Alternating Passing Lane Lengths

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This paper reports on a study of passing lane operations, with a focus on continuous three-lane cross sections with alternating passing lanes (three-lane alternate passing or 2+1) segments in Arkansas. The examined aspects include effects of passing lane length on platooning, passing, speed, and passing lane crash rates. Five sets of field data were collected at four rural sites. After a vehicle entered the passing lane, platooning decreased and eventually stabilized. Passing activity was greatest at the beginning of the segments. Speed patterns were found to vary among sites, but average speed rose when a vehicle entered the passing lane section. Five years of crash data from 19 sites were used. Even though the volumes for the passing lane segments were higher than the state average volume for rural two-lane roads, the passing lane crash rates were generally lower than the statewide average crash rate for rural two-lane roads.

As traffic volumes continue to grow, rural two-lane roadway users are experiencing increasing delay, frustration, and accidents. One response to these problems is the construction of passing lanes, which allow faster drivers to get around slower vehicles without encroaching into the lane for oncoming traffic.

Passing lanes can be provided in a number of ways. Roadways constructed with a continuous three-lane cross section and alternating passing lanes (three-lane alternate passing or 2+1 roads) have been viewed as an "attractive alternative to two- or four-lane roads" (*1*). For situations in which a two-lane road is not providing the desired level of safety or mobility and expansion to a four-lane roadway seems unjustified or prohibitively expensive, widening to a 2+1 cross section can be an economical alternative. Figure 1 is a schematic of a three-lane alternate passing section.

The Arkansas State Highway and Transportation Department (AHTD) has upgraded some two-lane highways to continuous three-lane cross sections and marked them for alternating passing lanes. AHTD sponsored research to examine the operation of these 2+1 passing lane sections. Research objectives included quantifying the following variables: passing rates, the percentage of vehicles in platoons, and changes in speed within the passing lanes. Aggregate crash data were also examined.

LITERATURE REVIEW

The following passing lane literature was reviewed.

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Platooning

Vehicle platooning was a more sensitive measure of traffic service than mean speed (*2*). The authors concluded that the percentage of vehicles in platoons decreased on average from 35.1% immediately upstream of a passing lane to 20.7% within the passing lane. Immediately downstream of the passing lane, vehicles in the platoon rose to 29.2% on average, still 5.9% less than the upstream percentage.

In another paper, Harwood et al. (*3*) proposed that when a passing lane is added, the percentage of vehicles following in the platoon falls dramatically and stabilizes at about half the value for the two-lane road.

Enberg and Pursula (*4*) conducted simulation studies to evaluate the effect of passing lanes on platooning. (Those authors considered the vehicles to be in a platoon if the headway between two successive vehicles was less than 5 s.) They concluded that passing lane sections had a smaller percentage of platoons than did two-lane sections.

Passing

The passing rate was strongly related to traffic flow and passing lane length (*2*). The passing rate decreased with increasing passing lane length and increased with increasing vehicular flow and increasing upstream percentage of vehicles in platoon. May found that the number of passes increased with vehicular flow (*5*).

Enberg and Pursula (*4*) found that the passing rate increased with increasing traffic flow. However, these authors also found that the passing lane length had a negligible effect on the passing rate.

Speed

Enberg and Pursula (*4*) found a statistically significant increase in the speed of traffic in the passing lane section but that the passing lane had no significant effect on downstream speeds. Harwood et al. (*2*) noted that the effect of passing lanes on traffic speeds varied widely from site to site and that the vehicle speeds were influenced more strongly by local geometrics than by the presence of passing lanes.

Length

Harwood et al. (*3*) calculated, on the basis of traffic flow rates, needed length of a passing lane. As the flow rate increased, optimum length of the passing lane also increased. For flow rates up to 200 vehicles per hour (vph) in one direction of travel, passing lane lengths between 0.4 and 1.2 km (0.25 and 0.75 mi) were most effective. For flow rates of 700 vph in one direction of travel, the required length of passing lanes appeared to be from 1.0 to 2.0 mi. However, passing lanes longer than 1.0 mi may not be desirable because the length is not needed during the remainder of the day, when traffic volumes are low. The authors suggested that more short passing lanes would be more effective than fewer long passing lanes.

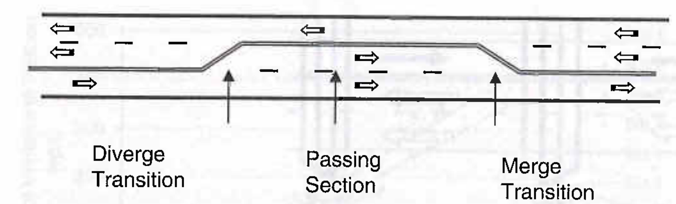

FIGURE 1 Schematic example of three-lane alternate passing design.

May (*5*) concluded that shorter passing lane lengths, from 0.4 to 1.2 km (0.25 to 0.75 mi) long, were most effective at improving passes, decreasing percentage of time delay, and saving travel time.

Enberg and Pursula (*4*) conducted simulation studies to analyze the effect of passing lane lengths. At 500 vph, the optimum length of a passing lane was 1 km (0.6 mi) or less. At 1,000 vph, the optimum length worked out to be 1.5 km (0.9 mi). At 2,000 vph, the optimum length was 2 km (1.2 mi).

In 1998, the Swedish National Road Administration (*6*) decided to proceed with a program of converting certain two-lane roads to a 2+1 design. The first conversion had section lengths (excluding the transition zone) of 0.9 to 1.8 km (0.6 to 1.1 mi).

Crash Rates

Comparing 13 passing lane sites with 13 corresponding untreated sites, Harwood et al. (*2*) found that the average total accident rate of the passing lane sites was 38% lower than the average rate of the untreated sites. The fatal and injury accident rates were 29% lower. After combining the results from other studies, Harwood et al. (*3*) concluded that passing lanes reduced accident rates by 25%.

Taylor and Jain (*7*) compared the crashes on highways with and without passing lanes. Roadways were grouped into one of three average daily traffic (ADT) levels: less than 5,000, between 5,000 and 10,000, and greater than 10,000. For all three groups, crashes on the highways with passing lanes were lower than those without passing lanes.

TRAFFIC FLOW DATA COLLECTION SITES

After a review of various documents and videotapes, the locations and the beginning and ending log miles of passing lanes, climbing lanes, and 2+1 segments were identified. Criteria were established to determine the sites best suited for study. Some of the following criteria were mandatory, while others were merely desirable:

1. The roadway must be a rural road (55-mph speed limit), with a three-lane passing section, and preferably have continuously alternating passing lanes.
2. The roadway must have a transition from two lanes to three lanes (cannot be four lanes immediately in advance of the three-lane segment).
3. The three-lane segment should be at least 4.5 km (2.8 mi) long.
4. The segment should be on a level grade.
5. The horizontal alignment of the segment should be straight.
6. The traffic volume should be relatively high (among the available sites).
7. The passing section should have a minimal number of intersecting side roads.

The researchers found that few sites in the state had most of the needed attributes. After examining the more promising sites in the field, the following sites were considered to be the best available (SB denotes southbound, EB denotes eastbound, and WB denotes westbound):

- US-65 Section 1 SB,
- US-70 Sections 9 and 10 WB,
- US-70 Section 10 EB, and
- US-82 Section 1 EB.

The US-82 site was selected, after discussion with the AHTD Research Section, to satisfy the need for a higher-volume traffic site. The site was the first of a series of five passing lanes that were separated from each other by a short distance. Thus, the passing lane was not continuously alternating for both directions of travel. Unfortunately, it was discovered during data collection that a good deal of the traffic turned off the road into subdivisions.

At each site, data were collected at a series of stations (sta). The initial station was positioned just before the number of lanes began to expand from two to three. Subsequent stations were spaced at 1.5-km (0.9-mi) intervals. Initially, data were collected at only three stations at each site. However, after examination of the data collected in the second study, the need to expand from three stations to four stations was realized. Hence, data were collected at three stations for the US-65 SB 1999 and US-70 WB 1999 studies, and for the rest of the studies, the data were collected at four stations. Table 1 contains geometric features of these segments. From this table, one can see

TABLE 1 Geometric Features of Data Collection Sites

Site	Alignment	Station 1	Station 2	Station 3	Station 4
US-65 SB	Horizontal	Straight	Curve to right	Curve to right	na
	Vertical	Upgrade	Level	Slight upgrade	na
US-70 WB (Sec. 9 & 10—Saline and Garland Counties) west of bridge LM 2.27	Horizontal	Curve to left $R = 711$ m (2,330 ft)	Curve to left $R = 686$ m (2,250 ft)	Curve to right $R = 1{,}151$ m (3,778 ft)	Curve to left $R = 873$ m (2,865 ft)
	Vertical	+1% to −1%	+1% to −1%	Near end of short +1.9%	Upper end of +2.78%
US-70 EB (Sec. 10—Saline County) east of bridge of LM 3.29	Horizontal	Straight	Curve to left, end of, $R = 582$ m (1,910 ft)	Curve to left, $R = 3{,}493$ m (11,460 ft)	Curve to left, $R = 861$ m (2,825 ft)
	Vertical	+1% to −1%	+1% to −1%	Upper end of upgrade, near crest, +3.54%	Upper end of upgrade +3.70%
US-82 EB	Horizontal	Straight	Straight	Straight	Straight
	Vertical	−0.8%	Near end of −0.8%	Upgrade	Near end of −2.0%

na = not applicable.

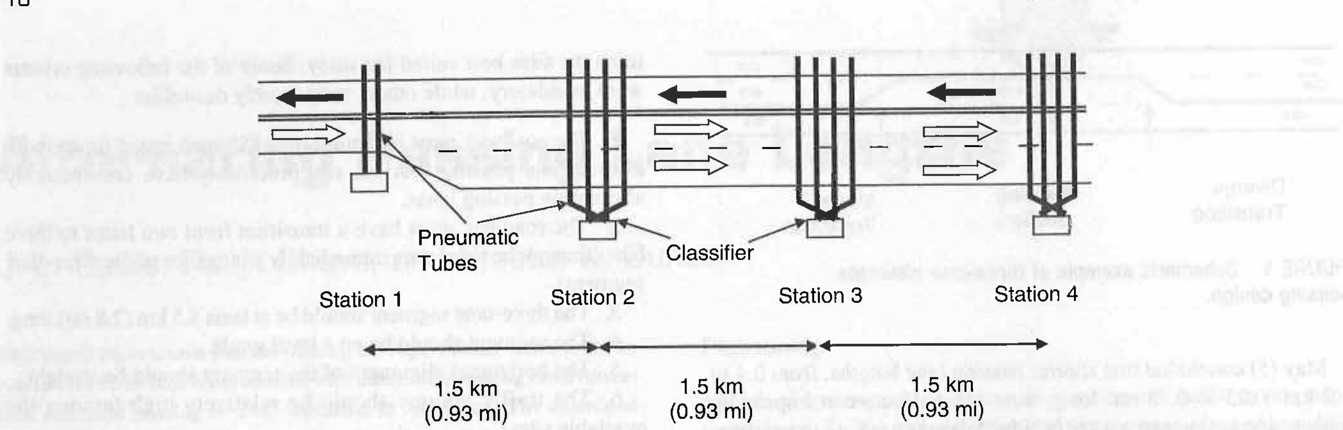

FIGURE 2 Typical classifier setup.

that horizontal alignment would be expected to have no effect on speed, but at some locations, the vertical alignment might affect speed.

DATA COLLECTION AND REDUCTION

For this study, crash data and traffic flow data in passing lanes were collected. Field data were collected for many hours at each site; doing so yielded traffic flow data over a range of volumes.

Traffic Operation Field Data

Classifiers, lidar and radar guns, and video cameras were used to collect speed, platooning, and passing attribute data in the field. Figure 2 shows a typical classifier setup. The classifiers recorded not only the speed and number of axles but also the time at which an axle passed.

After the traffic behavior was studied, it was decided that the vehicles traveling at speeds less than 35 mph probably represented either entering or leaving vehicles or an anomaly. These vehicles were atypical, and hence all vehicles traveling at speeds less than 35 mph were discarded from the analysis.

The data from videotapes were reduced for each 5-min interval for each station and entered into a spreadsheet. The sequence of vehicles was observed, and all vehicles that could be tracked at all the stations were marked. The vehicles that did not traverse the entire segment were identified. This information was used for computing the through volume (i.e., the volume of traffic that traversed all the data collection stations).

Crash Data

The AHTD furnished 5 years of crash data and a schedule of road construction during that time. The crashes that were coded as having occurred in a work zone were excluded from the analysis.

The initial list of crashes within and on either side of the log mile limits being queried was reviewed to determine the presence of seemingly incorrect entries. For instance, Crash Number 199928963 was listed to have occurred in US-70 Section 9, but after a check with maps and video logs, it was found that the crash actually occurred in Section 8. The accuracy of the crash mile point locations was checked by identification and cross-checking of the crash location with records that contained log miles.

DATA ANALYSIS AND RESULTS

The data collection studies were denoted as US-65 SB, US-70 EB, US-70 WB, and US-82 EB. Due to a variety of causes, some of the data from the US-65 SB and the US-70 WB 1999 studies were unusable.

Two measures of volume were used: total volume and through volume. Total volume was the total traffic volume that passed a particular station, while through volume was the volume of traffic that traversed through all the data collections stations (i.e., the entire passing lane segment). For speed and platooning analysis, total volume was used. For passing analysis, through volume was used. All 15-min flow rates were expressed as equivalent hourly volumes. Table 2 lists ranges of one-direction hourly flow rates during data collection.

Analysis of Platooning Data

The project considered the effects of passing lane length and traffic volume on platooning. According to the *Highway Capacity Manual* (*8*), two vehicles are said to be in a platoon if the headway between the two successive vehicles is less than 3 s. A study by Gattis et al. (*9*) had concluded that, for speeds higher than 80 km/h (50 mph), headways more than 3 s did not encourage drivers to undertake passing maneuvers. In other words, for high speed roads—speeds more than 80 km/h (50 mph), as defined in the AASHTO Green Book (*10*)—drivers are more likely to feel their trip is being impeded and are more inclined to pass if headways are less than 3 s.

To be consistent in comparisons of platooning between stations having passing lanes and those not having passing lanes, it was assumed that two vehicles traveling in adjacent lanes were in a platoon if the headway between them was less than 3 s. This assumption was based on the fact that vehicles in adjacent lanes eventually have to merge into one lane at the end of the passing lane segment.

The data were analyzed in 15-min intervals. Figures 3 and 4 are plots of the number and the percentage of vehicles in platoon at each station. There were fewer data points for Station 4 than for the other three stations because only three studies (US-70 EB 2000, US-82 EB 2001, and US-70 WB 2002) had four stations. Equivalent volume is the 15-min flow rate multiplied by four.

The plots show that, for the same volume, platooning at Station 1 (immediately before the beginning of the passing lane) was always higher than at any other station. The vehicles in platoons decreased at successive stations. As volumes increased, there was a greater reduction in platooning between Stations 2 and 3. Platooning at the end of passing lanes was less than that at the beginning.

TABLE 2 One-Direction Flow Rates

Study Site	Minimum	Average	50th %	90th %	Maximum
US-70 WB 1999	260	445	384	608	724
US-70 EB 2000	216	307	300	360	428
US-82 EB 2001	104	164	168	216	232
US-70 WB 2002	176	322	312	420	504

NOTE: Volumes are expressed in vehicles per hour (vph).

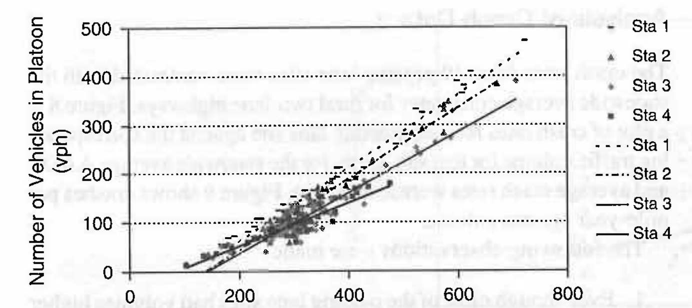

FIGURE 3 Number of vehicles in platoon for Studies US-70 WB 1999, US-70 EB 2000, US-82 EB 2001, and US-70 WB 2002 (Sta. 1, $y = 0.7491x - 89.761$, $R^2 = 0.9627$, $P < 0.0001$; Sta. 2, $y = 0.7249x - 101.72$, $R^2 = 0.9502$, $P < 0.0001$; Sta. 3, $y = 0.6199x - 87.568$, $R^2 = 0.9111$, $P < 0.0001$; Sta. 4, $y = 0.4469x - 38.102$, $R^2 = 0.8049$, $P < 0.001$).

Statistical Analysis of Platooning

The data were subjected to statistical analysis to determine whether the reductions in platooning between stations were significant. The null hypothesis was that a significant reduction in platooning occurred between two stations.

For the analysis, the independent variable was total traffic volume, and the response variable was the number of vehicles in the platoon. The natural log of volume was used as an offset variable so that the final result could be reported as the platooning rate (number of vehicles in platoon per total number of vehicles).

Initially, the underlying distribution of the data was assumed to be Poisson. If overdispersion was observed—that is, variance found to be greater than mean (as indicated in the deviance or Pearson chi-square goodness-of-fit statistics)—the negative binomial model was used instead of the Poisson.

Poisson regressions, negative binomial regressions, or both with repeated measures (generalized estimating equations) were used to determine whether and how the rate of platooning differed along the segment. As the same vehicles were observed going through each station, repeated measures were needed to account for possible correlations between observations. The statistical analysis could not be performed on US-82 EB 2001 because the amount of data was not adequate. There were insufficient data for flow rates above 450 vph.

Table 3 summarizes the statistical comparisons of platooning among the stations along a study segment. A yes indicates that there was a statistical difference in platooning between the pair of stations indicated. The following observations were made during the analysis:

1. The reduction in platooning was highest between Stations 1 and 2 [i.e., up to 1.5 km (0.9 mi)]. A smaller reduction in platooning or even some increases were observed between subsequent stations.
2. In some cases, platooning increased at the end of the passing lane segment. However, platooning at the end of the passing lane was less than that at the beginning.

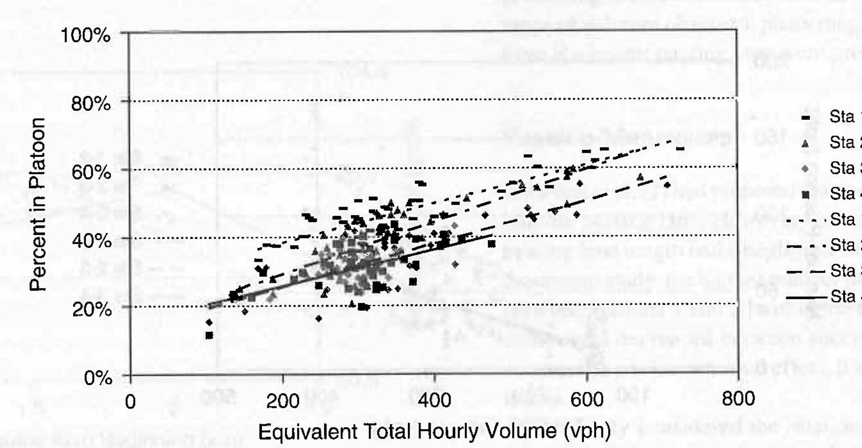

FIGURE 4 Percentage of vehicles in platoon for Studies US-70 WB 1999, US-70 EB 2000, US-82 EB 2001, US-70 WB 2002 (Sta. 1, $y = 0.0006x + 0.2719$, $R^2 = 0.7405$, $P < 0.0001$; Sta. 2, $y = 0.0008x + 0.1412$, $R^2 = 0.7017$, $P < 0.0001$; Sta. 3, $y = 0.0006x + 0.1297$; $R^2 = 0.6047$, $P < 0.0001$; Sta. 4, $y = 0.0005x + 0.1520$, $R^2 = 0.3612$, $P < 0.0001$).

TABLE 3 Statistical Differences in Platooning

Study Site	Station	Sta. 1	Sta. 2	Sta. 3	Sta. 4
US-70 WB 1999	1	na	Yes	Yes	na
	2	Yes	na	Yes	na
	3	Yes	Yes	na	na
US-70 EB 2000	1	na	Yes	Yes	Yes
	2	Yes	na	Yes	Yes
	3	Yes	Yes	na	No
	4	Yes	Yes	No	na
US-70 WB 2002	1	na	—	Yes	Yes
	3	Yes	—	na	No
	4	Yes	—	No	na

na = not applicable; Sta. = station; dashes indicate missing data.

Analysis of Passing Data

Because individual vehicles were identified during the data reduction, the number of passing vehicles and the number of vehicles that were passed could be counted. Figures 5 and 6 are the plots, for all the sites combined, of the number and the percentage passing at each station. The graphs show that maximum passing occurred between Stations 1 and 2. Past Station 2 [1.5 km (0.9 mi)], the amount of passing seemed to stabilize or decline. In addition, the rate of passing increased with higher volume. However, some individual sites exhibited different trends.

Analysis of Speed Data

Speed data were studied to ascertain what change in the traffic speed occurred through the passing lane segment. Figure 7 shows that the speed trends across the passing lane segments were not uniform for all study sites. As noted earlier, the traffic speeds could have been influenced by many factors, such as traffic volumes, geometric features of the road segment, and the like.

Average speed increased between Stations 1 and 2. Previously constrained drivers were freer to select their own speed upon entering the passing lane section.

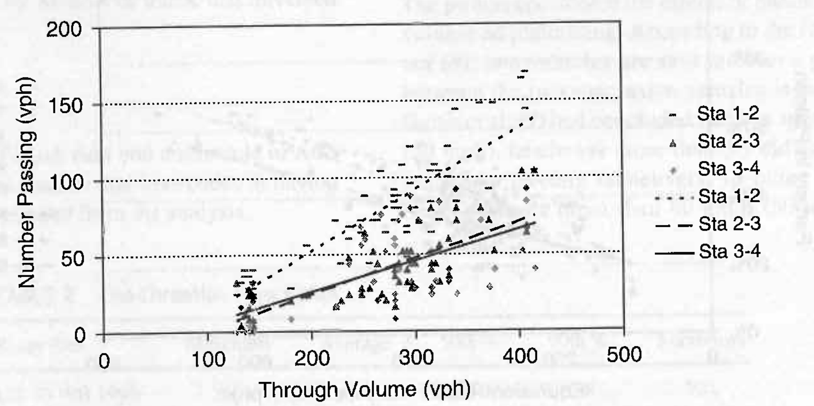

FIGURE 5 Number of vehicles passing for Studies US-65 SB 1999, US-70 EB 2000, US-82 EB 2001, and US-70 WB 2002 (Sta. 1–2, $y = 0.3996x - 28.059$, $R^2 = 0.7658$, $P < 0.0001$; Sta. 2–3, $y = 0.2351x - 22.881$, $R^2 = 0.6373$, $P < 0.0001$; Sta. 3–4, $y = 0.2007x - 14.242$, $R^2 = 0.3729$, $P < 0.0001$).

Analysis of Crash Data

The crash rates from 19 passing lane sites were contrasted with the statewide average crash rates for rural two-lane highways. Figure 8 is a plot of crash rates for each passing lane site against the corresponding traffic volume for that site. Lines for the statewide average AADT and average crash rates were also drawn. Figure 9 shows crashes per mile-year against volume.

The following observations were made:

1. Even though most of the passing lane sites had volumes higher than the statewide average for two-lane rural roads, the crash rates of passing lane sites were usually less than the statewide average crash rate for two-lane rural roads.
2. The crash rates of the passing lane sites exhibited a weak trend of increasing with volume. If the trend line were extended, the projected crash rate trend line would cross the statewide crash rate at a volume of 22,740 vpd.
3. The crash rates of three passing lane sites (1-13, 65-1 and 82-1e) exceeded the state average. The researchers did not identify any obvious reasons for this.

Comparison of crash severity attributes of the crashes that took place in passing lanes with the statewide crash averages showed that the percentages were somewhat similar. The passing lane severe injury rate was slightly higher than the statewide average, and the property-damage-only rate was slightly lower.

The percentages by crash type (such as head on, right angle, etc.) for the passing lane sites were not greatly different from the rural two-lane percentages. The greatest difference was for the single vehicle type: 51.6% of passing lane crashes were this type versus 54.1% for rural two-lane roads.

SUMMARY

This study examined the following operational parameters of rural three-lane alternating passing segments in Arkansas.

1. Platooning,
2. Passing,
3. Speed, and
4. Safety.

Although a number of three-lane alternate passing lane segments were identified in Arkansas, attributes peculiar to each of the sites restricted researchers' ability to obtain quality data. The available sites did not have the ideal combinations of geometric and traffic characteristics. Nevertheless, some results were obtained.

Platooning

An earlier study by Harwood et al. (*3*) concluded that passing lanes with lengths between 0.25 and 0.75 mi were most effective for flow rates up to 200 vph in one direction of travel. For very high flow rates, such as 700 vph in one direction of travel, the design length of passing lanes ranged from 1.0 to 2.0 mi. The authors also stated that passing lanes longer than 1.0 mi might not be desirable. A simulation study by Enberg and Pursula found that optimal passing length varied from 1 km (0.62 mi) for a one-direction flow rate of 500 vph to 2 km (1.24 mi) for a 2,000 vph flow rate (*3*). In general, the effective length of a passing lane segment increased somewhat as volume increased.

The researchers used data from US-70 WB 1999, US-70 EB 2000, and US-70 WB 2002 to determine relationships between traffic volume and platooning that occurred between successive pairs of stations. For all sites, platooning increased with an increase in volume.

When vehicles entered the passing lane segments, the percentage of vehicles in platoons dropped from an average of 48% immediately upstream of a passing lane to 34%. The reduction in platooning continued even downstream of a passing lane segment; however, the rate of reduction was very low.

For the range of volumes encountered in this study, platooning at Station 1 (the beginning of the passing lane) was statistically significantly higher than platooning at the other stations located downstream. The percentages in a platoon at Stations 3 and 4, located 3 km (1.9 mi) and 4.5 km (2.8 mi), respectively, downstream of Station 1, were not statistically different from each other. Thus, it could be concluded that a significant reduction in platooning occurred within the first 1.5-km (0.9-mi) length of the passing lanes. For lower volumes, decreases in platooning diminished after that. For higher volumes, platooning tended to stabilize after about 3.0 km (1.9 mi), and for the range of volumes observed, platooning did not decrease significantly, even if a longer passing lane were provided.

Passing Maneuvers

Harwood et al. (*2*) had proposed that the passing rate decreases further into the passing lane. However, Enberg and Pursula (*4*) found that passing lane length had a negligible effect on passing maneuvers. In the current study, the highest number of passing maneuvers took place between Stations 1 and 2 [within the first 1.5 km (0.9 mi)]. Passing maneuvers decreased between successive stations located downstream. It is not known what effect, if any, roadway gradients played in this.

This study considered the relationships between the amount of passing and both passing lane length and traffic volume. It was found that passing maneuvers increased as volume increased. The model predicted that, as volumes increase, higher numbers of passing maneuvers would occur further into the passing lane. Thus, it could be inferred that higher-volume roads could use longer passing lanes.

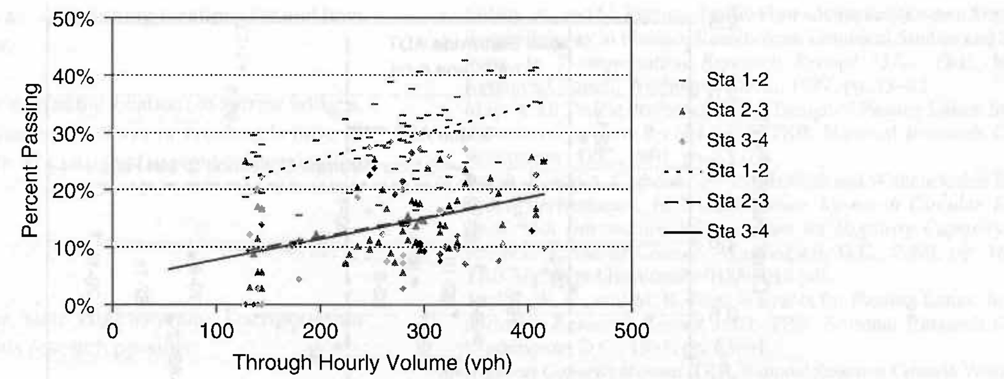

FIGURE 6 Percentage of vehicles passing for Studies US-65 SB 1999, US-7 EB 2000, US-82 EB 2001, and US-70 WB 2002 (Sta. 1–2, $y = 0.0005x + 0.1604$, $R^2 = 0.291$, $P < 0.0001$; Sta. 2–3, $y = 0.0003x + 0.0504$, $R^2 = 0.2066$, $P = 0.0002$; Sta. 3–4, $y = 0.0006x - 0.0333$, $R^2 = 0.287$, $P < 0.0001$).

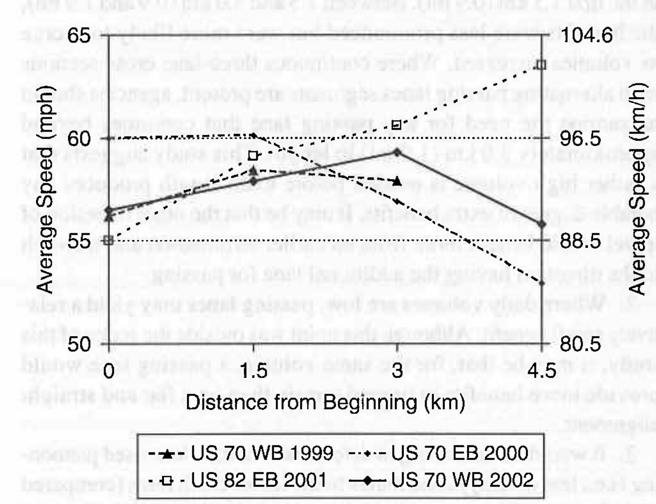

FIGURE 7 Average speeds at various stations.

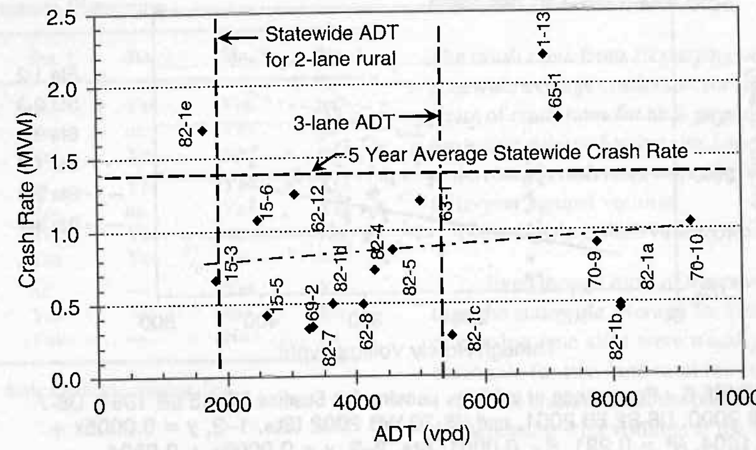

FIGURE 8 Crash rates in segments contrasted with rural two-lane road ($y = 3 \times 10^{-5}x + 0.7278$, $R^2 = 0.0176$, $P = 0.5880$).

Speed

Studies cited in the literature review had some conflicting conclusions. The study by Enberg and Pursula concluded that the passing lanes allow an increase in traffic speed (*4*). However, the study by Harwood et al. (2) noted that the effect of passing lanes on traffic speeds varied widely from site to site, and the study concluded that vehicle speeds were more strongly influenced by local geometrics of the road than by presence of a passing lane.

Speed data were analyzed for US-70 WB 1999, US-70 EB 2000, US-82 EB 2001, and US-70 WB 2002. The study sites generally exhibited a modest increase in average speed immediately after a vehicle entered a passing lane segment. After a vehicle proceeded past the 1.5 km (0.9 mi) data collection station, speed trends at different study sites varied. It was hypothesized that the variations were due to factors such as grade, traffic volume, and curvature possibly masking the effect of a passing lane on the speed of the traffic. Thus, the results obtained from this study seemed to concur with the Harwood et al. (2) findings.

Safety

One of the objectives of providing passing lanes is to improve safety. The study analyzed crash and volume data. The ADT (weighted by

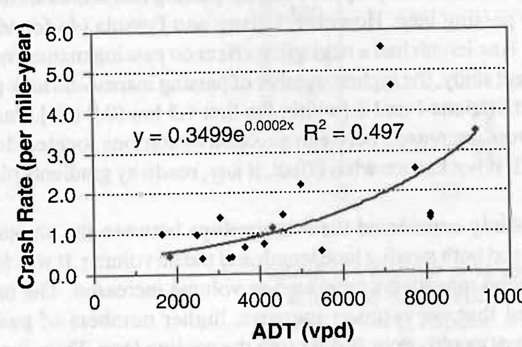

FIGURE 9 Crash rates (per mile-year) in segments.

VMT) of all passing lane segments (5,293 vpd) was higher than the statewide average ADT (1,857 vpd) for rural two-lane, undivided (no control of access) highways. However, the crash rates on all but three of the passing lane segments were lower than the statewide average for rural two-lane highways.

The crash rate on passing lanes weakly trended upward as volume increased. If the trend line of the passing lane crash rates were projected, it would cross the statewide rural two-lane average rate at an ADT of 22,740 vpd.

CONCLUSION

The three-lane alternate passing segments appeared to provide benefits to the motoring public. Some short-term increase in speed and amount of passing was exhibited. The greater benefits seemed to be in the form of decreased platooning and increased safety.

The following observations related to this study were made:

1. Within the range of volumes observed and the spacing of the data collection stations in this project, greater benefits were observed in the first 1.5 km (0.9 mi). Between 1.5 and 3.0 km (0.9 and 1.9 mi), the benefits were less pronounced but were more likely to accrue as volumes increased. Where continuous three-lane cross sections with alternating passing lanes segments are present, agencies should reexamine the need for any passing lane that continues beyond approximately 3.0 km (1.9 mi) in length. This study suggests that a rather high volume is needed before extra length produces any notable degree of extra benefits. It may be that the other direction of travel would benefit more from an earlier termination and a switch in the direction having the additional lane for passing.

2. Where daily volumes are low, passing lanes may yield a relatively small benefit. Although this point was outside the scope of this study, it may be that, for the same volume, a passing lane would provide more benefits in rugged terrain than on a flat and straight alignment.

3. It would be interesting to determine whether decreased platooning (i.e., less density) contributes to the lower crash rates (compared with the statewide average for two-lane roads) observed in the passing lane sections. If it does, then platooning effects may need to

be considered when agencies are determining locations for and how to set lengths of passing lanes.

In addition, practical factors such as the locations of narrow bridges, uphill grades, and higher-volume driveways or crossroads have to be considered when the length of a passing lane and its termination point are being established.

ACKNOWLEDGMENT

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