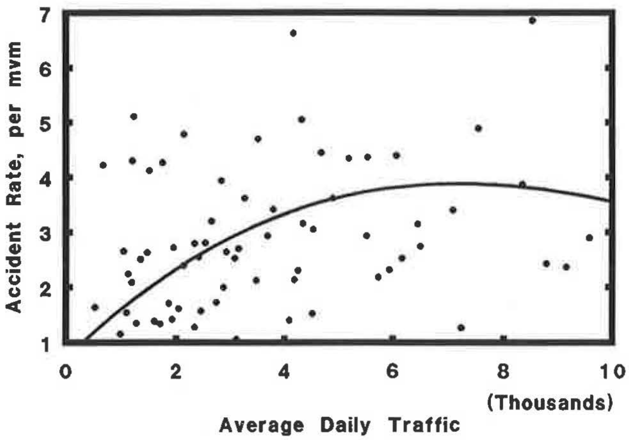

FIGURE 1 Relationship between accident rates and ADT (2).

Lundy (*3*) analyzed traffic accident experience on 659 mi of four-, six-, and eight-lane California freeways from 1960 through 1962. For each type of facility, accident rates increased with increasing ADT. In addition, Lundy observed that, for any given ADT, the four-lane freeway had the highest accident rate and the eight-lane freeway had the lowest rate. Lundy developed a set of regression equations of the following form:

$$\text{Accident rate} = \alpha + \beta * \text{ADT} \qquad \alpha, \beta > 0$$

Although the values of α are similar for the three types of freeways, the values of β decrease from four- to six- to eight-lane facilities. A discussion of Lundy's paper by Byington (*3*) noted that it may be appropriate to incorporate segment length in an accident prediction model. Another discussion by Champagne (*3*), using Lundy's data, showed a consistent increase in accident rates as the *v/c* ratio increased.

An NCHRP study (*4*) examined the accident experience on roadway sections in three states in relation to traffic volumes as well as an assortment of highway design and operational features. The study found that the single-vehicle accident rate decreased with increasing ADT, whereas the multiple-vehicle accident rate increased with increasing ADT. However, the researchers were unable to define a relationship between total accident rate and ADT because they found "in some instances the rate increased with increasing ADT and in other instances the rate decreased with increasing ADT."

A 1969 state-of-the-art review (*5*) examined these and other articles in the technical literature and concluded the following:

> It has been shown that accident rates tend to increase sharply with average daily traffic. Whether the levels of service which are being increasingly used to describe highway operation are related to the accident rate is unknown. Definition of this relationship might provide a useful method to predict future operational effectiveness of roadway designs.

The previously cited studies focused on the relationship of accident rates to ADT. In the mid-1960s, Gwynn (*6*) examined the hourly accident experience on a 3.8-mi section of a four-lane divided highway in New Jersey. During the 5-year study period (1959 through 1963), the ADT on this section was approximately 64,000 vehicles per day (vpd), for a total travel of 445 mvm. Directional hourly volumes on the section ranged from 200 to 3,300 vehicles per hour (vph). Gwynn found the highest accident rates (4/mvm to 6/mvm) during hours in the low-volume ranges. Rates decreased to approximately 2/mvm during those hours in which the directional volume was between 1,000 and 1,800 vph. At even higher hourly volumes, rates increased to 4/mvm to 5/mvm. Subject to some scatter in the data, a plot of the accident rates as a function of hourly volume assumed a U shape.

Dart (*7*) studied 5 years of accident experience (1962 through 1966) on 1,000 mi of rural highway in Louisiana in an attempt to determine which geometric variables contribute the most to traffic accidents. As part of this effort, he analyzed the relationship between accident rates and a traffic volume ratio, with the latter defined as the ratio of peak-hour volume to the service volume at Level of Service (LOS) B. Calculation of the traffic volume ratio required that specific design and operational features be collected for each of the 246 study sections. The ratio varied from a low of 0.04 to a high of 2.12. Dart reported that, for the traffic volume ratio range of 0.1 to 1.2, which presumably accounted for the bulk of the study sections, the accident rate exhibited a continuous increase with increasing traffic volume ratio.

Taylor (*8*) described a hazardous rating formula incorporating both accident and nonaccident measures. The model included the *v/c* ratio "because it incorporates the basic volume information, and yet normalizes these data to compensate, to some extent, for the number of lanes, traffic mix, control devices, etc." Because the model was designed to serve as a screening tool for identifying hazardous locations, Taylor minimized the data required for its application by defining the *v/c* ratio in a nontraditional manner as ADT divided by 24 times hourly capacity. On the basis of this definition and technical input from a panel of experts, a *v/c* ratio of more than 0.52 was judged as hazardous. As a point of comparison, the high-volume section in New Jersey studied by Gwynn would by this definition have a *v/c* ratio of approximately 0.44.

In 1980, Orne (*9*,p.20) described some preliminary efforts to examine the relationship between traffic accidents in Michigan and the actual traffic volumes at the time of the accident. This approach, which had also been suggested by Gwynn (*6*), is hampered to a considerable extent by the availability of reliable traffic volume data at accident sites.

More recently, researchers in Greece (*10*) examined the relationship between traffic accident rates and *v/c* ratios on an 11.2-mi section of a four-lane undivided toll road. Because the facility was a toll road, with access available only at the ends of the section, it provided reliable traffic volume data. Although traffic volumes were not specifically indicated, an analysis of the number and rate of accidents for the 89-month study period suggested that ADT values were in the range of 17,000 to 18,000 vpd. The analysis concentrated on 9.3 mi of the road, which experienced 517 accidents, for an average accident rate of approximately 1.2/mvm. Using the techniques of the *1985 Highway Capacity Manual* (*HCM*) (*11*), the researchers calculated the capacity of each of the 15 study sections and determined the *v/c* ratio and level of service at the time of each accident. For LOS A and B operating conditions, which accounted for 81 percent of the travel and 71 percent of the accidents, the accident rate was approximately

10 percent below the average rate. At LOS C, the rate was close to the overall average. However, at *v/c* ratios greater than 0.65, corresponding to LOS D through F, the accident rates increased sharply. For LOS F, a forced-flow condition, the accident rate was approximately 2.9/mvm.

The results of the Greek study are encouraging, but they must be viewed circumspectly. At the most basic level, how well the procedures of the 1985 HCM apply to the driving environment in Greece is not known. Also, the accident study conducted over the 7-year period was subject to changes in the environment, even though there were no changes to the roadway itself. In addition, the accident sample size was relatively small in comparison with several of the other studies cited previously.

Perhaps the most extensive evaluation of this subject was a 1967 to 1975 study (*12*) of eight sections of four-lane interurban road in Israel. The study, which was limited to fatal and injury accidents on weekdays, contained thorough analyses both of single- and multiple-vehicle crashes. The study included two primary procedures: (a) a time-sequence analysis for each roadway section and (b) a cross-section analysis on an annual basis. Single-vehicle accident rates were extraordinarily high for flow rates below 250 vph. The multiple-vehicle accident rates were more diverse, with half the sites showing a substantial increase in rates for flow rates greater than about 900 vph, and the remaining sites exhibiting little change with increases in hourly traffic volumes. When the two crash types were combined, the results were dominated by the data for multiple-vehicle crashes. More specifically, those study sections that encompassed a broad range of traffic volumes had a U-shaped relationship when accident rates were plotted as a function of hourly volume; the minimum rate occurred near 500 vph. The remaining four sites, three of which did not have hourly volumes in excess of 1,000 vph, did not show an increase in accident rates as hourly volumes increased.

The technical literature offered some useful guidance for the development of the methodology to be used in this study. It appears valid to assume that there is a relationship (albeit unknown at this time) between traffic accident rates and traffic volume. Because a variety of driver, vehicle, and roadway factors contribute to crash occurrence, it would of course be unrealistic to expect traffic volume variations to explain a large share of the differences in accident rates. The data scatter observed in these studies is a partial reflection of this problem.

The literature suggests two approaches for achieving a suitable sample for studying this issue. One procedure is to select a comparatively short section of road and to study its volume and accident characteristics for an extended period of time. By using a single, reasonably homogeneous site it is possible to thoroughly monitor the parameters of interest. On the other hand, the site chosen may not be representative of the remainder of the road system. Furthermore, accident studies that continue for an extended period are not able to account for system-wide changes in the driver, vehicle, or environment variables. An alternate approach is to use a larger number of study sections. A major advantage of this tactic is that it encompasses the characteristics of a broader section of the roadway system and offers the potential for conducting the study over a shorter period. However, it is difficult to ensure that the sections are comparable with respect to those design and operational characteristics that can affect crash occurrence. All things considered, it appears that the use of multiple sections of constant length is the superior study procedure.

STUDY DESIGN

The essential requirement for a study of the relationship of accident rates to *v/c* ratios is reliable information on traffic accidents, hourly traffic volumes, and factors that influence highway capacity.

New Mexico maintains a computerized accident record system that includes approximately 50,000 accidents reported annually throughout the state. The system allows accidents to be selected by route and location and classified according to characteristics of interest to this study.

Traffic volume data pose a somewhat more serious problem. In New Mexico, rural traffic volumes are collected at 50 permanent count stations, and short-term counts are conducted throughout the state on a rotating basis. A recent critique by the New Mexico State Highway and Transportation Department identified valid concerns about the reliability of data from the short-term counts. Although the root problems that affected the data quality have been corrected, it will take 1 or 2 years to develop a suitable traffic volume data base for the rural state highway system. Therefore, this study relied on traffic volume data from the permanent count stations; these data are reportedly reliable.

Another principal data need is the information necessary to calculate capacity. Roadway sections at the study sites include two-lane roads, a couple of four-lane divided highways, and four-lane freeways. With a small sacrifice in accuracy, all can be assumed to have 12-ft lanes and clear roadsides. When necessary for capacity calculation, a reasonable judgment can be made regarding driver familiarity with the roadway. A major factor affecting capacity is the combination of terrain and traffic composition, especially of heavy trucks; these parameters are available for some of the sites and could be measured at the others. For two-lane sites, the extent of the road subject to passing restrictions is necessary for the calculation of capacity; unfortunately, this information is not readily available in existing record systems.

ASSEMBLING THE DATA BASE

In accordance with Byington's recommendation (*3*), the study plan involved the identification of constant-length segments around each of the permanent count stations. The length chosen for this purpose was 10 mi. A review of maps and the roadway inventory file found that six of the permanent count locations were on sections of road with significant numbers of access and egress points, to the extent that the volume counted at the permanent count station may not reflect the volume on the entire 10-mi section; therefore, these sites were deleted from the analysis. At three additional sites, the permanent count station was on a section bounded by a pair of major intersections or interchanges less than 10 mi apart; in these cases, the sections were shortened to 5 mi. In the remaining 41 cases, it was possible to identify a 10-mi section around the permanent count station that was reasonably homogeneous and free of significant access points. The resulting 44 study sites, with a length of approximately 425 mi, had a combined annual travel of 960 mvm (on the basis of the FY 1988 travel volumes). The average daily traffic at individual sites ranged from 500 to 26,200 vpd.

The next step in creating the data base involved a search of the computerized accident records to identify all reported traffic accidents (fatal, injury, and property damage only) on these 44 sections for the 3-year period from 1985 to 1987. The search identified a total of 2,006 accidents, for an overall accident rate of 0.70/mvm. The accidents were subsequently categorized by hour of the day and collision type (single- versus multiple-vehicle crashes).

DATA ANALYSIS

In an effort to establish a tie to the results reported in the technical literature, the initial phases of the analysis examined the volume and accident experience for the entire data base. Figure 2 shows the hourly variation in total annual vehicle miles of travel for the 44 study sections. Peak travel occurs in the hours of 4:00 to 5:00 p.m. and 5:00 to 6:00 p.m., both of which account for approximately 7.4 percent of the ADT. Because of rural travel characteristics, there is no discernible morning peak but rather a gradual increase in hourly travel from about 7:00 a.m. through the late afternoon. At the other extreme, the hours beginning at 2:00, 3:00, and 4:00 a.m. each account for about 0.9 percent of the daily travel.

Figure 3 shows the hourly distribution of accidents for the 3-year study period. The most striking feature of this graph is that it exhibits substantially less hourly variation than was evident for the traffic volumes. The maximum number of accidents (127) occurred in the hour beginning at 6:00 p.m. (6.3 percent of the daily total), followed by 5:00 p.m. and 7:00 a.m., each with about 5.6 percent. By contrast, the lowest number of accidents (54) occurred between 4:00 and 5:00 a.m., accounting for 2.7 percent of the total. When hourly accident rates are calculated, therefore, the peak rates do not occur during those hours with the greatest number of accidents but rather during those hours with the lowest volumes of traffic. As shown in Figure 4, the peak accident rate (3.2/mvm) occurred between 2:00 and 3:00 a.m.; all the hours from 11:00 p.m. to

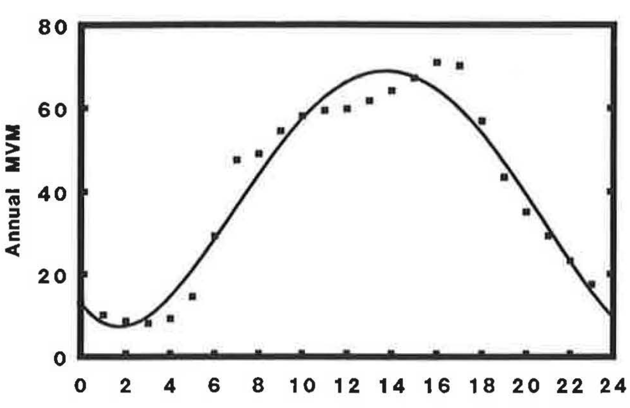

FIGURE 2 Hourly travel variations.

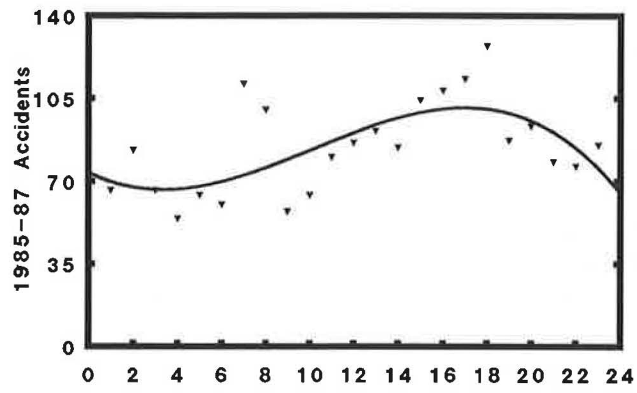

FIGURE 3 Traffic accidents, 1985 through 1987.

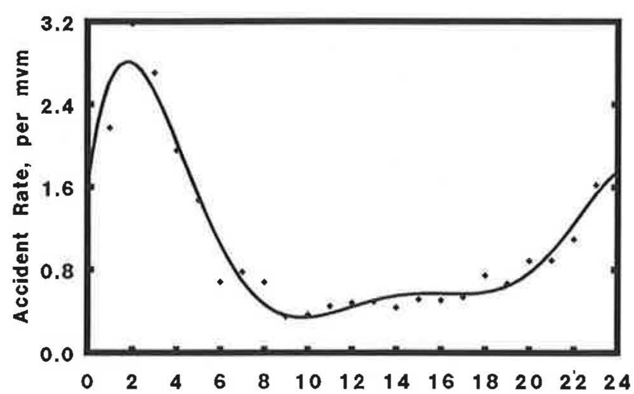

FIGURE 4 Traffic accident rates, 1985 through 1987.

5:00 a.m. had accident rates that were more than twice the overall daily average of 0.7/mvm. The finding that accident rates are high during the hours of darkness is not unexpected. However, the relatively constant daytime accident rate was not anticipated. For the relatively high-volume hours between 6:00 a.m. and 7:00 p.m., only the hours beginning at 7:00 a.m. (0.78/mvm) and 6:00 p.m. (0.74/mvm) had accident rates greater than the average for the entire day.

Figure 5 shows the same information included in Figure 4 but in a manner that highlights the pattern of accident rates versus average hourly volumes. Over the range of volumes studied, the data demonstrate that rural accident rates decrease with increasing hourly volumes. Although this same pattern emerges in subsequent analyses, a cause-and-effect relationship was not assumed, especially between the low traffic volumes and their accompanying high accident rates. However, mentioning two potential explanations for this pattern is appropriate.

Single-vehicle accidents have been shown (*13*) to be a serious problem in New Mexico, accounting for approximately 45 percent of the state's highway fatalities. Hourly accident rates were therefore calculated separately for single- and multiple-vehicle accidents. For the entire day, the rates of single- and multiple-vehicle accidents were 0.44/mvm and

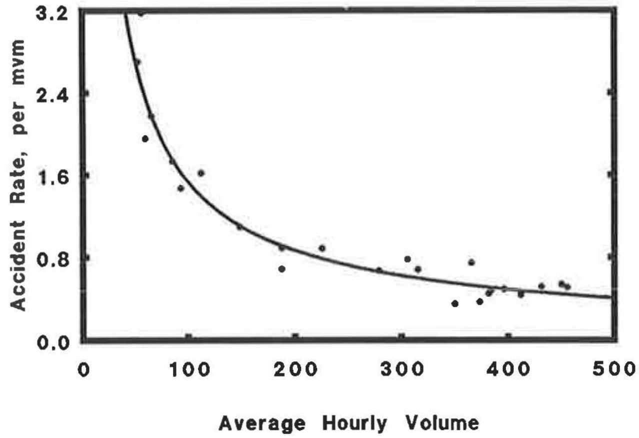

FIGURE 5 Traffic accident rates, 1985 through 1987.

0.26/mvm, respectively. The plot of hourly accident rates shown in Figure 6 suggests two findings. First, the major component of the peaking of accident rates in the late evening and early morning hours is because of single-vehicle accidents; this certainly makes sense, because the lower traffic volumes during these hours lessen the opportunity for multiple-vehicle conflicts. Second, the rates of single- and multiple-vehicle accidents during daylight hours are similar; with the exceptions of the hours beginning at 1:00 and 2:00 p.m., the single-vehicle accident rate is always greater than the multiple-vehicle accident rate.

Numerous characteristics differ between daytime and nighttime operation, especially on rural highways. On the one hand, enforcement presence is much lower on these roads at night, thus reducing the likelihood that a reportable accident will be reported. On the other hand, there is ample evidence that the driving environment changes during the hours of darkness. Visibility is obviously worse, and drivers during the low-volume hours are more likely to be tired or impaired.

The role of single-vehicle accidents and the complexities of nighttime operation vis-à-vis hourly volumes in contributing to the substantial accident rate variations at low flow rates is beyond the scope of this project, which is more concerned with the relationship at high volumes. Despite the pattern shown in Figure 5, it may be that, over the volume range of interest to the analyst, accident rates on rural New Mexico roads are independent of hourly volumes.

A flaw is inherent in the results shown in Figures 2–6. Specifically, the 44 study sites include a mix of two-lane and four-lane roadways, with obviously different volumes and capacities. This mixture of the two types of sites tends to mask the effects both at low and high volume levels. To resolve this shortcoming, the data base was divided into two sets: (a) a group of 24 low-volume sections with ADT values less than 4,500 vpd and (b) a group of 20 high-volume sections with ADT values greater than 4,500 vpd. With two exceptions, this grouping divided the data base into two-lane and four-lane facilities. Graphs analogous to Figures 4 and 5 were prepared for each group.

The 24 low-volume sites had an average ADT of approximately 2,200. The total number of accidents was 567, for an average accident rate of 0.97/mvm. The hour beginning at 6:00 p.m. had the highest number of accidents (55); on the basis of a mean volume of 130 vph, the accident rate during this hour was 1.61/mvm. With the exception of this hour, accident rates for the hours from 6:00 a.m. to 7:00 p.m. were all below the daily average. As shown in Figure 7, peak accident rates occurred during the early morning hours. The pattern in this figure is similar to that shown in Figure 2, although the rates are substantially higher. In Figure 8, the accident rates are plotted as a function of average hourly volumes, which varied from 13 at 3:00 a.m. to 172 at 4:00 p.m. As a coarse approximation, the two-directional capacity of these sections could be estimated at 1,800 vph; the abscissa in Figure 8 therefore corresponds to a range of *v/c* ratios from 0 to approximately 0.10. The trend of decreasing accident rate with increasing average hourly volume is evident, with the only significant exception occurring at 6:00 p.m.

The 20 high-volume sites, with an aggregate length of 185 mi, had an average ADT of nearly 11,300. On the basis of the total of 1,439 accidents during the period 1985 through 1987, the average accident rate was 0.63. In contrast to the two-lane roads, the peak number of accidents (87) occurred at 7:00 a.m., when the accident rate was 0.75. The hourly variation in accident rates shown in Figure 9 displays the familiar pattern of below-average rates during the daytime and above-average rates at night. However, peak accident rates are only half the values for the low-volume sections.

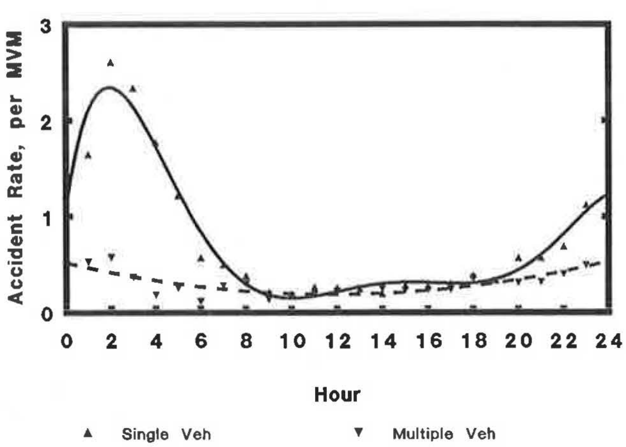

FIGURE 6 Single- and multiple-vehicle accident rates.

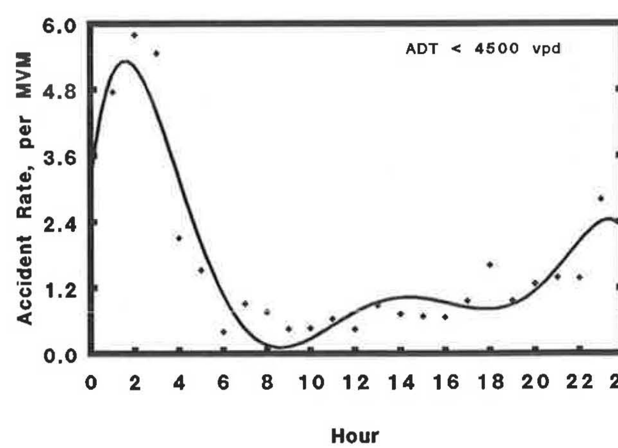

FIGURE 7 Accident rates on low-volume sections.

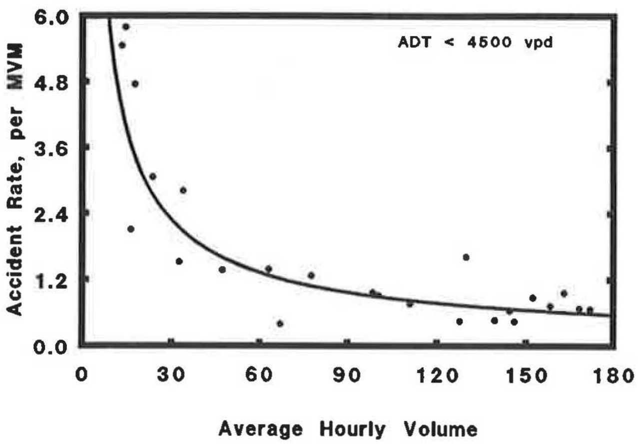

FIGURE 8 Accident rates on low-volume sections.

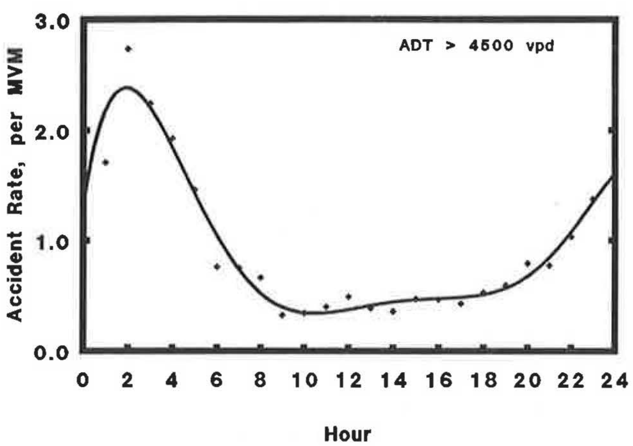

FIGURE 9 Accident rates on high-volume sections.

The relationship between accident rates and average hourly volume is shown in Figure 10. In this figure, the maximum peak hourly volumes of 821 vph (at both 4:00 and 5:00 p.m.) correspond to a *v/c* ratio value in the range of 0.15 to 0.20. Over the range of moderate traffic volumes shown in this figure, there is no indication that accident rates increase as the *v/c* ratio increases.

On the basis of the conditions studied and the relationships displayed in Figures 2–10, it is possible to draw the following intermediate conclusions:

1. Accident rates tend to be below the daily average during the daylight hours and are substantially greater during the low-volume hours of darkness.
2. Over the range of average hourly volumes studied on rural New Mexico highways, accident rates decrease with increasing volumes. However, when the very low-volume hours are ignored, it may be that accident rates are independent of flow rates.
3. The major difference between daytime and nighttime accident rates appears to be attributable to the unusually high single-vehicle accident rates during hours of low traffic volume. In addition, the single-vehicle accident rate is, in most cases, higher than the multiple-vehicle accident rate.

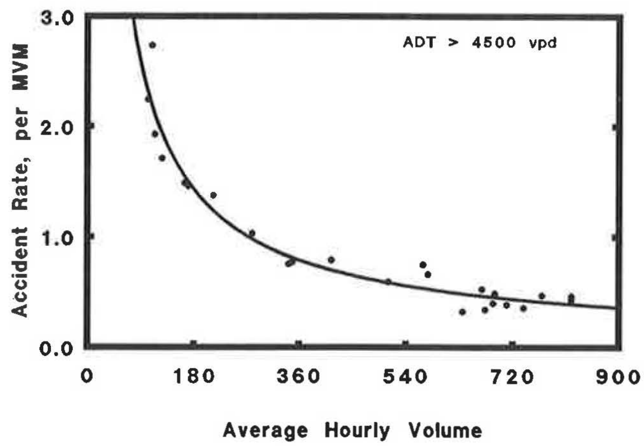

FIGURE 10 Accident rates on high-volume sections.

4. Although New Mexico's permanent count stations are located at representative locations on rural two-lane roads, they do not embrace a full range of hourly volumes and *v/c* ratios. The highest average hourly volume at any of the two-lane sections is 365 vph, corresponding to a *v/c* ratio of approximately 0.20. Because of the limited latitude of *v/c* ratios, it is not possible to use the New Mexico data base to develop a meaningful relationship for these facilities over the full range of *v/c* ratios.
5. Accident rates on New Mexico freeways and other four-lane highways are about 65 percent of those on two-lane roadways. However, because of their significantly higher volumes and marginally higher *v/c* ratios, the multilane highways provide a better opportunity for establishing the relationship between accident rates and *v/c* ratios.

These findings are not particularly surprising in hindsight. However, a better understanding of this subject requires sections of road with higher *v/c* ratios. The next task, therefore, involved a more detailed study of the highest volume four-lane sections in an effort to extend the relationship shown in Figure 10.

HIGH-VOLUME FOUR-LANE ROADWAYS

The trade-offs between the long-term examination of high-volume sections and the shorter-term evaluation of a more extensive portion of the roadway system were described previously. Although overall preference was given to the examination of a larger number of sections, it was necessary to focus on the highest volume sites if information was to be developed regarding the upper ranges of the *v/c* ratio. It was recognized at the onset that an individual 10-mi section, even though examined for a 3-year period, would exhibit significantly more variation in volume and accident parameters than the larger group of high-volume sections shown in Figures 9 and 10. Nevertheless, this course of action was the only one feasible within the constraints of the existing data base. As a result, the three multilane, permanent count stations with the highest ADT values were examined in greater detail. Two of these sections are on the Interstate highway system, whereas the third is on a federal-aid primary system. The characteristics of these sections are presented in Table 1.

TABLE 1 SUMMARY OF THREE HIGH-VOLUME SITES

Station	99	270	520
Route	US 84	I-40	I-10
Milepost	168.61	176.07	155.25
1988 Volumes			
ADT	26214	19226	19185
Ave Min Hr	54	219	204
Ave Max Hr	2354	1389	1345
%HC (1987)	4	25	22
Highest Hourly Volumes			
50th Highest	2817	1605	1613
30th Highest	2869	1640	1642
10th Highest	3157	1740	1740
Highest	5064	1978	1951
Capacity (Approx.)			
Design Speed	60	70	70
PHF	0.9	0.9	0.9
Driver	Commuter	Weekend	Weekend
Terrain	Rolling	Rolling	Level
Capacity/dir	2864	1851	2808
Capacity	5700	3700	5600
V/C Ratios			
Ave Min Hr	0.01	0.06	0.04
Ave Max Hr	0.41	0.38	0.24
50th Highest	0.49	0.43	0.29
30th Highest	0.50	0.44	0.29
10th Highest	0.55	0.47	0.31
Highest	0.89	0.53	0.35

As shown in Table 1, the ADT on these high-volume sections ranged from 19,200 to 26,200 vpd. On the two Interstate sections, more than 20 percent of the traffic consisted of heavy commercial (HC) traffic, whereas on the divided four-lane rural arterial, only 4 percent of the traffic was HC. This particular characteristic, along with the nature of the terrain, has a significant effect on highway capacity. In general, drivers on the Interstate sections are relatively unfamiliar with the roadway, whereas those near Station 99 tend to be commuters, which has an effect on highway capacity. Data are also shown for selected highest hourly volumes. The highest hourly volume is the two-way traffic during one of the 8,760 clock hours (e.g., 4:00 to 5:00 p.m.) that was the highest for the entire year. A similar definition applies to the 10th, 30th, and 50th highest hours. As indicated by the data, the section on US-84 has some rather extreme peaking characteristics, with the *v/c* ratio at the highest hour being 0.89; by contrast, the comparable figures on the Interstate sections are 0.35 and 0.53. Some level of stability is reached, however, when the 30th highest hourly volume, a value often considered in highway design, is examined. At this point, the *v/c* ratios range from approximately 0.30 on I-10 to 0.50 on US-84. As shown in Table 1, *v/c* ratios change only slightly between the 30th and the 50th highest hours. The data reveal that even if a study is restricted to the highest hourly volumes at the highest ADT sites, *v/c* ratios at New Mexico's rural permanent count stations rarely exceed 0.5.

From this study's perspective, it is difficult to evaluate the extreme points on the *v/c* curve. If, for example, the highest hour of the entire year at Station 99 (5:00 to 6:00 p.m. on the last Monday in August) had no accidents during 1985 through 1987, the resulting accident rate would be 0.00/mvm. On the other hand, with one accident during this particular hour, the accident rate would be 6.58/mvm; intermediate rates are not possible. In fact, none of the 147 accidents of Station 99 during 1985 through 1987 occurred between 5:00 and 6:00 p.m. on the last Monday in August. Looking at a broader slice of time, all of the hours from noon to 7:00 p.m. on the last Monday in August were among the year's 30th-highest-volume hours. During the 3-year study period, there were no accidents during any of these hours on the last Monday in August. Continuing one step further, there was only one accident during these 7 hr on any Monday in August, yielding an accident rate of 0.45 versus an overall rate of 0.51 at this site. Finally, during all hours of the 13 August Mondays in 1985 through 1987, there were two accidents on this section, for a rate of 0.44. The conclusion from this microanalysis of the highest volume section is that evaluation at this level can produce sporadic and inconsistent results.

As a compromise between the earlier analysis that grouped 20 four-lane facilities and the preceding analysis that examined specific hours with the highest volume, an intermediate approach was taken. The three high-volume sites characterized in Table 1 were examined individually and collectively. Figures 11–13 show the relationship between accident rates and traffic volumes at the three sites. Although the best-fit lines in these figures are generally similar to those seen in the earlier graphs, the data exhibit a higher degree of scatter because, with smaller amounts of travel at a specific site, a difference of one or two accidents can cause a substantial

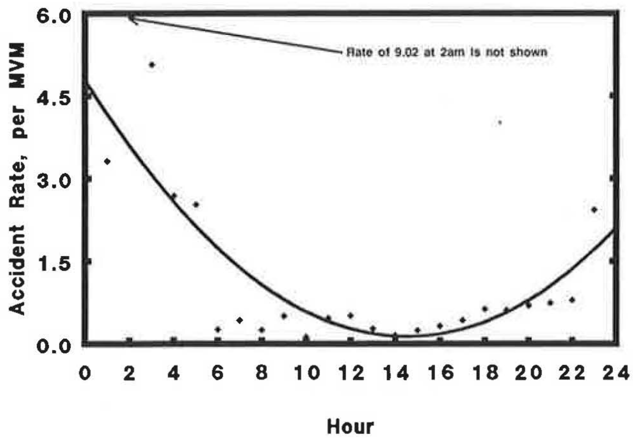

FIGURE 11 Accident rates on US-84.

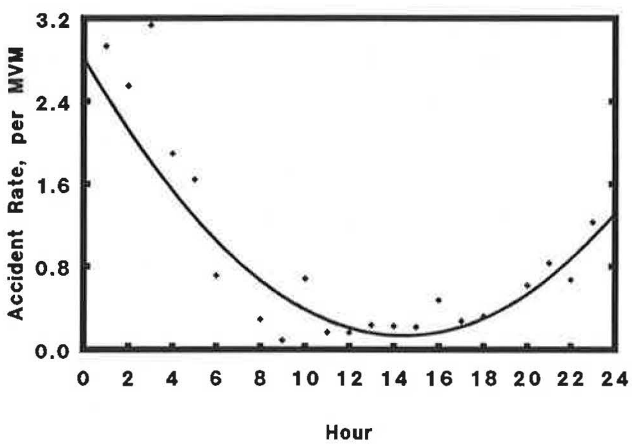

FIGURE 12 Accident rates on I-10.

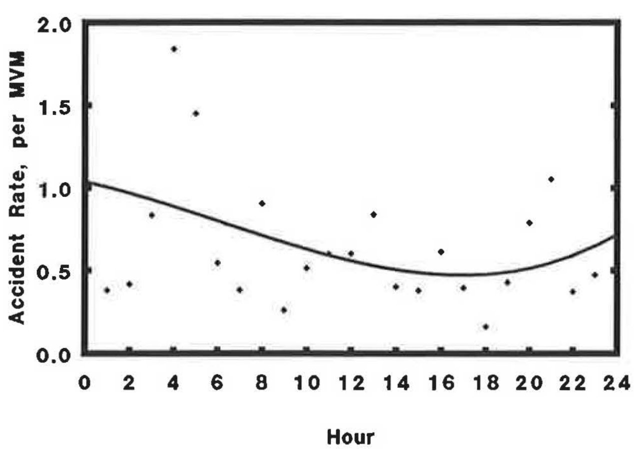

FIGURE 13 Accident rates on I-40.

change in the accident rate. These wide variations are moderated to some extent when the accident and travel data from the three sites are combined. As shown in Figure 14, data from the three sites allow the average accident rate to be evaluated for average hourly volumes as high as 1,700 vph. As a rough approximation, this average volume level corre-

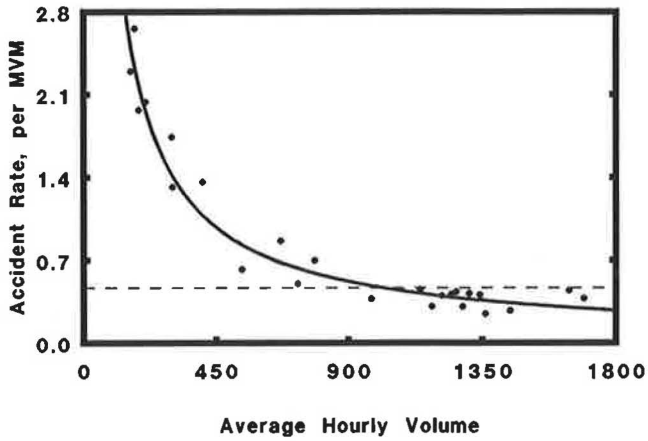

FIGURE 14 Three high-volume count stations.

sponds to a v/c ratio of 0.34. The inevitable conclusion is that, over the range of volumes and v/c ratios found at the highest-volume rural four-lane roadways, accident rates decrease sharply as average hourly volumes increase to about 900 vph (v/c = 0.18). Between hourly volumes of 900 and 1,700 vph, accident rates level off at approximately 70 percent of the overall average accident rate. It is not possible to determine from these data if a further increase in traffic volumes would be accompanied by an increase in accident rates.

CONCLUSIONS AND RECOMMENDATIONS

An attempt was made to determine if a relationship exists between hourly accident rates and the ratio of traffic volume to capacity. Knowledge of any such relationship would help engineers and planners assess the safety implications both of projected traffic growth on existing highways and of highway improvements designed to increase capacity. The tool could therefore be a valuable supplement to current analysis techniques.

This objective was not achieved because peak traffic volumes on the rural highways examined are rarely as high as 50 percent of capacity. Although the variation in accident rates at low flow rates was documented, conclusions were not reached for the potentially more critical case of high v/c ratios. For such highways, it is probably impossible to resolve this issue.

The highest accident rates were shown to occur at low volumes. This finding was expected because these conditions occur at night, when accident rates are known to be higher. But it also raises a related issue concerning the type of accident that should be included in the accident rate. It was assumed that vehicle conflicts, and in turn accidents, would increase as congestion increased beyond some threshold value. However, multiple-vehicle rather than single-vehicle accidents would increase. Figure 6 showed that the peaking of accident rates during the low-volume hours of darkness was caused primarily by the occurrence of single-vehicle accidents, although few crashes of this type can be attributed to congestion. Further study of this subject might achieve better results if restricted to multiple-vehicle crashes.

The New Mexico State Highway and Transportation Department has implemented a set of procedures that over time will improve the quality of traffic volume data collected at short-term count locations. The availability of a more extensive data base, possibly including sites with higher *v/c* ratios, might provide an opportunity for further study of this topiç. The other major variable considered in this study was traffic accident experience. The techniques used highlight the importance of high-quality accident data, especially with respect to crash location.

Significant progress was made on several major components of the problem. General trends were identified, and data problems that need to be addressed before further progress can be made were highlighted. Two preliminary studies, described in the project report (*14*), examined the feasibility of applying the techniques discussed herein to urban intersections and freeway sections. Although there are potential data problems with both of these highway elements, they both provide the opportunity to evaluate operation at high *v/c* ratios. A proposed study will attempt to evaluate the relationship between accident rates and *v/c* ratios at high-volume intersections in the Albuquerque area.

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