

SAFETY OF FREEWAY MEDIAN HIGH OCCUPANCY VEHICLE LANES: A COMPARISON OF AGGREGATE AND DISAGGREGATE ANALYSES

THOMAS F. GOLOB, WILFRED W. RECKER, and DOUGLAS W. LEVINE
Institute of Transportation Studies, University of California, Irvine, Irvine, CA 92717, U.S.A.

(Received 16 August 1988; in revised form 7 January 1989)

Abstract—This paper addresses safety issues associated with High Occupancy Vehicle (HOV) lanes constructed along freeway medians, without physical separation from adjacent traffic. Data associated with operation of such an HOV facility in Southern California are analyzed relative to the pattern of accidents on the facility and the potential role of congestion. Detailed analyses of accident characteristics point out that potentially false conclusions regarding the safety of HOV lanes can be drawn from simple analyses that are based on aggregate measures of accident frequencies and assumed traffic volumes.

INTRODUCTION

As travel demand has increased and our ability to build new or expanded transportation facilities has decreased, the concept of special carpool, or High Occupancy Vehicle (HOV) lanes, on urban freeways has become increasingly attractive as a transportation system management strategy. The objectives underlying the installation of HOV lanes are typically to increase the person-trip capacity of a freeway and to encourage switching from drive-alone to carpooling by providing a travel time advantage for carpools through the use of a less-congested lane. HOV lanes are operating in urban areas throughout the United States; an increasing number are being planned. These HOV installations reflect a wide range of operational characteristics and traffic conditions.

HOV facilities span a range of scale and cost options, from low-cost restriping of existing facilities, to transitways with completely exclusive rights-of-way. More than a decade has passed since the first HOV facilities were implemented in Washington, DC and Los Angeles. The HOV concept now has some history, and experiences have been both positive and negative.

Evaluation studies show that most HOVs are working; some are carrying several times more trips at greater speeds than adjacent general purpose facilities (Caltrans 1977; Kuo and Mounce 1986; Southworth and Westbrook 1986). However, the studies also show that most of the HOV facilities that were abandoned were also working. Technical success does not guarantee project success; HOV projects must be politically successful, and political success requires community consensus that the HOV strategy is both appropriate and safe.

Low-cost HOV alternatives have become increasingly popular as the availability of capital construction funds has declined. In its most extreme form, a low-cost HOV lane can be created simply by restriping and converting part or all of the existing median (or left) shoulder for use as a traffic lane. Although low-cost projects are attractive when comparing capital costs, and indeed may be the only feasible shorter-term alternative, they have some significant operational disadvantages, including safety and enforcement.

Safety problems associated with HOV projects can be critical. Contraflow projects are generally considered unsafe, and very few of the contraflow projects initiated in the 1970s are operating today, even though accident records do not necessarily substantiate this claim. Concurrent flow projects without physical barriers—again, the low-cost HOV—are also perceived to be unsafe. Safety problems associated with accessing and leaving the HOV lane, and with the differential speed between HOVs and the general purpose traffic are much discussed, but are documented only for one case, namely Orlando, Florida (Spielberg et al. 1980).

Safety issues have high visibility, and can easily be magnified by project opponents. Public sponsors cannot afford to take risks on safety issues, and thus are quite vulnerable to safety concerns. One such example involves a controversial implementation of the HOV concept in Orange County, California, in which the interior shoulders of a highly congested freeway have been converted to HOV lanes without physical separation. Opponents have mounted a vociferous campaign calling for the abandonment of the project on the basis that the lanes are unsafe, pointing to aggregate data that indicates that the total number of accidents on the facility has risen significantly when compared to previous years. Arguments based on accident rates rather than accident counts are complicated by the unavailability of reliable exposure measures (traffic volumes and vehicle occupancy counts).

The research reported herein addresses safety issues on this facility through both an aggregate analysis and a detailed analysis of accident characteristics; it also attempts to assess the role of congestion on accidents. The results point out how potentially false conclusions regarding the safety of HOV lanes can be drawn from simple analyses based on aggregate measures of accident frequencies and assumed traffic volumes.

THE CASE STUDY

An analysis was conducted of the HOV facility on State Route 55 (SR-55), the Costa Mesa/Newport Freeway in Orange County, California (Caltrans November 5, 1986). The HOV lane operation on SR-55 effectively spans the length of the freeway (approximately 10 miles) in both the northbound and southbound directions. It has been in operation since November 1985. The lanes were created from the median shoulders, with multiple ingress and egress areas along the HOV facility. In each direction, the HOV lane is separated from the three mixed-flow lanes by a double yellow strip (approximately eight inches in width).

The principal data source is the TASAS (Traffic Accident Surveillance and Analysis System) data base maintained by the California Department of Transportation (Caltrans 1978). These data cover all accidents reported by a police officer in the field. The period for which data were available at the onset of the study is January 1, 1979 through August 31, 1986. This includes nine full months of HOV operation on SR-55. Data on highway characteristics, traffic volumes, and other project operational parameters were obtained from Caltrans project-monitoring reports (e.g. Caltrans 1986). Information on congestion levels was provided by computerizing diagrams of speed by postmile and time of day provided for several dates by Caltrans District 7.

TIME SERIES ANALYSIS OF ACCIDENT FREQUENCIES

A monthly time series of accident frequencies on SR-55 exhibited extensive month-to-month variation. Some of this variation was judged to be random because it was found to be due to yearly differences in weather conditions and the number of working days per month: The eight-year averages for wet and dry days are 3.03 and 1.69, respectively, with corresponding standard deviations of 1.55 and 1.63; the difference between wet and dry days is statistically significant at the $p = .01$ level. The averages for working days and weekends or holidays are 2.08 and 0.99, respectively, with corresponding standard deviations of 1.71 and 1.20; this difference is also statistically significant at the $p = .01$ level. The number of rainy days varies considerably in Southern California (e.g. 26 days in 1983 and 14 in 1984) and this affects yearly comparisons of total accidents. The distribution of rainy days over the year, and variations in the number of working days per month affects monthly comparisons of total accidents.

Thus, the average number of accidents per dry weekday in a particular month was judged to be the most effective measure of the safety uncorrected for exposure. This series, shown in Fig. 1, accounts for differences in weather conditions and the number of weekend days and holidays in a month. Nevertheless, the month-to-month variations in the accidents per dry weekday series were still so great as to make conclusions regarding the effect of the HOV lane impossible; although the months of HOV operation

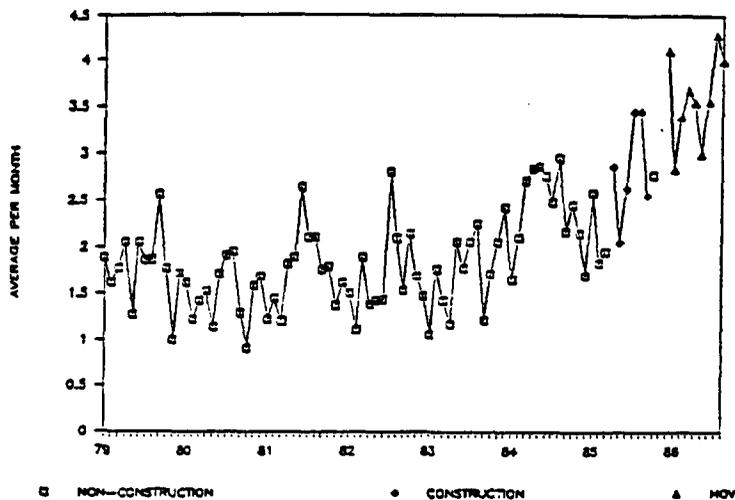


Fig. 1. SR-55: Highway accident history (dry weekdays only).

were found to be within confidence intervals established by variations in the prior years for the case of all weekday data, no reasonable statistical model could be estimated for the preferred dry weekday data.

Standardization for changes in vehicle exposure due to changes in travel volumes should be in terms of vehicle miles of travel (VMT), but such data requires both traffic volume and trip length data (or traffic volumes on all key points along a route) and is unavailable for SR-55. The only alternative was to use AADT (annual average daily traffic) at one central cross section of SR-55 as a proxy measure of travel changes over time.

Published AADT data for all central locations on SR-55 report constant volumes for the entire period 1981–1985 (Caltrans 1979–1985). The published AADT's for the location used in this study are down in the solid curve in Fig. 2. This constant level of demand is generally regarded to be inaccurate, because the SR-55 Freeway serves a rapidly growing portion of the Los Angeles conurbation. Apparently, the updating of the published information has been hindered by the failure of counting devices in the field. Such devices were not replaced or repaired until construction of the HOV lane in 1985. This problem of unreliable preproject traffic volume data plagues many project evaluation studies and brings into question the accuracy of studies that rely on “before”

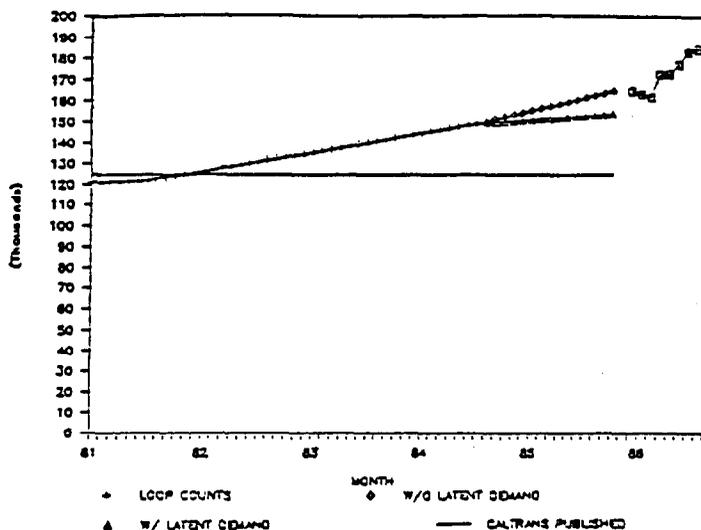


Fig. 2. SR-55: AADT estimations and observations.

and “after” published traffic volume in computing accident rates (e.g. Urbanik and Bonilla 1987). Volume data for post-project periods will be generally more accurate because counting devices are typically attended to during project construction and there will be more vigilant monitoring due to the interest in project evaluation. However, it is important to thoroughly investigate the sources of volume data in comparative studies based on accident rate computations for different roadways (e.g. Newman, et al. 1988) in order to avoid unwittingly using extrapolated data of the type exhibited for SR-55 in the 1981–1985 period.

AADT estimates were computed based on data collected from the Caltrans records of traffic volumes for the years 1979, 1981, and 1984. Volumes for 1986 were estimated as the average of either the actual mixed-flow lane volumes or the total SR-55 volumes observed during the first nine months of the HOV project (published in the Caltrans HOV lane nine-month operational report, November 5, 1986). The first estimate assumes that if the HOV lane were not present the 1986 AADT would be that which is observed in the mixed-flow lanes; the volume observed in the HOV lane is due to latent demand generated by the additional lane. The second estimate assumes that there has been no latent demand whatsoever on SR-55 due to the additional capacity introduced by the HOV lane. Neither is a completely realistic assumption, and both are included to test the sensitivity of the results to AADT assumptions. These AADT estimates (December 1981–October 1985) are shown in Fig. 2, together with the observed AADT's during the HOV period (Caltrans, November 5, 1986).

The estimated AADT series was used to standardize the monthly series of average accidents per dry weekday for the period since late 1981. The resultant series, graphed in Fig. 3, is measured in terms of accidents per dry weekday/AADT at Santa Clara Avenue $\times 10^{-6}$. In this figure the monthly observations are divided into three ranges: (1) observations for the nine-month period of December through August of each year, (2) observations for the three months of September through November of each year, and (3) the nine-month HOV period of December 1985 through August 1986. Because of systematic seasonal variations not accounted for in the AADT estimates (e.g. summer months generally have higher traffic volumes and consequently more accidents), only the observations in the first range (December through August of each year) can be directly compared to the HOV period.

The effect of the HOV lane construction period (April–September 1985) on traffic safety on SR-55 is unknown. Consequently, two analyses of the standardized time series were performed: one deleting the 1985 observations to eliminate any bias due to construction effects, and a second analysis using all of the first range observations to test the consequences of ignoring the 1985 information. The estimation of trends in the standardized accident series was restricted to a linear analysis because of the well-known

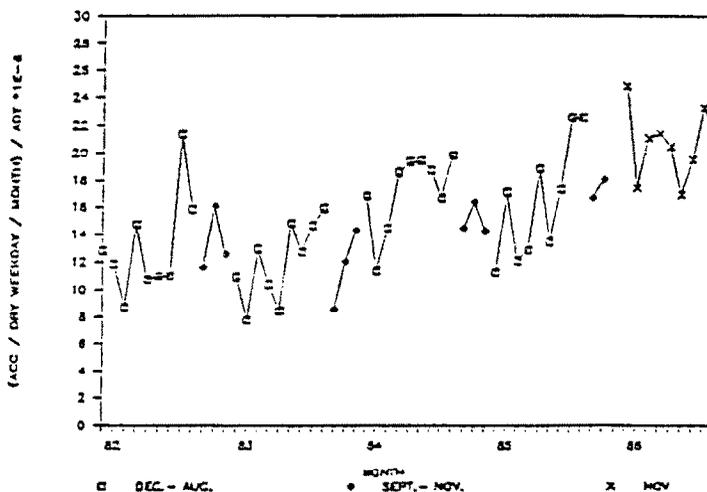


Fig. 3. SR-55: Accidents per dry weekday per month, standardized by AADT $\times 10^{-6}$.

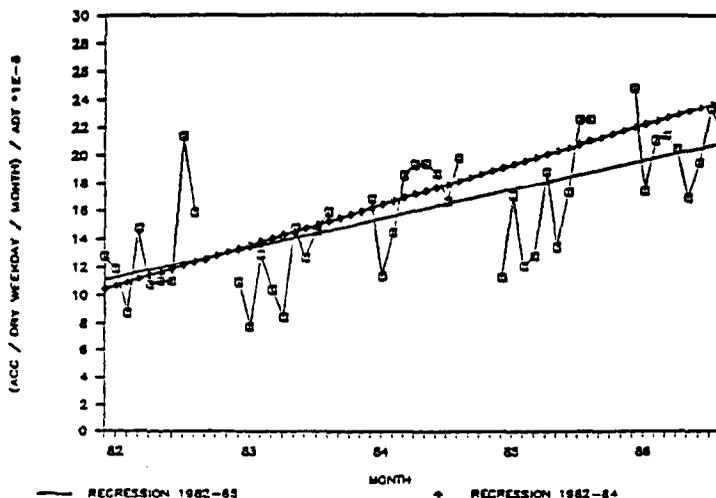


Fig. 4. SR-55: Regression analyses accidents per dry weekday per month, standardized by AADT * 1E-6 with projections to HOV period.

dangers of extrapolating nonlinear functions beyond the range on which they are calibrated.

Shown in Fig. 4 are ordinary least-squares linear regressions for the two series (with and without the construction period). Both series use the AADT estimates that are based on the assumption that *latent demand is present in the HOV period*. The regression for the series *excluding* the construction period has an intercept of 10.44 at December 1981, and the slope represents an increase of 0.241 accidents/dry weekday/AADT $\times 10^{-6}$ per month. The slope coefficient is statistically significant, indicating that there was a degradation in SR-55 safety during the entire 1982-84 period. The proportion of variance accounted for (R^2) is 0.38. The regression for the series *including* the construction year 1985 has an intercept of 11.11 at December 1981, and the slope is 0.175 accidents per dry weekday per AADT $\times 10^{-6}$ per month. This slope coefficient is also significantly different from zero, but is less than the slope coefficient of the previous regression, because the 1985 observations are lower than the trend established by the 1982-84 observations.

The HOV period observations are also shown in Fig. 4. Applying the trend regression that avoids the construction period (the line designated by diamonds in Fig. 4), all

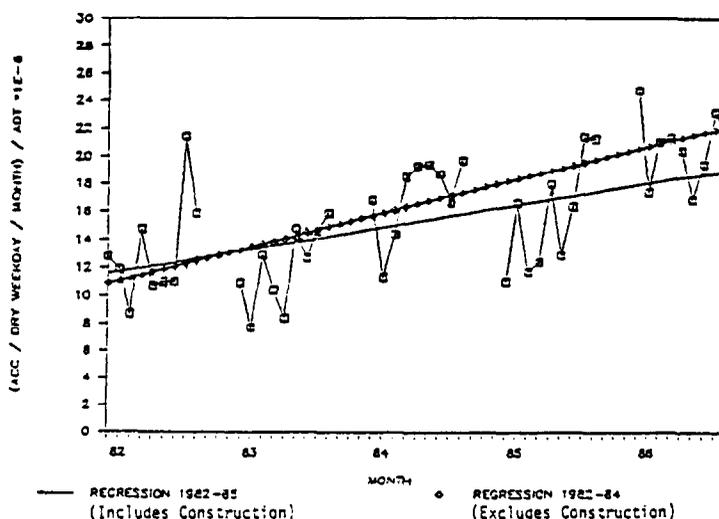


Fig. 5. SR-55: Accidents per dry weekday per month, standardized by AADT * 1E-6 (no latent demand in 1986).

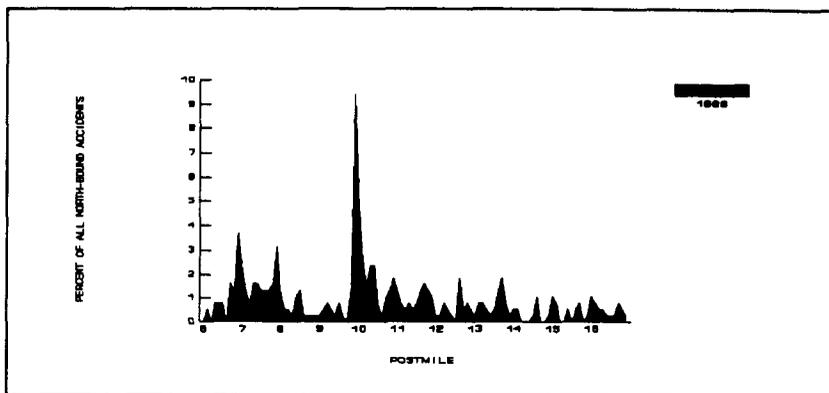


Fig. 6a. SR-55: Percent accidents by tenth-mile, northbound, 1986.

HOV period observations are less than predicted with the exception of the first full month of HOV operation, December 1985. Applying the regression using the construction year over-predicts standardized accidents for three of the HOV months and under-predicts standardized accidents for six HOV months.

As a comparison, the best linear regression using the AADT estimates that are based on the assumption that there is no latent demand on SR-55 present in the HOV period, is shown in Fig. 5. Regressions are shown in Fig. 5 with and without the construction year. The HOV period observations are again generally bracketed by the two regressions. Alternative assumptions regarding AADT estimates, periods over which to estimate trends, and choices of the mathematical functions to represent such trends arbitrarily determine any calculations of HOV effects on such an aggregate basis.

The conclusion from the time series analysis is that the HOV lane has no adverse effect on safety. Trends in the degradation in safety on SR-55 from 1982 through 1985 are considerably stronger than any potential HOV lane effects.

ACCIDENT LOCATIONS

Changes over time in the accident characteristics, specifically, changes before and after the introduction of the HOV lane can be identified in the time series analyses. However, the determination of accident causes, and the role of HOV versus mixed-flow operation of the added lane require more detailed investigation than can be provided by aggregate time series analyses. The distribution of accident locations is critical to determining any influence of the operation of the HOV lane. Changes over time in the distributions of accidents along the length of the SR-55 freeway were investigated. Separate analyses were conducted for the northbound and southbound sides.

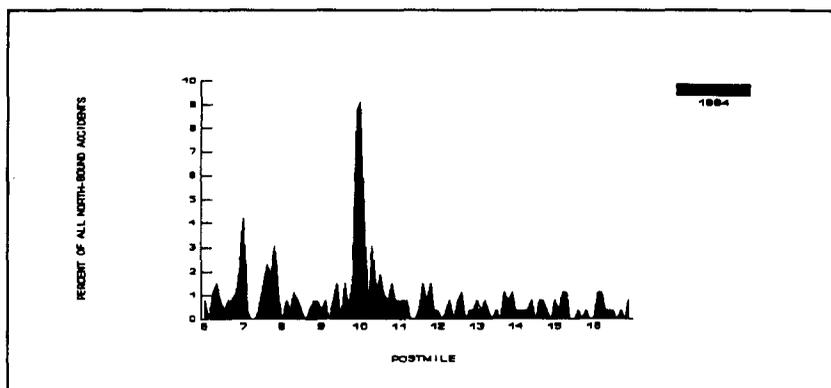


Fig. 6b. SR-55: Percent accidents by tenth-mile, northbound, 1984.

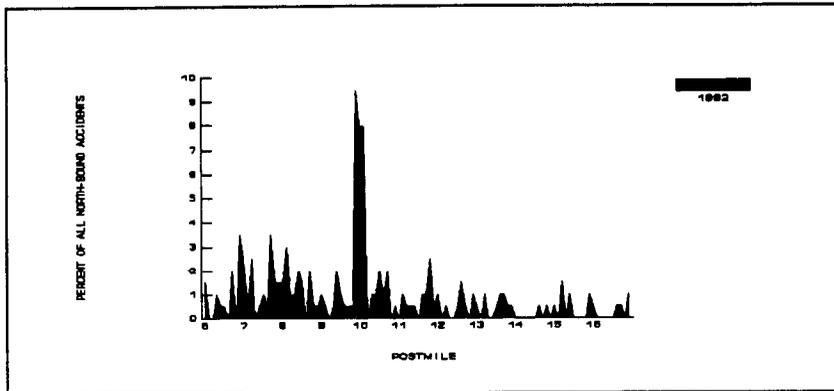


Fig. 6c. SR-55: Percent accidents by tenth-mile, northbound, 1982.

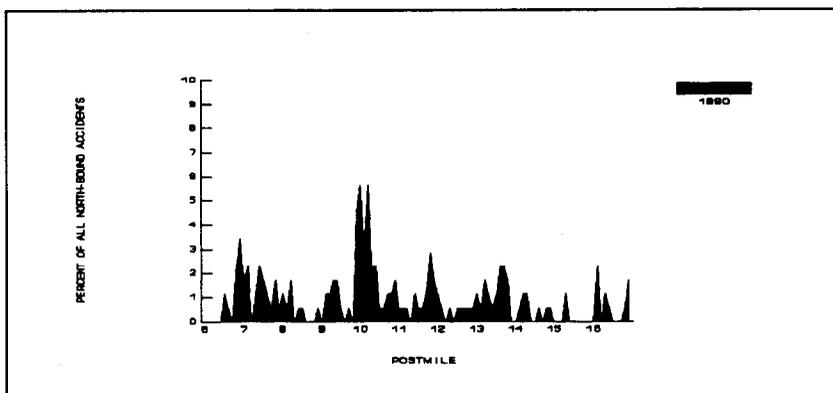


Fig. 6d. SR-55: Percent accidents by tenth-mile, northbound, 1980.

The distributions of northbound highway accidents for four time periods are graphed in Fig. 6 (parts a through d). The four time periods are December 1979–August 1980 (Fig. 6d), December 1981–August 1982 (Fig. 6c), December 1983–August 1984 (Fig. 6b), and December 1985–August 1986, the period of HOV operation (Fig. 6a). The locational distributions are *not* significantly different over these periods. The distinguishing characteristic of all of the distributions is the substantial concentration in the range postmiles 9.9 to 10.1, which is from just past an on-ramp to 0.1 miles before the connector off to the I-5 freeway. Approximately 15% of all northbound accidents occurred in this 0.2 mile section (representing about 1.5% of the roadway) in 1986 and in prior years.

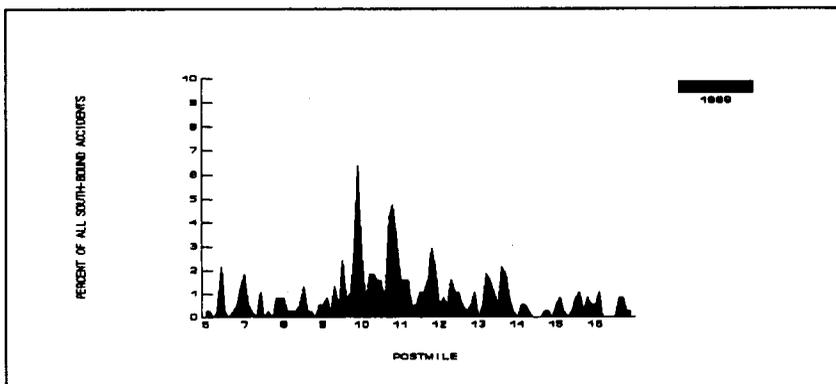


Fig. 7a. SR-55: Percent accidents by tenth-mile, southbound, 1986.

The locational distributions of southbound highway accidents for the four time periods are shown in Fig. 7 (a through d). All four time periods are characterized by concentrations of accidents in the postmile 9.9 to 10.1 section; in the HOV period approximately 12% of all southbound accidents occurred in this 0.3-mile section. This section encompasses a heavily-used on-ramp and is 0.2 to 0.5 miles downstream from the on-ramp for the I-5 connector.

The principal locational shift is for southbound accidents in the range of postmiles 10.7 to 11.6. There is a new concentration for the HOV period in the postmile 10.7 to 11.0 range that is not present in previous years. Approximately 12.5% of all southbound accidents occurred in this 0.3-mile section in 1985–86, but less than 5% occurred in that

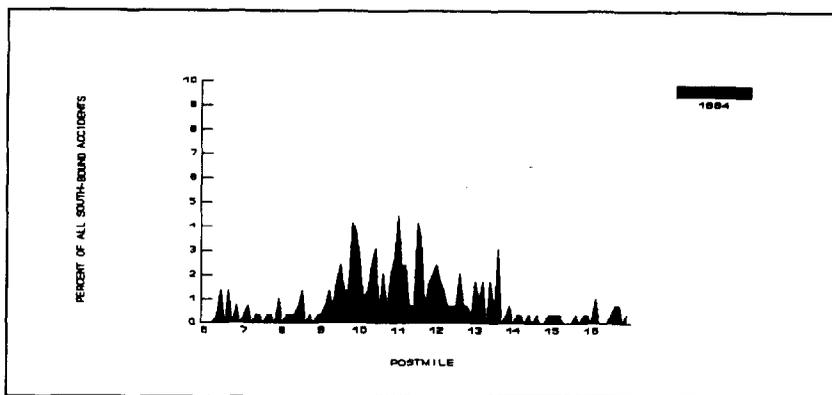


Fig. 7b. SR-55: Percent accidents by tenth-mile, southbound, 1984.

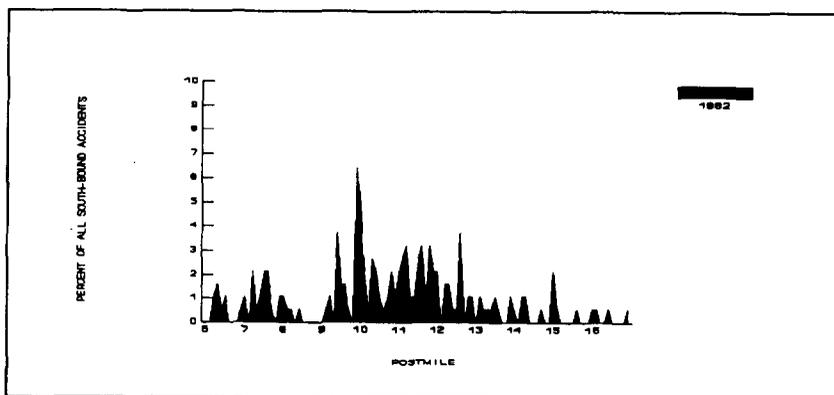


Fig. 7c. SR-55: Percent accidents by tenth-mile, southbound, 1982.

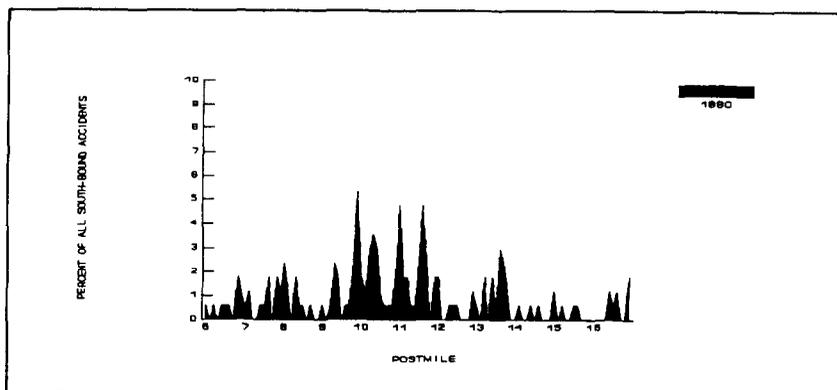


Fig. 7d. SR-55: Percent accidents by tenth-mile, southbound, 1980.

section in any previous corresponding nine-month period. This area also encompasses a heavily used on-ramp and is 0.35 to 0.05 miles upstream from the off-ramp for the I-5 connector, and includes an HOV lane ingress/egress area. There is a corresponding new relief from accidents for the HOV period in the postmile 11.0 to 11.6 range, immediately upstream of the 10.7 to 11.0 range. This locational shift is consistent with a downstream migration of accidents of the type identified by Levine et al. (1988) in a study of the effects of added freeway lanes.

Both northbound and southbound accidents are concentrated in particular postmile locations. However, the southbound locational distribution has shifted, pre-HOV versus post-HOV, while the northbound distribution has not. Further investigation is required, taking into account the locations of HOV lane ingress/egress areas, collision locations (left roadway area versus other location), and accident characteristics, particularly those related to congestion patterns.

Regarding the HOV lane ingress/egress areas, there was no statistically significant change in the percentage of accidents that occurred within the ingress/egress areas in 1985-86, compared to prior years, for both the northbound and southbound directions. Regarding collision locations relative to freeway lanes, it is not possible to compare specific collision locations before and after construction of the new inside lane because of ambiguity in accident coding involving "interior" and "exterior" lanes. However, analyses of time trends in collision locations on the basis of broad definitions are useful indicators, and it is possible to compare collision locations for accidents within different postmile ranges for the same time period.

The locational differences between ingress/egress area accidents and accidents in other postmile ranges are statistically significant for the southbound accidents (Fig. 8), but not for northbound accidents. Southbound accidents in the postmile ranges of the ingress/egress areas are relatively more concentrated in the left area of the roadway. The low levels of right-side accidents in the postmile ranges of the HOV ingress/egress areas are expected, as these areas are not located at or near ramps.

Shown in Fig. 9 are breakdowns of all accidents in the pre-HOV (six nine-month periods combined, 1980-1985) and post-HOV periods into four classes: (1) within the postmile range of the HOV ingress/egress areas, with the primary collision located left of the interior lane(s), (2) within the postmile range of the ingress/egress areas, with the collision located in the interior lane(s) or right of them, (3) outside of the postmile range of the ingress/egress areas, with the collision located left of the interior lane(s), and (4) outside of the postmile range of the ingress/egress areas, with the collision located in the interior lanes or to the right of them.

For the northbound accidents, there is no difference in the split between left and non-left locations for ingress/egress area accidents, pre-HOV versus post-HOV. However, for southbound accidents there is no significant change over time in the total percent of accidents located in the range of the HOV ingress/egress areas. The relatively high proportion of southbound accidents in the HOV ingress/egress areas located on

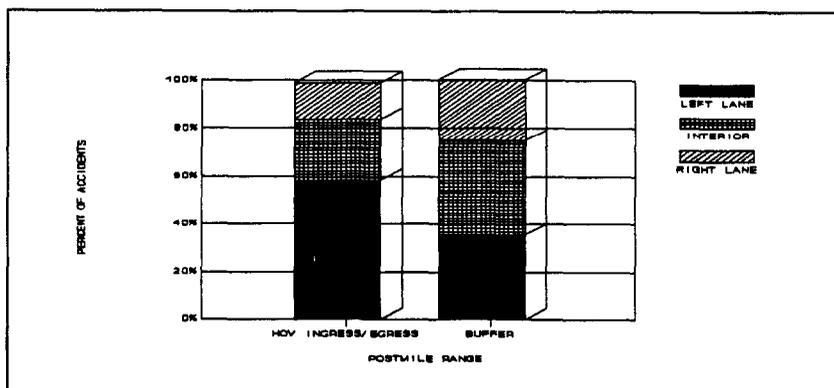


Fig. 8. SR-55: Collision locations southbound: December 1985-August 1986 by postmile ranges.

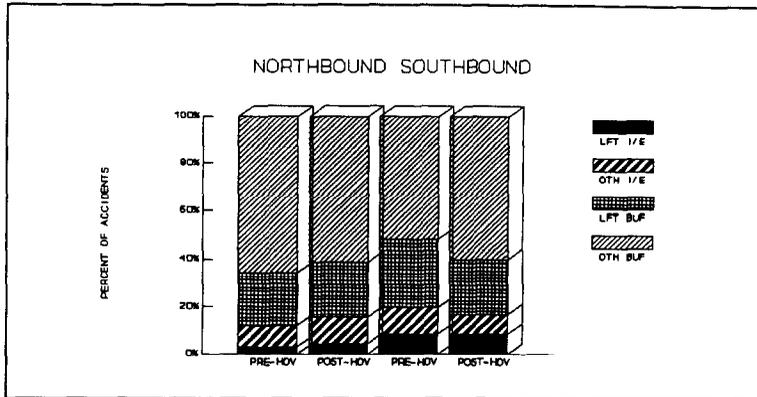


Fig. 9. SR-55: Locational distribution of accidents: Pre-HOV and post-HOV in four categories.

the left side of the freeway is approximately the same before and after the HOV lane, and this explains why left-area accidents in the ingress/egress areas are outstanding in Fig. 8. For accidents outside the range of the HOV ingress/egress areas, there is a decrease in the proportion of accidents located in the left roadway area.

As a final locational analysis, the distributions by postmile of northbound and southbound left-area accidents are shown in Figs. 10 and 11. The distributions are limited to the postmile 7.0 to 12.0 range, with 0.2 mile increments. Northbound (Fig. 10), there is a new peak in the HOV period for left-area accidents in the postmile 7.4–7.8 range, but this is offset by a relative decrease in left-area accidents in the immediate upstream range of postmile 8.2 to 8.8. There is no HOV ingress/egress area in the range of the new peak. Downstream, in the 10.8 to 11.0 range, there is a new peak that coincides with an HOV ingress/egress area. This increased concentration of accidents is not explainable in terms of accident migration from an adjacent postmile range.

Southbound (Fig. 11), there has been a substantial increase in the peak in left-area accidents in the HOV period in the range of postmile 9.4–9.6, which coincides with an HOV ingress/egress area. This new peak in the vicinity of postmile 8.4 is well within the range of the HOV buffer; consequently, there is no explanation for the increase except in terms of possible buffer violations. Other distributional changes in southbound left-area accidents appear to be shifts from adjacent locations reflecting accident migration due to changes in congestion patterns.

The total number of unexplainable accidents in the new concentrations of left area accidents identified in Figs. 10 and 11, over and above the number that would be expected based on previous distributional patterns, is 13 in a nine-month period. This corresponds to less than a 2% increase in accidents over the course of a year.

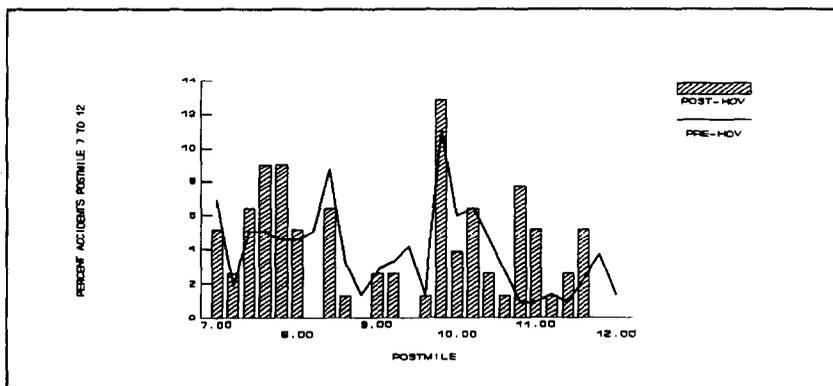


Fig. 10. SR-55: Northbound left-area accidents by postmile (0.2 mile categories, postmile 7.0 through postmile 12.0).

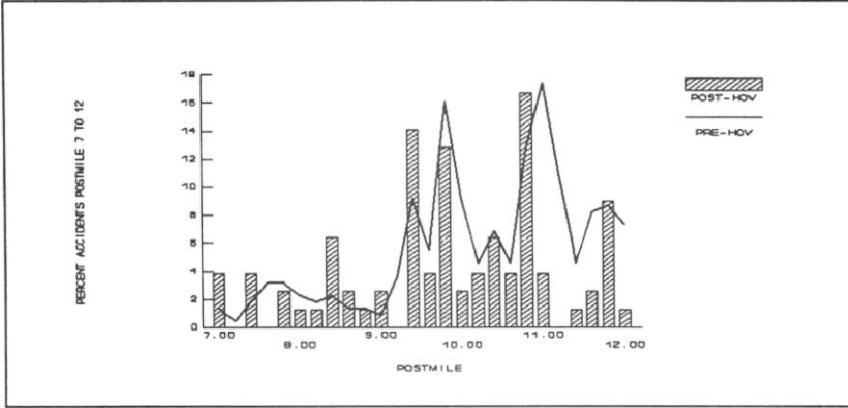


Fig. 11. SR-55: Southbound left-area accidents by postmile (0.2 mile categories, postmile 7.0 through postmile 12.0).

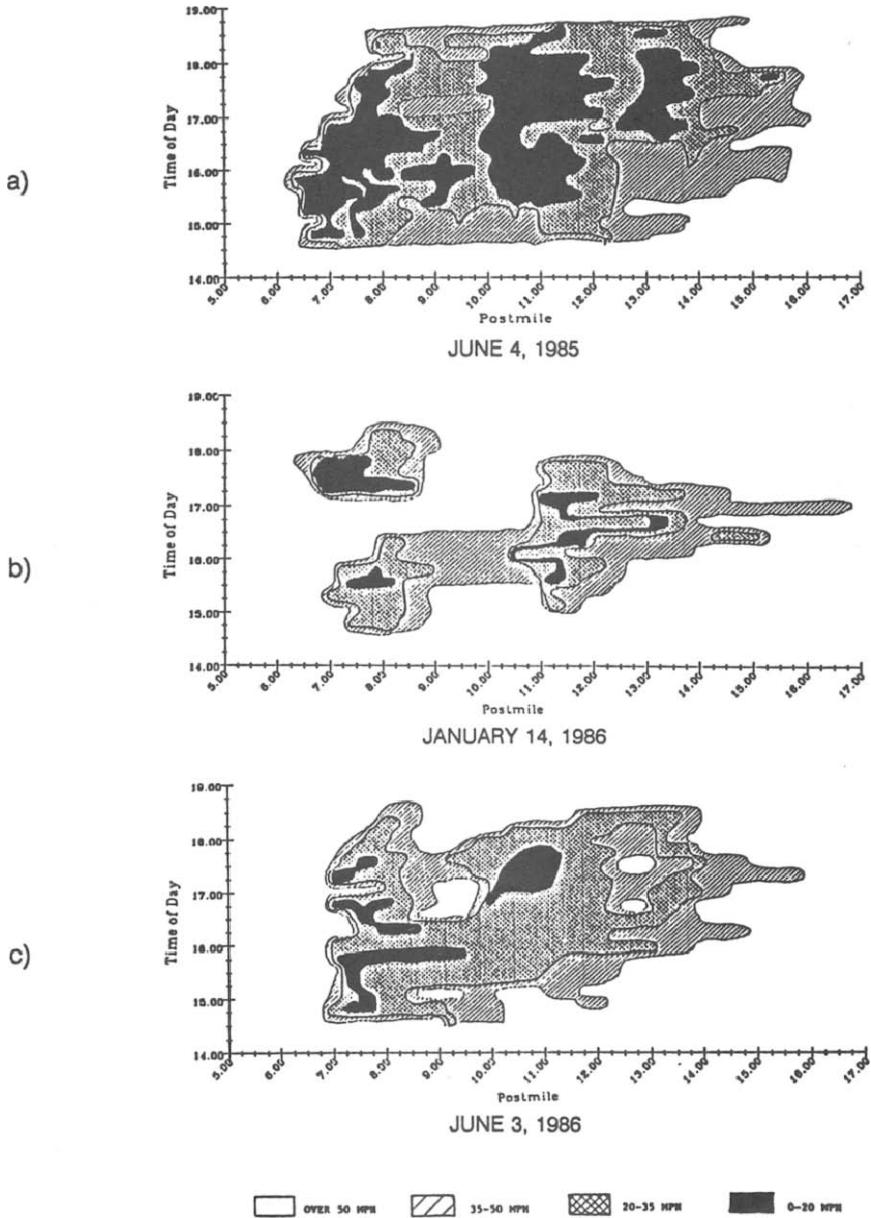


Fig. 12. Congestion diagram for northbound SR-55.

There is also an increase in the concentration of southbound accidents in the postmile range from 10.91 (end of the HOV ingress/egress area) to 10.646 (off-ramp to the I-5 connector). In nine-month periods prior to HOV implementation, between 1.5% and 6.3% of all southbound accidents were located in this postmile range, with 3.9% located there in December 1983–August 1984; in the nine-month HOV period, 8.5% of all southbound accidents were located there. This shift in location is statistically significant. However, there is *no* significant difference between the percent of accidents with collision locations in the left roadway area in the postmile 10.91–10.646 range versus all other non-HOV ingress/egress areas.

ACCIDENTS AND CHANGING CONGESTION PATTERNS

Data suitable for formulating congestion diagrams were available for SR-55 for both directions at three points in time: June 1985 (pre-HOV), January, and June 1986 (both post-HOV). Such diagrams depict average speeds at postmile locations by time of day and are produced from data recorded by a fleet of cars making repeated trips along the

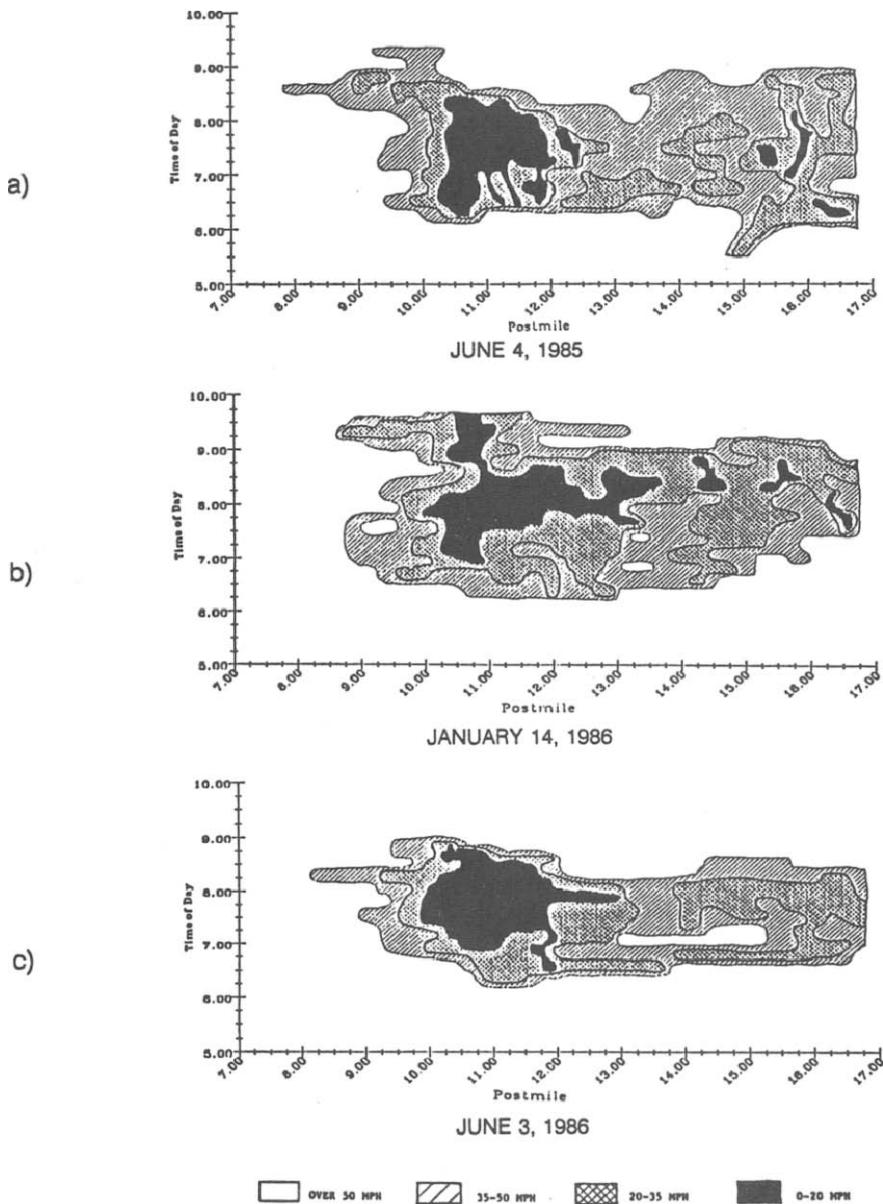


Fig. 13. Congestion diagram for southbound SR-55.

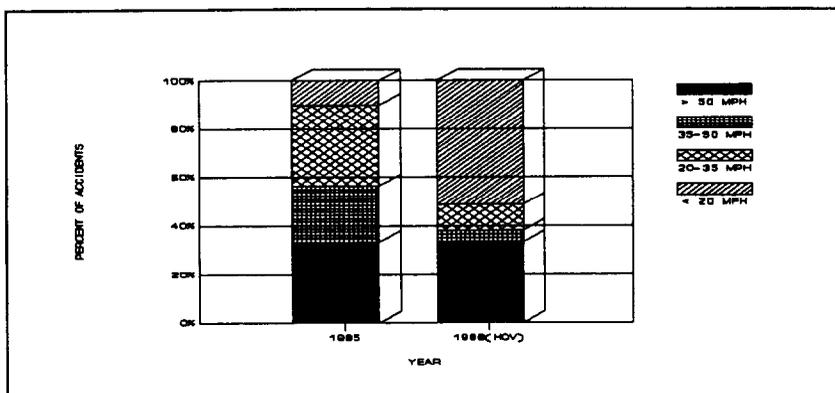


Fig. 14. SR-55: Northbound weekday accidents: 2:30–7:00 p.m. by estimated average traffic speed.

freeway. The days of observation were carefully chosen as having no unusual weather conditions and no major incidents in the area during the period of observation. If an accident or other disruptive incident occurred during the data collection, the operation was terminated and repeated at a later date. Spot checks on other dates confirmed that the days of observation were indicative of “normal” traffic conditions on weekdays during the month. The congestion diagrams are reproduced in Figs. 12 and 13 for the three dates and two directions.

In comparing the patterns of congestion for northbound SR-55 during the p.m. period (Fig. 12), there is a general relief of congestion from June 1985 (Fig. 12a) to January 1986 (Fig. 12b), with congestion in the latter period being more segmented, particularly along the time dimension. The added capacity represented by the HOV apparently aided in congestion relief in the first few months of operation, although the June to January comparison is clouded by seasonal factors. However, a comparison of the northbound June 1985 (Fig. 12a) and June 1986 (Fig. 12c) congestion diagrams reveals that within seven months of the implementation of the added lane, extremely heavy congestion has returned to most of the length of northbound SR-55 over most of the 2:30 p.m. to 6:45 p.m. time period. The downstream shifting of congestion is only present in the shift of the onset of congestion from approximately postmile 6.5 in 1985 to postmile 7.0 in 1986.

With regard to southbound congestion during the a.m. period, the comparison between June 1985 (Fig. 13a) and January 1986 (Fig. 13b) indicates that the level of congestion relief exhibited for the northbound p.m. situations is not realized for the southbound a.m. situation. There is increasing congestion in the 8:30 to 9:45 time period in January, as compared to the previous June. But by June 1986 (Fig. 13c), the congestion pattern of the previous year is reestablished, with the exception that upstream congestion (in the range of postmiles 15.0 to 17.0) is relieved.

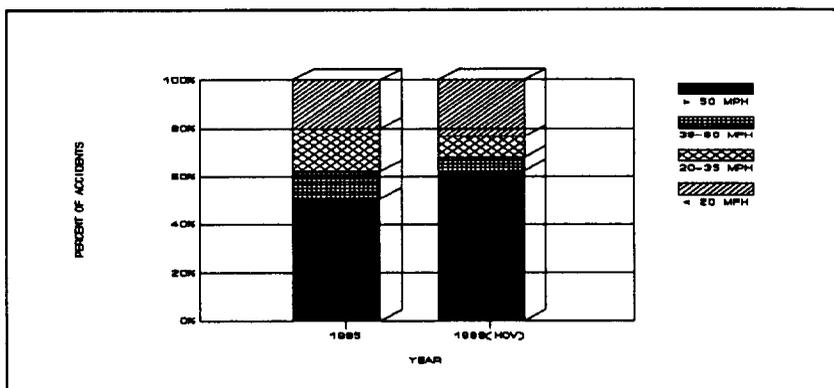


Fig. 15. SR-55: Southbound weekday accidents: 5:30–10:00 a.m. by estimated average traffic speed.

These changes in congestion patterns reveal that there has been a substantial degree of latent demand for travel on SR-55. There is increased demand, indicating that motorists may have taken advantage of the extra freeway capacity provided by the added HOV lane and are making new and/or diverted trips on the freeway. These results indicate that the assumption of latent demand for AADT estimates is more appropriate than the assumption of no latent demand.

Tests were conducted to establish the extent to which accidents on SR-55 are related to congestion, and how this relationship might be changing over time. It was established in a preliminary analysis that the proportions of accidents involving three or more vehicles and the proportions of accidents that are sideswipes or rear-end collisions are up, post-HOV versus pre-HOV periods. Similarly, property damage accidents are up, versus injury accidents. All of these types of accidents are generally congestion related. A further investigation was conducted in which comparisons were made between the pre-HOV and post-HOV time periods and for the postmile ranges corresponding to HOV ingress/egress and buffer areas.

Expected levels of congestion were assigned to all peak-period accidents that occurred during two time periods. The expected congestion levels were measured in terms of the observed speed categories in the congestion diagrams of Figs. 12 and 13: greater than 50 MPH, 35–50 MPH, 20–35 MPH, and less than 20 MPH. Peak periods were defined to be the periods covered by the congestion diagrams: 2:30 p.m.–7:00 p.m. northbound, and 5:30 a.m.–10:00 a.m. southbound. And the relevant time periods were assumed to be April through July 1985 (pre-HOV, corresponding to the congestion diagrams of June 1985) and December 1985 through August 1986 (post-HOV, corresponding to the diagrams of January and June 1986). The assignment of expected congestion levels to accidents was accomplished for the post-HOV time period by interpolating between the congestion diagrams of January and June and extrapolating the interpolation functions to December 1985 and July–August 1986.

The expected congestion levels at the postmile location and time of occurrence of weekday peak *northbound* accidents is broken down in Fig. 14 by pre-HOV and post-HOV time periods. There is a statistically significant change over time in the breakdowns by congestion level: In the post-HOV period there are relatively fewer accidents in the mid-range of congestion (average speeds 20–35 MPH and 35–50 MPH), but there are substantially more accidents in areas and times estimated to have severe congestion (average speeds less than 20 MPH). This is an important indicator of the underlying cause of increases in the number of northbound accidents.

The congestion-level breakdowns for southbound accidents are shown in Fig. 15. A pattern similar to that of northbound accidents is emerging for southbound accidents, but the change over time is much less dramatic in the southbound case. In fact, the change in the breakdowns by congestion level, pre-HOV versus post-HOV, is statistically insignificant. It can be concluded that, while congestion plays a role in both northbound and southbound accident causality, the two directions represent different situations.

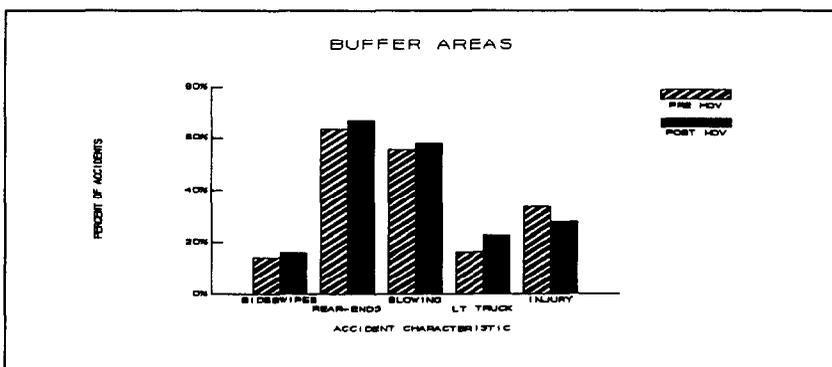


Fig. 16a. SR-55: Accident characteristics for HOV buffer areas by pre-HOV versus post-HOV.



Fig. 16b. SR-55: Accident characteristics for HOV ingress/egress areas by pre-HOV versus post-HOV.

To uncover further evidence concerning potential accident causality, the characteristics of accidents in the postmile ranges of the ingress/egress areas were compared over time and to the characteristics of accidents outside these ranges for the 1985–86 HOV period. Shown in Fig. 16 are five accident characteristics broken down by pre-HOV versus post-HOV and postmile ranges corresponding to the HOV ingress/egress areas versus other areas (i.e. the HOV buffer area). Sideswipes are a significantly lower percent of post-HOV collisions within the ingress/egress areas, but there was no significant difference for pre-HOV collisions. Correspondingly, rear-end collisions are a significantly higher percent of ingress/egress collisions in the post-HOV period, again with no significant difference between ingress/egress and other areas in the pre-HOV period. There is also a significantly higher percentage of accidents involving vehicles that were slowing or stopped in the ingress/egress areas in the HOV period with no differences in the pre-HOV period. There are more collisions involving light trucks as the second party in the HOV period, but there is no significant difference between the ingress/egress and other areas. Finally, none of the differences involving the percentage of injury accidents are significant. The comparisons in Fig. 16 are for all accidents, as there were no substantial differences in these characteristics for the northbound and southbound directions. These results indicate that the accidents in the postmile ranges of the HOV ingress/egress areas are congestion related.

SUMMARY AND CONCLUSIONS

In situations where accurate exposure measures in terms of traffic volumes are not available in both the preproject and post-project periods, it may not be possible to determine the effects on traffic safety of an HOV lane installed in a freeway median using aggregate accident history information alone. A case study analysis has shown that using the best traffic volume information available, the results of the aggregate analyses are dependent on the assumptions regarding levels of latent demand, seasonal influences, and the time period covered. The resulting conclusion of “no effect” of the HOV lane on safety must be verified or rejected using disaggregate analyses that focus on accident characteristics and their potential causes.

In the case study, a detailed analysis of accident types by locations and timing, in relation to changes in congestion patterns, led to a result that was only slightly different from the “no effect” result of the aggregate analysis. It was estimated that the HOV lane on SR-55 in Orange County has contributed to an increase in accidents on that route of 2 percent over and above the level that would be expected from mixed-flow operation of the lane. That is, there are up to approximately 2% more accidents on SR-55 resulting from HOV operation of the added lane, as opposed to mixed-flow operation. There is no way to place a confidence bound on this estimate.

The principal conclusion of the case-study analysis is that congestion plays the major role in the changes over time in the accident occurrence on SR-55. The increases in

accident rates since 1982 are apparently due largely to increases in congestion levels. Congestion is centered at a specific freeway interchange in the center of the study area, but eight or nine miles of the route are typically severely congested. The additional lane, while serving more demand, aids in delivering more vehicles to congested situations. If the HOV lane were in mixed-flow operation, most of the congestion-related effects would still be present. Such congestion effects are typically overlooked in aggregate analyses of accident histories. Further research aimed at isolating the specific role of congestion is needed so that congestion-related effects can be accounted for in future studies of the safety of projects on congested facilities.

Acknowledgments—The research reported herein was supported in part by grants from the AAA Foundation for Traffic Safety, the Orange County Transportation Commission, the California Department of Transportation, the Los Angeles County Transportation Commission, and the Southern California Association of Governments. Their support is gratefully acknowledged. The efforts of Paula Nohalty in the construction of congestion diagrams appearing in this paper is also acknowledged.

The views expressed in this report are those of the authors and do not necessarily reflect the views of the sponsoring agencies. The authors are solely responsible for any errors.

REFERENCES

- Caltrans. Bus/Carpool Lanes, Route 101, Marin County—Evaluation Report. Sacramento: California Department of Transportation, Office of Traffic Engineering; 1977.
- Caltrans. *Manual of traffic accident surveillance and analysis system*. Sacramento: California Department of Transportation, Office of Traffic Engineering; 1978.
- Caltrans. *Traffic volumes on California state highways 1979/1980/1981/1982/1983/1984/1985*. Sacramento: California Department of Transportation, Division of Traffic Engineering; 1979–1985.
- Caltrans. 1985 California State Highway Log, District 7. Sacramento: California Department of Transportation; 1986.
- Caltrans. Route 55 Newport-Costa Mesa Freeway Commuter Lane Demonstration Project: Operational Report Based on 9 Months of Use. Los Angeles: California Department of Transportation, District 7; November 5, 1986.
- Caltrans. Route 91 Artesia Freeway: Operational Report Based on 18 Months of Commuter Lane Use. Los Angeles: California Department of Transportation, District 7; December 8, 1986.
- Caltrans. Route 55 Newport-Costa Mesa Freeway from the San Diego to the Riverside Freeways in Both Directions: One Year Report of Commuter Lane Use, November 1985 to November 1986. Los Angeles: California Department of Transportation, District 7; December 29, 1986.
- Kuo, N. M.; Mounce, J. M. The Katy Freeway authorized vehicle lane: Evaluation of the first year of operation. Research Report 339-6, The Texas Transportation Institute, Texas A&M University, College Station, Texas; 1986.
- Levine, D. W.; Golob, T. F.; Recker, W. W. Accident migration associated with added capacity on urban freeways. *Traffic Engineering and Control*, 29:624–629; 1988.
- Newman, L., Nuworsoo, C. K.; May, A. D. Operation and safety experience with freeway HOV facilities in California. Paper presented at Annual Meeting of Transportation Research Board, Washington, DC. January 1988; 1988.
- Southworth, F.; Westbrook, F. High-occupancy vehicle lanes: Some evidence on their recent performance. *Transportation Research Record*, 1081:31–39; 1986.
- Spielberg, F.; Zillner, C.; Anderle, S.; Tching, M. *Evaluation of Freeway High Occupancy Vehicle Lanes and Ramp Metering*, Report DOT-P-50-80-29. U.S. Department of Transportation. Washington, DC: Office of Assistant Secretary for Policy and International Affairs; 1980.
- Urbanik II, T.; Bonilla, C. R. The California Experience with Inside Shoulder Removals. Paper prepared for presentation at the 66th Annual Meeting of the Transportation Research Board, Washington, DC. College Station, TX: Texas Transportation Institute, Texas A & M University System; 1987.