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INTERACTION OF DRIVER BEHAVIOR; GEOMETRIC DESIGN; AND VEHICLE MOVEMENT ON ACCELERATION LANES ON URBAN FREEWAYS IN KANSAS

by

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INTRODUCTION

General Significance of the Research

Recently, highway designers have become more concerned than in the past with the relationship between freeway design and traffic behavior. This is evident from the many studies which have been made to provide factual data on the operational characteristics of freeway elements and particularly of acceleration lanes. Such studies were made to aid in the evaluation of the various types of designs and to provide the basis for future designs that would eliminate present operational difficulties.

As a result of other studies it is now known that freeways must be designed so that acceleration lanes will provide a safe and efficient area for vehicles to accelerate to a speed which closely coincides with the speeds of vehicles traveling on the through traffic lanes if satisfactory operation is to be obtained. They must also serve as a space for the maneuvering of vehicles laterally into acceptable gaps in the adjacent stream of traffic. The optimum condition is to have traffic on the acceleration lane merge with the through lane traffic at the speed of the through lane traffic.

A driver entering the freeway from an acceleration lane is required to adjust his speed and lateral movement to take advantage of available gaps in the through lane traffic stream. The driver's movement is thus constrained by the design of the acceleration lane and by the relative location of other vehicles. Entry into the through lane traffic stream at speeds, or in paths, that differ substantially from the norm causes disruptions in the flow of through traffic and is harmful to the safe and efficient operation of a road system.

As long as studies show that a portion of the driving public are failing to use acceleration lanes correctly, the efficiency of a road system is reduced. As long as a difference remains between optimum traffic performance and actual traffic performance on acceleration lanes, there will be a need for studies to re-evaluate the designs.

Purpose and Scope

Prior studies have shown that operating characteristics of on-ramp vehicles have differed significantly for locations having the same design (1)(2). These results indicated that through lane and ramp volumes will affect the operational characteristics on acceleration lanes. It may therefore be hypothesized that acceleration lane design should reflect the anticipated design volumes.

The purpose of this research was to examine the interaction of driver behavior, geometric design, and vehicle movement on acceleration lanes on urban freeways in Kansas. Attention was given to the effect that different volume levels on both the freeway and on the acceleration lane have on vehicle movement, a comparison of the speeds attained by vehicles at the point of entry onto the freeway and the speeds of through lane freeway vehicles, and the effect of freeway lane distribution on vehicle movement.

The study was limited to two sites on urban freeway facilities in Kansas. Data were obtained for volumes and speeds of freeway and on-ramp traffic, the percentage of freeway volumes by lane as the traffic approached the merging area with the acceleration lane, and on the distance from the nose point to the point at which ramp vehicles entered the through lane traffic stream.

Only passenger cars were included in the analysis because of the small number of trucks observed.

REVIEW OF PRIOR STUDIES

Various designs of acceleration lanes have been used to provide an area for acceleration and merging. Designs vary significantly from state to state. Some states follow the standards set forth in the AASHO Manual (3) while others have developed their own standards using the AASHO criteria only as a guide.

The AASHO Manual gives two general basic forms for the design of acceleration lanes:

1. A lane of uniform width followed by a taper is suggested where long acceleration lanes are required and where high traffic volumes exist. This type of design is adjacent to and flush with the through pavement.
2. A direct on-ramp which merges with the freeway at a constant taper in which all entry is restricted to the point at which the ramp contacts the freeway forcing ramp vehicles to enter the freeway in the order in which they come down the ramp is suggested for high speed highways. The ramp is of sufficient length to provide the required acceleration.

Several conclusions (4)(5)(6) have been reached about these two forms of on-ramp design from observations of traffic behavior.

1. All drivers do not use the first type of acceleration lane in the same manner, some utilizing little of the facility available. On the whole, however, a sufficient length of acceleration lane has been provided to safely accommodate on-ramp traffic volumes.
2. The length of the first type of acceleration lane used by on-ramp traffic increases with increasing freeway volume, with the majority

of drivers using the full length, or nearly so, at high volumes.

3. The constant-taper direct on ramp fits the behavior of drivers more closely than the extra lane type which, to be fully used, requires maneuvering on a reverse curve path.

In 1956 a study in Texas (7) which compared the effect of geometric design of four different types of acceleration lanes on the operational characteristics of vehicles showed approximately fifty-eight percent of the ramp traffic made little or no use of the acceleration lane and entered within 175 feet of the nose point. The four types of acceleration lanes studied were as follow: a two lane direct entry ramp; a one lane direct entry ramp; a one lane ramp with a short acceleration lane; and, a one lane ramp with a long acceleration lane. The ramp with the short acceleration lane was modified by increasing its length and restudied to provide the fourth study condition. Lengthening the acceleration lane resulted in only a slight increase in acceleration lane usage at this location.

Classification of paths of entry according to volume in the outside lane of the freeway indicated an increase in the direct or abrupt path of entry with volume increase. This was true for each of the ramps studied. This particular finding contradicted earlier conclusions (5). Studies of two-lane ramp operation indicated minor use of the ramp as a two lane facility with only thirteen percent of the entering traffic using the outside lane.

The following data were obtained in each study of a lane:

1. Paths of entry and use of acceleration lane.

2. Paths of entry and use of second ramp lane (two lane study).

3. Gaps accepted and rejected by traffic.

4. Delays encountered by ramp traffic.

Data were further grouped according to conditions of entry:

1. Direct entry into outside lane with no use of acceleration lane.
2. Semi-direct entry along a curved path and full entry within 175 feet of the nose point.
3. Partial use of the lane with full entry from 150 to 250 feet from the nose point.
4. Full use of the acceleration lane.
5. Combined use of the acceleration lane and the outside through lane. Encroachment was sufficient to insure a gap in the outside lane.

Fukutome and Moskowitz undertook a study in California during 1958 regarding traffic behavior as affected by ramp geometry in which an added lane originally provided to accommodate on-ramp traffic was altered by striping and curbing to form acceleration lanes of differing lengths (2). It was found that the majority of drivers used the same path for entering the freeway regardless of ramp length or design. Only small variations were observed in wheel paths of entering vehicles for changing freeway volumes and for fixed ramp volumes. This suggested that if on-ramp lane lengths were adequate for heavy freeway volumes they would be used in the same way when freeway volumes were lower. However, as ramp volumes increased, the length of ramp used was observed to decrease, thus verifying a similar finding from the earlier Texas study.

For low ramp volumes, eighty-five percent of the vehicles merged within 600 feet from a point where the left edge of the ramp was six feet from the edge of the freeway; approximately a 40:1 taper. It was also found that the nose point should not be used as a control in computing the length of lane required, but that a distance six feet from the edge of the through lanes to the left edge of the ramp should be used. The angle of convergence was found to be a more significant control than the distance from the nose point. It was concluded that a constant taper made it easier for the driver to merge and, at the same time, made the freeway driver more aware of the merge.

The above results were demonstrated in an experiment in which vehicle operations were observed at a location where three types of ramp terminals were painted successively at one on-ramp location. The first sequence of observations was made with the ramp curb encroaching on the shoulder (two feet from the edge of the freeway pavement). A second sequence was observed with the ramp curb offset the width of the shoulder (in this case eight feet).

The three types of acceleration lanes observed were:

1. A one lane, 50:1 taper, on-ramp.
2. A one-lane parallel on-ramp.
3. A one lane, 30:1 taper, on-ramp.

Observations were made of the following: ramp volumes; freeway volumes; ramp speeds at a point 150 feet back of the nose point and at 150 foot intervals to a point 600 feet beyond the nose point; freeway speeds at 150 foot intervals beginning 500 feet back of the nose point; lateral placement at five locations at 100 foot intervals from the nose point; and, freeway lane changes in the vicinity of the acceleration lane.

Because of the wide variations of traffic behavior observed on the different types of designs, it was concluded that some standardization of design for acceleration lanes should be adopted. Using the results of their study as a guide, the authors proposed that a 50:1 taper on-ramp be used as a standard design. The details of this design, together with supporting data and reasoning, are included in their paper (2). This ramp geometry provides a direct alignment to the nose point. From this point, the right edge of the on-ramp is tapered to provide 300 feet for merging, which was judged to be adequate for both high and low freeway volumes and for high and low speeds; an adequate length of ramp for required acceleration; minimum requirements for paved surface; and, an alignment having a natural or "unforced" appearance.

In the 1960 Proceedings of the Institute of Traffic Engineers (8) three types of entrance designs were proposed. The first design proposed was a direct taper with flush contrasting shoulders, with an abrupt change in alignment of 1°24' along the right edge accenting the point of entry onto the main roadway. The second design proposed was a direct taper curving into the roadway alignment. The initial angle of convergence was 1°24', with the curved end portion having an angle of convergence of 0°42'. The third design proposed was a ramp of continuous curvature providing an initial angle of convergence of 0°30' and a final angle of 0°06'.

The lengths of all of the designs were from 500 to 600 feet measured from the nose point to a point where the width between the through lane and the right edge of the ramp is five feet.

If an upgrade or other restricting feature on the ramp does not permit the development of sufficient speed, a longer acceleration lane, utilizing a parallel auxiliary lane ahead of the tapered section, may be required.

Another study in California in 1961 reported the incorrect usage of entrance ramps by drivers (9). The study was undertaken to determine the basic operating characteristics of a weaving section on an auxiliary lane serving both on-ramp and off-ramp traffic for adjacent loops of a cloverleaf interchange. A method of striping the weaving section to encourage greater usage of the auxiliary lane was tried. This consisted of a solid stripe along the edge of the freeway for a distance sufficient to guide the vehicle into a position parallel to the main freeway lanes. This was followed by a dashed lane stripe along the longitudinal joint common to the freeway and the weaving section to encourage the vehicles to stay in the auxiliary lane longer.

It was observed that many of the drivers did not use much of the weaving section before striping. Also, many of the vehicles stopped or slowed markedly prior to merging and actually waited for a gap long enough to be acceptable from a stopped position. Little correlation was found between volumes and entry into the outside lane within 300 feet of the nose point. As volumes increased, a greater proportion entered within 100 feet of the nose point. After the striping was applied, it was observed that a greater percentage of drivers used the weaving section correctly.

A nationwide Freeway Ramp Capacity Study was conducted by the Highway Research Board and the U. S. Bureau of Public Roads in 1960 and 1961 (10). Emphasis of the study was on the merging operations at freeway ramp terminals. Formulae were developed by regression analyses for use in computing the merging capacities of ramps of different designs. It was found that ramp capacity was dependent on the following: freeway volume and lane usage upstream from the ramp; commercial vehicles in the merge; a ratio of the ramp volume to the total merging volume; the angle of convergence of the ramp; the length of the acceleration lane; and, the metropolitan area population.

A study similar to the 1956 Texas study, but more comprehensive, was conducted at fifteen different locations in Indiana by Jouzy and Michael in 1962 (1). For each 100 foot section of ramp, data were reported for the following: average speed; eighty-fifth percentile speed; standard deviation; and, the percentage of total vehicles entering the freeway. A cumulative frequency graph of freeway entrance location was presented for each study site to help in evaluating the different designs. In addition, spot speeds of the through traffic were measured at an area where acceleration lanes joined the through lanes and at points one mile preceding and following the interchange.

The types of acceleration lane designs studied were:

1. A 52:1 direct taper on-ramp.
2. Two different types of parallel on-ramps.
3. A 25:1 direct taper on-ramp.

Study sites selected included: eight located on tangent alignment; four on right-curving alignment; and, three on left-curving alignment. In addition, one location was observed where an acceleration lane joined the through lane on the upgrade portion of a crest vertical curve and another location was observed where an acceleration lane joined the through lane on a sag vertical curve.

Large differences in speed between acceleration lane traffic and through lane traffic at the time of merging were observed, but traffic entering from the acceleration lanes had little effect on the speed of the through traffic.

Most drivers tended to merge soon after entering all parallel lanes studied and at too low a speed. A longer length of lane showed no better usage than a shorter length. Results were not similar at all locations having the same design and operating under the same roadway geometry. It was concluded that through lane and on-ramp volumes were affecting the behavior of traffic entering the roadway from the ramp.

Best usage of acceleration lanes was observed when the lane met the through lane on a right curve. The long direct taper with separation from through lanes for 500 feet was found to be the only type where drivers approached the optimum conditions of operation. For this design a high percentage of drivers followed a natural straight path from the beginning of the acceleration lane at the end of the ramp curve until they merged into the through lane within a maximum of 260 feet beyond the nose point. Some control such as a curb appeared to be desirable beyond the nose point of the ramp to align some motorists properly in a straight path and to prevent too early merge at too low a speed.

To briefly summarize the results of all the studies, the following general statements appear to be warranted. Acceleration lanes are undergoing a change to a more liberal design. It is only as further studies provide additional information concerning the operational aspects of various designs that improvement can continue to take place in the design of acceleration lanes. Although acceleration lanes have been in use for many years, there is such a diversity in design that a large number of motorists apparently still do not know how to use the lanes properly.

EQUIPMENT AND APPARATUS

In this study, data on speed, freeway and ramp volumes, and on the point at which vehicles entered the freeway from an on-ramp were obtained by time-lapse photography. A 16 mm motion picture camera (Bolex Paillard with Pan-Cinor 85 Zoom Lens) was used. One hundred foot rolls of Kodak Tri-X Reversal Movie Film were used for the studies. The camera was driven by a Bolex Unimotor (Type MC-17). A Samenco intervalometer control timer activated a solenoid which released the camera shutter for frame-by-frame pictures.

A Terado Power Converter (Model No. 50153) was used to convert 12 volt direct current, supplied by a car battery, to 110 volt 60 cycle alternating current required for the operation of the intervalometer. The Bolex camera drive motor was powered in the initial stages of the study by 6 volt dry-cell batteries. The dry-cell batteries were discarded in favor of a 12 volt car battery which could be recharged as needed. Figure 1 shows a diagram of the proper equipment connections. The 12 volt car battery was recharged after each usage to make sure the power supply was always adequate.

A time and motion analysis projector (Keystone, Belmont K161) was used for frame-at-a-time viewing of the film. This projector was used because it was especially constructed so that heat from the lantern was isolated from the film thereby preventing film damage. The film projection could be completely controlled by the operator for speed of projection and for frame-by-frame, advance or reverse, viewing. The projector was equipped with a frame counter which obviated the need for a clock in the film. Figure 2 shows the projector and the viewing screen.

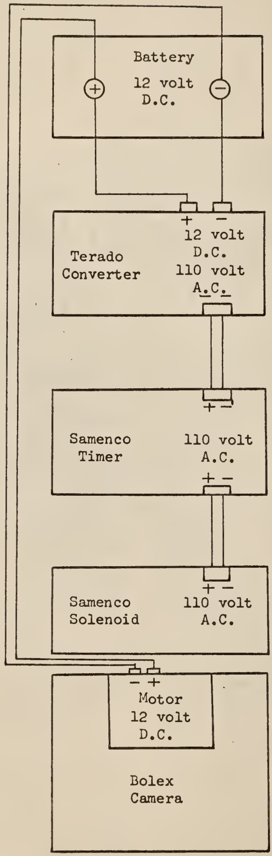

Figure 1. Diagram of equipment connections.

Figure 2. Time and motion analysis projector (Keystone, Belmont K161) and viewing screen.

PROCEDURE

The time-lapse photography method of study was chosen because it provided a permanent record of data for detailed study and analysis. Data on vehicle paths, speeds and other instantaneous type data were easily obtained. A major advantage of this method was that one person was able to collect and analyze the data. This reduced the cost of the study considerably. A possible disadvantage of the method was the tedious man-hours required to reduce and analyze the data from the film.

In order to measure speeds and location of lateral movements, it was necessary to locate identification points in the pictures so that a grid could be prepared from the film. Prior to the days when filming was to be done, identifying marks were located along the shoulder of the acceleration lane at 100 foot intervals, beginning at the nose point. Traffic cones were placed over these marks prior to filming in order to determine distances required for analysis. These cones were orange in color and were made more highly visible by striping with adhesive tape.

The filming was done from an overpass over the freeway. Figure 3 shows how the camera and apparatus were set up on the overpass walkway. A safety precaution was taken by placing two traffic cones two feet away from the hubguard of the bridge and preceding the camera to warn vehicle drivers in the outside lane.

The Pan-Cinor 85 Zoom Lens provided an excellent means of framing exactly the desired area of study within a picture since the focal length of the lens was easily changed and could be adjusted to include the entire length of the acceleration lane.

Figure 3. Camera and apparatus set up on the overpass walkway at the 18th and I-35 location.

Continuous frame-by-frame filming was obtained at the locations studied. It was planned that an interval of two seconds between frames would be used; however, the time setting on the Samenco Timer was not quite accurate and resulted in an interval of 2.13 seconds. It might have been more desirable to use a lesser interval; however, the particular timer available had a lower limit of two seconds between frames.

The film was analyzed by projecting it through the time-motion study projector described previously. A grid was made by projecting a frame of the film onto a viewing screen. A sheet of vellum paper was superimposed over the viewing screen and the location of traffic cones and the edge of pavement traced. Parallel lines were drawn through the traffic cones located at 100 foot intervals along the ramp so that the lines intersected the edge of the freeway at right angles to form an analysis grid. After a suitable grid had been prepared, it was transferred to a Bohn thermomaster by the Thermofax process. This produced a clear plastic overlay grid that could be superimposed on the viewing screen. A separate grid was needed for each location since the camera view of the acceleration lane was at different heights and resulted in a different perspective in each case.

Freeway lane and ramp traffic volumes at each location were observed at the nose point of the acceleration lane. Distance measurements and a projection frame count for each vehicle on the freeway and the acceleration lane were recorded. The location at which the left rear wheel of vehicles on the acceleration lane crossed the right edge of the outside lane of the freeway was considered to be the point of entry or merging point. The left rear wheel of the vehicle was chosen as the criterion because the merging vehicle comes into conflict with vehicles on the through lane at the moment this wheel crosses the right edge of the freeway pavement. The lane into which a vehicle weaved and the location at which the weave was made were also recorded. Because the camera was operated at a constant speed, it was possible to determine the time required for a vehicle to travel a known distance. Speeds were computed from the known time and distance relationships.

STUDY SITES

Figure 4 is a map of Kansas City, Kansas, showing the locations of acceleration lanes studied. The two interchanges at which studies were made were both of the cloverleaf design without collector roads. The locations studied were chosen because they had similar interchange geometry and varying volume levels of usage. Both locations had bridge structures upon which the camera equipment could be assembled at a convenient height above the acceleration lane to be studied.

The acceleration lane at 18th Street and I-35 Interchange was filmed from 7:00 a.m. to 9:00 a.m., Wednesday, April 14, 1965. Because of rain, the evening filming at this location was done on Friday, April 16, from 3:45 p.m. to 6:05 p.m.

The acceleration lane at the 63rd Street Interchange was filmed from 7:00 a.m. to 8:10 a.m. and from 4:15 p.m. to 5:25 p.m., Thursday, April 15, 1965.

18th Street Expressway and Interstate-35

Figure 5 is an aerial photograph showing the interchange geometry. The acceleration lane studied at this location is in the northwest quadrant of the interchange and is used by the south 18th Street Expressway to west Interstate-35 traffic movement.

The design of the acceleration lane is shown in Figure 6. The acceleration lane is of the parallel type having a full lane width from the end of the ramp curve for 575.33 feet plus 225 feet of taper. The distance from the nose point to the end of the ramp curve is 58.67 feet. This provides a total length of acceleration lane of 859 feet from the nose point to the

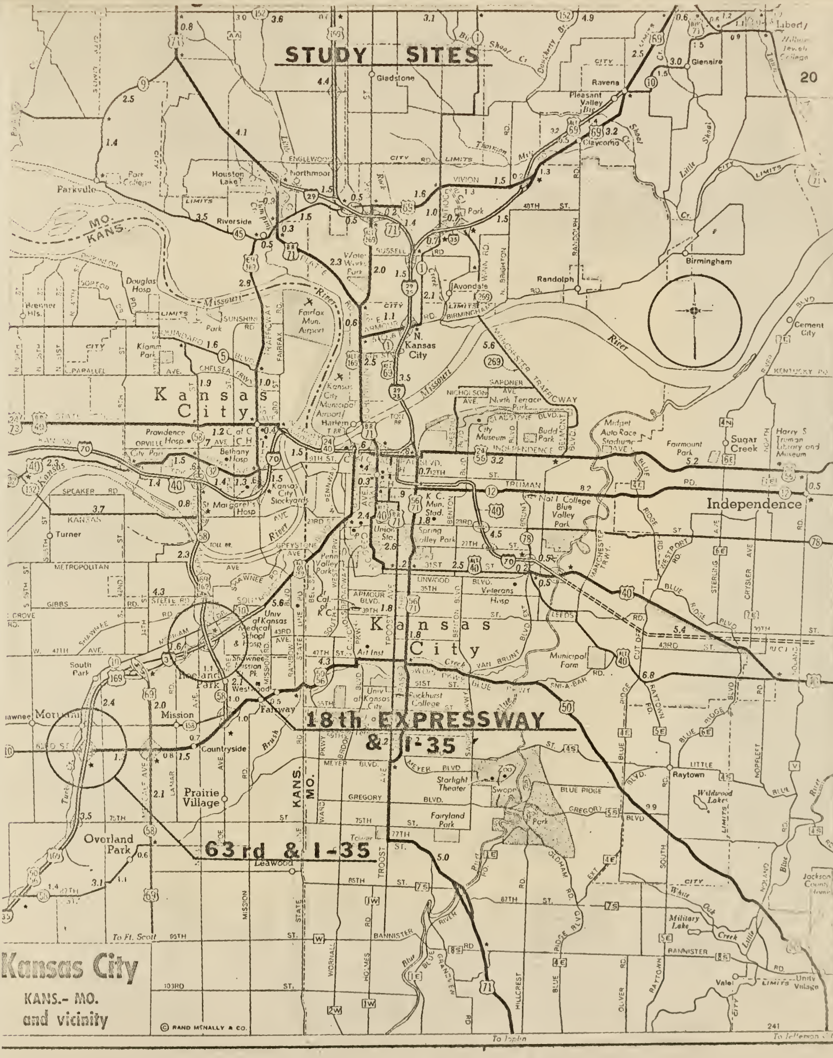

Figure 4. Map of Kansas City, Kansas, showing the locations of acceleration lanes studied.

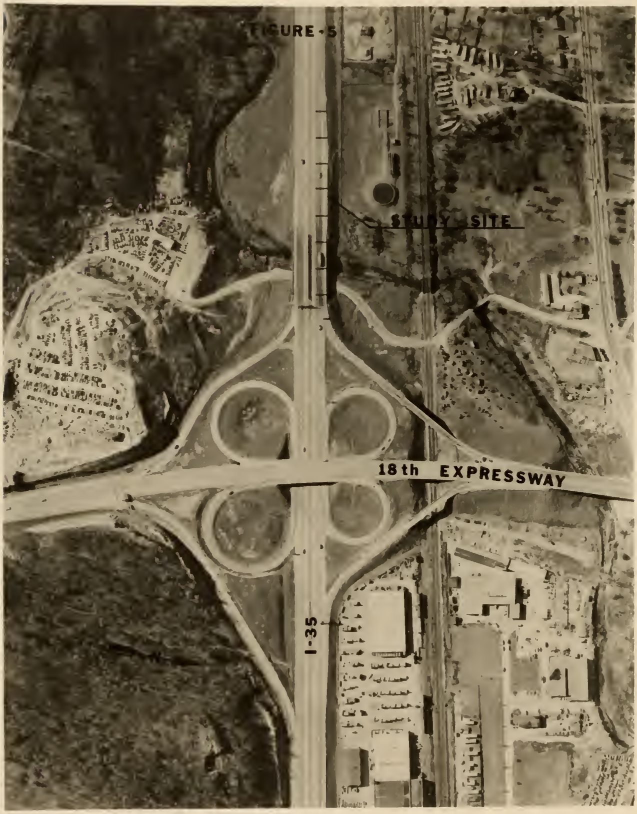

Figure 5. Aerial photograph showing the interchange geometry at the 18th Street Expressway and Interstate-35.

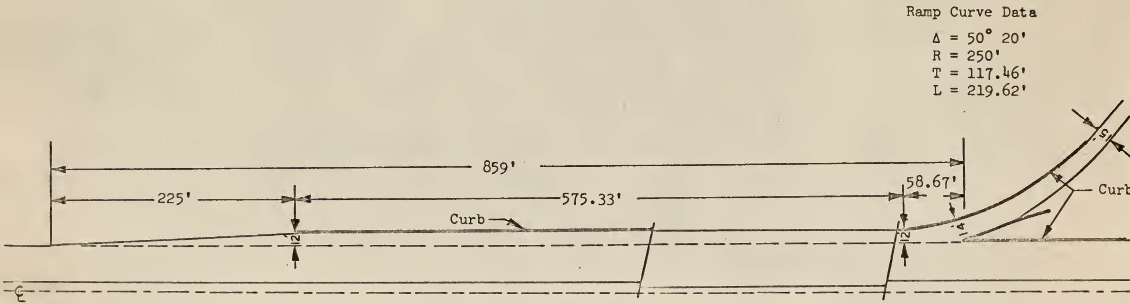

Figure 6. Geometric design of the acceleration lane studied at the 18th Street Expressway and Interstate-35 Interchange.

intersection of the taper with the right edge of the freeway. The acceleration lane meets the through lanes on a tangent. Station 0 + 00 for this lane was considered to be at the nose point because acceleration lane traffic could merge into any of the three westbound freeway lanes at any point beyond this.

The speed of ramp vehicles is controlled by a 250 foot radius curve which precedes the acceleration lane. This provides for a speed of about thirty mph; however, the ramp is signed for twenty-five mph. Other pertinent signing that affects traffic operation in the vicinity of the acceleration lane consists of a Yield Right-of-Way sign placed at the nose point of the acceleration lane, a Merging Traffic sign 160 feet preceding the nose point to warn freeway traffic, and a sixty-five mph speed limit controlling the freeway traffic.

Part of the acceleration lane was located on a 235 foot long bridge structure which was sixty feet beyond the nose point. Because the bridge is on a crest vertical curve, drivers of vehicles arriving at the nose point are unable to see the rest of the acceleration lane beyond the crest. Although this particular design feature should have affected the operation of only the drivers who were unfamiliar with the acceleration lane geometry, it was hypothesized before the study was made that this would be a major factor affecting the operation of all vehicles.

Traffic on the 18th Street Expressway is stopped at a toll booth 1.5 miles north of the interchange at I-35. Because of this, vehicles using the north to west movement at the interchange tended to arrive at random intervals. Occasionally, however, large trucks would pass each other after leaving the toll booths. This caused other vehicles to platoon behind them and arrive at the acceleration lane in clusters. Congestion was only momentary, and the average speed of acceleration lane vehicles was affected very little.

Westbound traffic on I-35 did not arrive at completely random intervals usually observed on freeways. A signalized intersection was located at the beginning of westbound I-35, 1.4 miles east of the study site. The freeway vehicles were able to disperse from platoons before they arrived at the study site, but the instantaneous merging rate at the acceleration lane was much higher than the five minute volumes indicate. Although this condition caused some momentary congestion, the average speeds of freeway vehicles were affected very little because congestion lasted such a short length of time.

Traffic estimates obtained by the Kansas State Highway Commission are given in Table 1. The annual Average Daily Traffic (ADT) and Design Hour Volume (DHV) are shown.

63rd Street - I-35 Interchange

Figure 7 is an aerial photograph showing the interchange geometry at the 63rd Street - I-35 Interchange. The acceleration lane studied at this location is in the southwest quadrant of the interchange and is used by east 63rd Street to south I-35 movement.

The design of the acceleration lane is shown in Figure 8. The acceleration lane is of the parallel type having a full lane width from the end of the ramp curve for 550 feet plus 250 feet of taper. The distance from the nose point to the end of the ramp curve is eighty-seven feet. This provides a total length of acceleration lane of 887 feet from the nose point to the intersection of the taper with the right edge of through lane pavement. The

Figure 7. Aerial photograph showing the interchange geometry at the 63rd Street Expressway and Interstate-35.

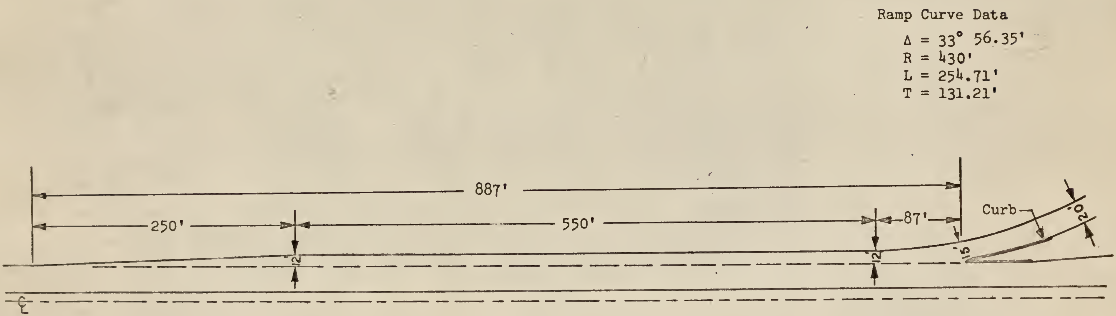

Figure 8. Geometric design of the acceleration lane studied at the 63rd Street and Interstate-35 Interchange.

acceleration lane meets the through lanes on a tangent at a +3.28 percent grade. Station 0 + 00 for this lane was also considered to be at the nose point.

The speed of ramp vehicles is controlled by a 430 foot radius curve which precedes the acceleration lane. This provides for a speed of about forty mph; however, the ramp is signed for thirty-five mph limit. Other pertinent signing that affects traffic operation in the vicinity of the acceleration lane consists of a Yield Right-of-Way sign placed at the nose point of the acceleration lane, a Merging Traffic sign on the freeway about 250 feet preceding the nose point to warn freeway traffic, and a seventy mph speed limit controlling the freeway traffic.

During the time data were obtained, traffic on both the ramp and freeway arrived at random intervals. A somewhat unusual geometric condition existed which may have lowered the average speed of freeway vehicles in the vicinity of the acceleration lane. The lane was preceded by a weaving section serving traffic from adjacent loops of the interchange which terminated approximately 200 feet prior to the nose point. Also, sixty feet beyond the acceleration lane under study a deceleration lane began which caused infrequent interference between on-ramp to freeway and freeway to off-ramp vehicles.

Traffic estimates obtained by the Kansas State Highway Commission are given in Table 2. The annual Average Daily Traffic (ADT) and Design Hour Volume (DHV) are shown.

Table 1

Traffic Volume	
Location: 18th and I-35	
Estimated ADT	Design Hour Volume
Ramp Volume - 18th Street Southbound to I-35 Westbound	
1962 - 9,120	11.0 %
1975 - 10,140	11.0 %
1990 - 11,260	11.0 %
Freeway Volume - Two-way I-35 Traffic	
1962 - 8,310	11.0 %
1975 - 11,380	11.0 %
1990 - 12,380	11.0 %

Table 2

Traffic Volume	
Location: 63rd Street Interchange	
Estimated ADT	Design Hour Volume
Ramp Volume - 63rd Street Eastbound to I-35 Southbound	
1962 - 540	--
1975 - 800	12.0 %
1990 - 850	12.0 %
Freeway Volume - Two-way I-35 Traffic	
1962 - 11,750	--
1975 - 22,110	12.0 %
1990 - 30,560	12.0 %

PRESENTATION AND DISCUSSION OF DATA

Length of Acceleration Lane Used by Passenger Cars

As stated earlier, prior studies indicated that through lane and on-ramp traffic volumes affected the length of acceleration lane used by passenger cars when entering a freeway from an on-ramp (1)(2). Data were taken to determine whether traffic behavior patterns at the two study locations conformed with the patterns reported in the earlier studies.

For purposes of analysis, ramp and freeway traffic volumes were totaled at the end of each five minute interval and the point beyond the nose point at which each ramp vehicle entered the freeway was noted. The five minute ramp volumes and accompanying freeway volumes were then identified as belonging in light ramp-light freeway, light ramp-medium freeway, etc., categories. The range of five-minute ramp and freeway traffic volumes in each category, chosen primarily as a convenient way of grouping data for analysis, are shown in Table 3 for the two study locations. It should be noted that the heaviest traffic volumes observed on the freeway at either location are relatively light in terms of equivalent hourly volumes for two-lane freeways. The complete presentation of ramp and freeway five minute volume counts is contained in Appendix A.

Only passenger cars were included in this analysis because of the few trucks observed and their erratic behavior. Table 4 shows the number of ramp passenger cars (summed over five minute intervals) observed in each ramp volume-freeway volume category for the two locations.

In order to compare the lengths of acceleration lanes used by ramp passenger cars, for the different categories of ramp and freeway volumes,

Table 3

Categories of Five Minute and Equivalent Hourly Rates for Ramp and Freeway Passenger Car Volumes Selected for Analysis Purposes

Ramp Group	5 Minute Volume	Hourly Rate	Freeway Group	5 Minute Volume	Hourly Rate
		18th and I-35 Location			
R1	0- 24	0- 299	F1	0- 49	0- 599
R2	25- 49	300- 599	F2	50- 99	600-1,199
R3	50- 74	600- 899	F3	100-149	1,200-1,799
R4	75- 99	900-1,199	--	--	--
R5	100-124	1,200-1,499	--	--	--
		63rd and I-35 Location			
R1	0- 24	0- 299	F1	0- 49	0- 599
--	--	--	F2	50- 99	600-1,199
--	--	--	F3	100-149	1,200-1,799

Table 4

Number of Ramp Passenger Cars in Each Ramp Volume-Freeway Volume Category for Which Freeway Entry Location Data were Obtained

Ramp Volume Rate (veh/5min)	Ramp Category	One Way Freeway Volume Rate Prior to Ramp (veh/5min)		
		0-49	50-99	100-149
		Freeway Category		
		F1	F2	F3
		18th and I-35 Location		
0- 24	R1	114	--	--
25- 49	R2	76	71	--
50- 74	R3	42	52	64
75- 99	R4	--	68	80
100-124	R5	--	90	91
		63rd and I-35 Location		
0- 24	R1	17	101	39

the numbers of passenger cars were recorded which entered the freeway in each fifty foot increment of acceleration lane, using the ramp nose point as station 0 + 00.

As a result of an insufficient viewing height for the camera and a crest vertical curve located on the acceleration lane at the 18th and I-35 location, the analysis grid constructed for this location provided accurate measurements by fifty foot intervals for only the first 300 feet from the nose point. Measurements were possible for 100 foot intervals from station 3 + 00 to station 5 + 00. Because of the small number of vehicles using more than 500 feet of the acceleration lane, these were ignored in the analysis.

<u>18th and I-35 Location</u>

The number of passenger cars, the percentage of total passenger cars, and cumulative percentage of the total, which entered the freeway in each fifty foot increment of acceleration lane are presented in Table 5 for each ramp volume-freeway volume category at the 18th and I-35 location. These data show that the largest percentage of ramp passenger cars entered the freeway fifty to 100 feet beyond the ramp nose point for all ten ramp volume-freeway volume categories. The next most frequent location was zero to fifty feet. The cumulative percentage of ramp passenger cars entering the freeway within 100 feet of the ramp nose point ranged from sixty to seventy-five percent.

To further emphasize the early freeway entrance, the percentage of the total length of acceleration lane used by eighty-five percent of ramp passenger cars is presented in Table 6.

Table 5

Number of Ramp Passenger Cars, Percentage of Total and Cummulative Percentage of Total, Which Enter the Freeway in Each 50 Foot Increment of Acceleration Lane for Each Ramp Volume-Freeway Volume Category

18th and I-35 Location

Ramp Freeway Category	Total Observations		Equivalent Veh/Hr			Distance from Nose Point to Point of Freeway Entry, Feet								
	Ramp	Freeway	Ramp	Freeway		0-50	50-100	100-150	150-200	200-250	250-300	300-400	400-500	over 500
R1-F1	114	224	171	336	Cars	33	51	10	2	5	2	4	4	3
					% of Total	29.0	44.7	8.8	1.7	4.4	1.7	3.5	3.5	2.7
					Cum. %	29.0	73.7	82.5	84.2	88.6	90.3	93.8	97.3	100.0
R2-F1	76	116	304	464	Cars	24	341	5	3	2	1	4	0	3
					% of Total	31.6	44.8	6.6	3.9	2.6	1.3	5.3	0	3.9
					Cum. %	31.6	76.4	83.0	86.9	89.5	90.8	96.1	96.1	100.0
R2-F2	71	127	426	762	Cars	20	26	3	4	3	3	9	3	0
					% of Total	28.2	36.7	4.2	5.6	4.2	4.2	12.7	4.2	0
					Cum. %	28.2	64.9	69.1	74.7	78.9	83.1	95.8	100.0	100.0
R3-F1	42	44	504	528	Cars	13	16	2	5	2	3	1	0	0
					% of Total	30.9	38.1	4.8	11.9	4.8	7.1	2.4	0.0	0.0
					Cum. %	30.9	69.0	73.8	85.7	90.5	97.6	100.0	100.0	100.0
R3-F2	52	88	624	1056	Cars	17	16	2	3	3	0	4	2	5
					% of Total	32.7	30.8	3.8	5.8	5.8	0	7.7	3.8	9.6
					Cum. %	32.7	63.5	67.3	73.1	78.9	78.9	86.6	90.4	100.0

Table 5 (continued)

Table 5 (continued)

Ramp Freeway Category	Total Observations		Equivalent Veh/Hr			Distance from Nose Point to Point of Freeway Entry, Feet								
	Ramp	Freeway	Ramp	Freeway		0–50	50–100	100–150	150–200	200–250	250–300	300–400	400–500	over 500
R3-F3	64	115	768	1380	Cars	21	17	3	8	2	1	3	7	2
					% of Total	32.9	26.6	4.7	12.5	3.1	1.5	4.7	10.9	3.1
					Cum. %	32.9	59.5	64.2	76.7	79.8	81.3	86.0	96.9	100.0
R4-F2	68	82	816	984	Cars	12	30	8	7	1	2	3	3	2
					% of Total	17.6	44.2	11.8	10.3	1.5	2.9	4.4	4.4	2.9
					Cum. %	17.6	61.8	73.6	83.9	85.4	88.3	92.7	97.1	100.0
R4-F3	80	119	960	1428	Cars	11	45	7	6	1	3	4	3	0
					% of Total	13.7	56.3	8.7	7.5	1.2	3.8	5.0	3.8	0.0
					Cum. %	13.7	70.0	78.7	86.2	87.4	91.2	96.2	100.0	100.0
R5-F2	90	97	1080	1164	Cars	22	39	6	7	3	2	7	0	4
					% of Total	24.5	43.3	6.7	7.8	3.3	2.2	7.8	0.0	4.4
					Cum. %	24.5	67.8	74.5	82.3	85.6	87.8	95.6	95.6	100.0
R5-F3	91	115	1092	1380	Cars	26	32	10	12	4	2	1	2	2
					% of Total	28.6	35.1	11.0	13.2	4.4	2.2	1.1	2.2	2.2
					Cum. %	28.6	63.7	74.7	87.9	92.3	94.5	95.6	97.8	100.0

Table 6

Acceleration Lane Length Used by Eighty-five Percent of Ramp Passenger Cars - 18th and I-35 Location

Ramp Volume (veh/5min)	Freeway Volume (veh/5min)	Volume Category	Lane Length Used (ft)	% of Total Length Used
0- 24	0- 49	R1-F1	250	29.1
25- 49	0- 49	R2-F1	200	23.3
25- 49	50- 99	R2-F2	400	46.5
50- 74	0- 49	R3-F1	200	23.3
50- 74	50- 99	R3-F2	400	46.5
50- 74	100-149	R3-F3	400	46.5
75- 99	50- 99	R4-F2	250	29.1
75- 99	100-149	R4-F3	200	23.3
100-124	50- 99	R5-F2	250	29.1
100-124	100-149	R5-F3	200	23.3

The data show that only vehicles in the R2-F2, R3-F2 and R3-F3 categories approached the use of even fifty percent of the total length of the acceleration lane. The vehicles in the remaining seven categories used only twenty to thirty percent of the available length. Also, the data show that, for fixed ramp volumes, the length of acceleration lane used increased from 200 feet to 400 feet for R2 and R3 ramp volume categories with increasing freeway volumes but decreased slightly from 250 feet to 200 feet for R4 and R5 categories. For fixed freeway volumes, there was a trend for the length of acceleration lane used by ramp passenger cars to decrease with increasing ramp volumes. This trend toward less use of the acceleration lane, at either higher ramp or higher freeway volumes, may be attributed to greater pressure for the ramp passenger vehicles to accept the first available gaps because of vehicles on the ramp behind it in the first instance and because of the scarcity of gaps in the freeway traffic stream in the second instance.

The cumulative percentage of passenger cars entering the freeway at increasing fifty foot increments from the ramp nose point are presented graphically in Figure 9. The curves are graphical illustrations of the data presented in Tables 5 and 6. In addition, the similarity of shape of these curves indicates the apparent absence of a significant influence of ramp and freeway volumes on the cumulative percentage of passenger cars which enter the freeway at any distance beyond the ramp nose point--for the levels of volume observed.

The average location of freeway entry ($\overline{X}$), the standard error of estimate of average entry location ($\sigma_{\overline{x}}$), and $\overline{X} \pm 3\sigma_{\overline{x}}$ limits, which would be expected to include the average location of freeway entry 99.765 percent of

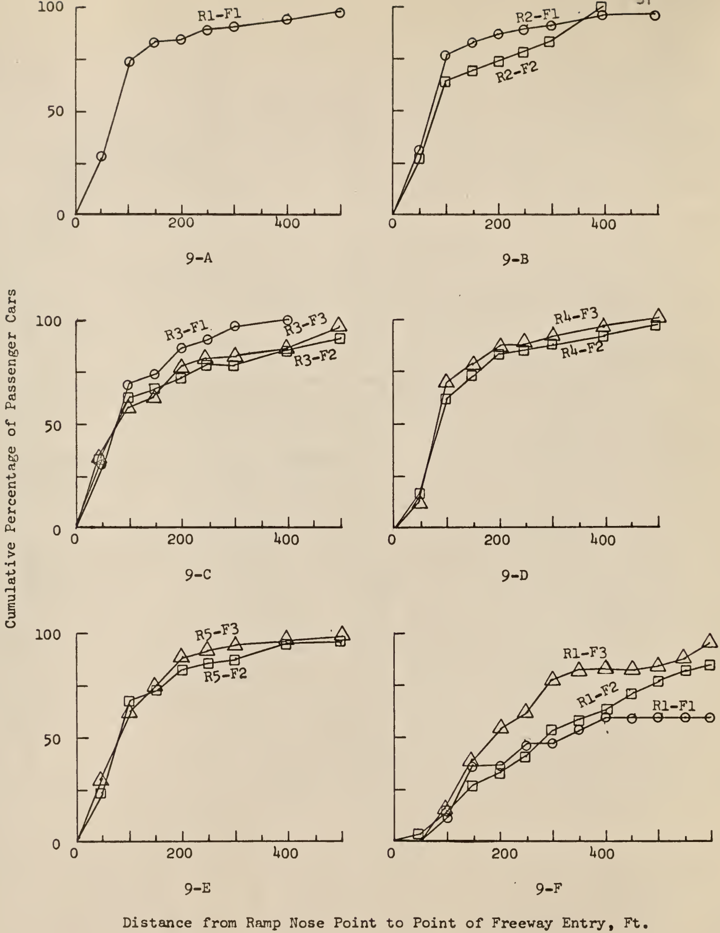

Figure 9. Distance from nose point of ramp to point of entry onto the freeway vs. the cumulative percentage of passenger cars entering the freeway from the ramp for the 18th and I-35 location (9-A to 9-E), and the 63rd and I-35 location (9-F).

the time, were computed for each ramp volume-freeway volume category and are presented in Table 7. Only the vehicles entering the freeway from zero to 500 feet beyond the nose point were included because the locations of entry beyond station 5 + 00 were not known. Since the number of vehicles using more than 500 feet of the acceleration lane in each ramp-freeway category was small, ranging from zero to five as shown in Table 5, it was assumed that the mean location of entry would not be significantly changed by eliminating these values.

The $\bar{\bar{X}} \pm 3\sigma_{\bar{x}}$ limits were plotted (Figure 10) for each ramp volume-freeway volume category. These plots show the considerable overlapping of the limits that existed for a given ramp volume and increasing freeway volumes, and for increasing ramp volumes for given freeway volume. This overlapping indicated that although there were differences among average values of $\bar{X}$, increasing ramp and freeway volumes, at the levels observed, did not significantly affect the freeway entry location of vehicles at this study site, thus confirming a similar observation made in reference to the effect of ramp and freeway traffic volumes on the cumulative percentage of ramp passenger cars that enter the freeway at any point.

<u>63rd and I-35 Location</u>

The merging characteristics of ramp passenger cars at the 63rd and I-35 location differed considerably from the merging characteristics at the 18th and I-35 location. The average distance from the ramp nose point to the point of freeway entry was considerably greater than that observed at the 18th and I-35 location. The greater use of acceleration lane was undoubtedly due to the greater length of lane provided because of the uphill grade on

Table 7

Average Distance from Nose Point to Point of Freeway Entry - 18th and I-35 Location

Ramp Volume (veh/5min)	Freeway Volume (veh/5min)	Volume Category	Total Time (min)	Total Ramp Vehicles Observed	Distance from Nose Point to Freeway Entry		
					Average $\bar{X}$	Standard Error $\sigma_{\bar{x}}$	$\bar{X} \pm 3\sigma_{\bar{x}}$ Limits
0- 24	0- 49	R1-F1	40	111	127	10	97-157
25- 49	0- 49	R2-F1	15	73	114	10	84-144
25- 49	50- 99	R2-F2	10	71	163	16	115-211
50- 74	0- 49	R3-F1	5	42	127	14	85-169
50- 74	50- 99	R3-F2	5	47	143	10	113-173
50- 74	100-149	R3-F3	5	62	166	19	109-223
75- 99	50- 99	R4-F2	5	66	148	14	106-190
75- 99	100-149	R4-F3	5	80	144	12	108-180
100-124	50- 99	R5-F2	5	86	133	11	100-166
100-124	100-149	R5-F3	5	89	131	9	104-158

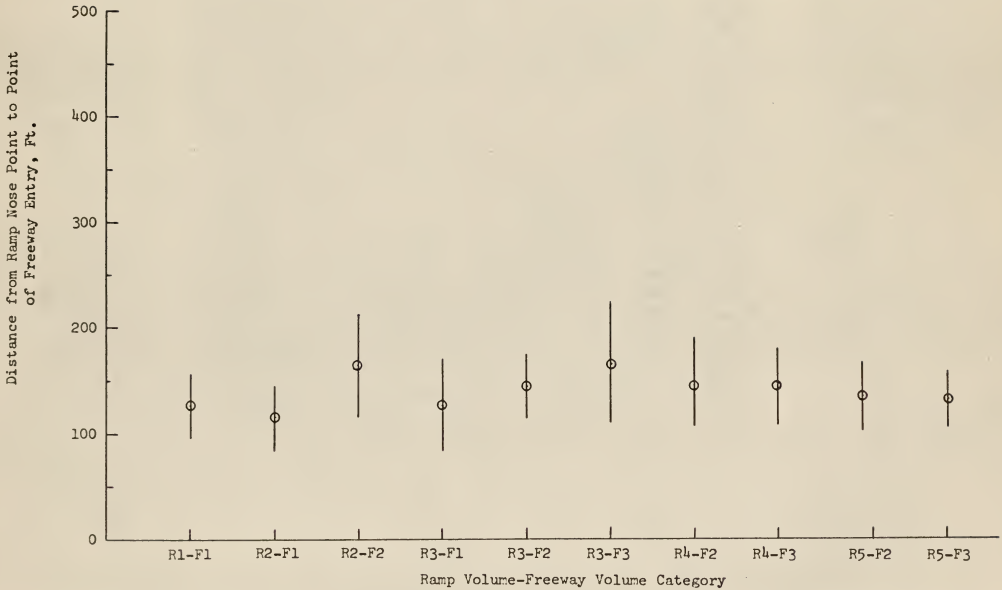

Figure 10. Average distance from ramp nose point to point of freeway entry and 99.765% confidence intervals ($\overline{X} \pm 3\sigma_{\overline{X}}$) for ramp passenger cars. 18th and I-35 location.

the ramp and freeway at this location and to the comparatively light ramp traffic volumes observed.

Because the ramp volume at this interchange was very light, the number of observations of ramp vehicles was rather small, as shown in Table 4. This was especially true for the lower ramp volume-freeway volume category, R1-F1, where only seventeen ramp passenger cars were observed.

The data are presented in Table 8 which show the number of passenger cars entering the freeway in each fifty foot increment of acceleration lane, the percentage of the total passenger cars by fifty foot increments, and the cumulative percentage of passenger cars, for the 63rd and I-35 location. These data show that the largest percentage of vehicles used the fifty foot interval from station 1 + 00 to 1 + 50 in all ramp volume-freeway volume categories. These percentages were 23.4, 12.8, and 23.0 for R1-F1, R1-F2, and R1-F3 respectively.

The cumulative frequency plots for this location, presented in Figure 9-F, show eighty-five percent of ramp passenger cars using 700 feet, 600 feet, and 500 feet respectively for freeway volumes in the F1, F2, and F3 categories. The much greater use of acceleration lane at this location may be attributed to the uphill grade and to the lack of any pressure for the ramp passenger cars to accept the first available gap in the freeway traffic stream.

The average distance from ramp nose point to point of freeway entry ($\bar{X}$), and the 99.765 percent confidence limits ($\bar{X} \pm 3\sigma_{\bar{x}}$), are presented in Table 9 and Figure 11 for each ramp volume-freeway volume category. These data show a considerable overlapping of these limits which indicates that increasing freeway volumes, for the low ramp and freeway volumes observed, did not significantly affect the freeway entry location of ramp passenger cars at this study site.

Table 8

Number of Ramp Passenger Cars, Percentage of Total and Cumulative Percentage of Total, Which Enter the Freeway in Each 50 Foot Increment of Acceleration Lane for Each Ramp Volume-Freeway Volume-Category

63rd and I-35 Location

Ramp-Freeway Category	Total Observations		Equivalent Veh/Hr			Distances from Nose Point to Point of Freeway Entry, Feet																
	Ramp	Freeway	Ramp	Freeway		0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	500-550	550-600	600-650	650-700	700-750	750-800	over 800
R1-F1	17	152	68	456	Cars	0	2	4	0	2	0	1	1	0	0	0	0	4	0	1	0	2
					% of Total	0.0	11.8	23.4	0.0	11.8	0.0	5.9	5.9	0.0	0.0	0.0	0.0	23.5	0.0	5.9	0.0	11.8
					Cum %	0.0	11.8	35.2	35.2	47.0	47.0	52.9	58.8	58.8	58.8	58.8	58.8	82.3	82.3	88.2	88.2	100.0
R1-F2	101	1227	76	920	Cars	1	13	13	8	7	12	5	4	8	7	4	3	4	3	3	3	3
					% of Total	1.0	12.8	12.8	7.9	6.9	11.9	4.9	4.0	7.9	6.9	4.0	3.0	4.0	3.0	3.0	3.0	3.0
					Cum %	1.0	13.8	26.6	34.5	41.4	53.3	58.2	62.2	70.1	77.0	81.0	84.0	88.0	91.0	94.0	97.0	100.0
R1-F3	39	924	59	1386	Cars	0	6	9	6	3	6	2	0	0	1	1	3	1	0	1	0	0
					% of Total	0.0	15.3	23.0	15.4	7.7	15.4	5.1	0.0	0.0	2.6	2.6	7.7	2.6	0.0	2.6	0.0	0.0
					Cum %	0.0	15.3	38.3	53.7	61.4	76.8	81.9	81.9	81.9	84.5	87.1	94.8	97.4	97.4	100.0	100.0	1.00.0

Table 9

Average Distance from Nose Point to Point of Freeway Entry - 63rd and I-35 Location

Ramp Volume (veh/5min)	Freeway Volume (veh/5min)	Volume Category	Total Time (min)	Total Ramp Vehicles Observed	Distance from Nose Point to Freeway Entry		
					Average $\bar{X}$	Standard Error $\sigma_{\bar{x}}$	$\bar{X} \pm 3\sigma_{\bar{x}}$ Limits
0-24	0- 49	R1-F1	20	15	360	63	171-549
0-24	50- 99	R1-F2	80	98	347	21	285-411
0-24	100-149	R1-F3	40	39	373	27	292-454

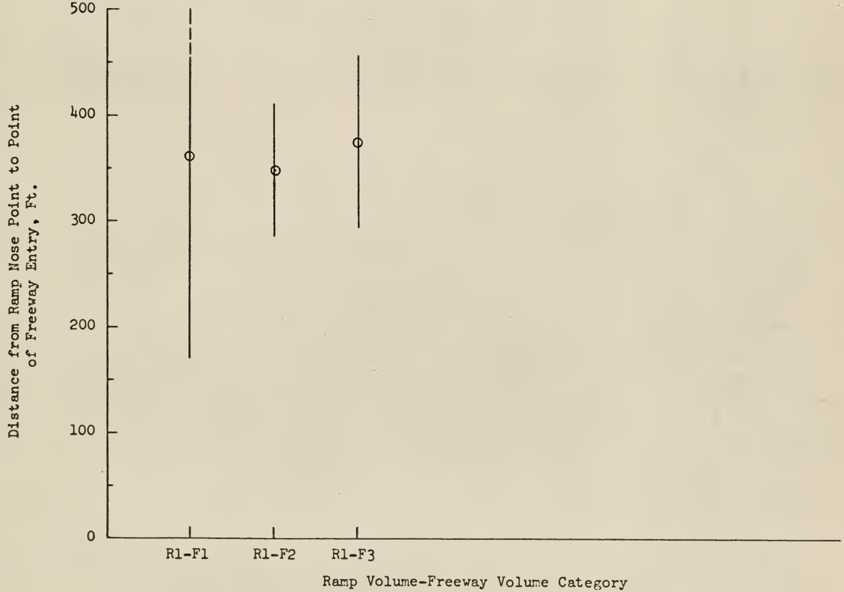

Figure 11. Average distance from ramp nose point to point of freeway entry and 99.765% confidence intervals ($\overline{X} \pm 3\sigma_{\overline{x}}$), for ramp passenger cars, 63rd and I-35 location.

Speeds of Ramp and Freeway Passenger Cars

One of the purposes of an acceleration lane is to provide a safe and efficient area for vehicles to accelerate to a speed which closely coincides with the speeds of vehicles traveling on the through traffic lanes. In order to compare speeds of acceleration lane traffic at the point of freeway entry with speeds of through lane traffic, speeds of ramp and freeway passenger cars were analyzed.

Speed data were obtained for ramp and freeway passenger cars by noting the distance traveled for a fixed number of time increments. Speeds determined for ramp passenger cars represented the speed attained at the point of entry onto the freeway. The speeds for freeway passenger cars represented the speeds of these cars as they proceeded along the freeway a distance equivalent to the length of the acceleration lane being observed. The complete presentation of ramp and freeway passenger car speed data is presented in Appendix B.

Table 10 shows the speed data for each ramp volume-freeway volume category for both locations studied. Data in this table include the number of ramp passenger cars observed, the average speed ($\overline{S}$), the standard error of average speed ($\sigma_{\overline{S}}$), and the values of the $\overline{S} \pm 3\sigma_{\overline{S}}$ limits for the ramp passenger cars entering the freeway in each fifty foot increment of acceleration lane. Only the average speeds for the first 300 feet of acceleration lane are shown for the 18th and I-35 location because accurate speed data could not be analyzed beyond this point. The average speed data for each lane of freeway traffic are presented in Table 11.

Plots of the average entering speed, $\overline{S}$, are shown in Figure 12 for each ramp volume-freeway volume category at both locations studied. Dashed lines were used to emphasize average speeds based on less than three observations. The average speeds in the outside freeway lane were also plotted on Figure 12 for convenience in comparison with ramp passenger car speeds.

Table 10

Number of Ramp Passenger Cars Observed, the Average Speed $\bar{S}$, the Standard Error of Average Speed $\sigma_{\bar{S}}$, and the $\bar{S} \pm 3\,\sigma_{\bar{S}}$ Limits for $\bar{S}$, for Ramp Passenger Cars Entering the Freeway in Each 50 Foot Increment of Acceleration Lane

18th and I-35 Location

Ramp-Freeway Category	5 Min. Volume	Equivalent Hourly Rate		Distance from Nose Point to Point of Freeway Entry, Feet 0-50	50-100	100-150	150-200	200-250	250-300
R1-	0-24	0-299	Cars	33	50	10	2	4	2
			$\bar{S}$	27.8	30.6	29.4	42.4	34.0	31.2
F1	0-49	0-599	$\sigma_{\bar{S}}$	1.1	.8	2.6	2.4	3.8	4.0
			$\bar{S}\pm3\sigma_{\bar{S}}$	24.5-31.1	28.2-33.0	21.6-37.2	35.2 49.6	22.6 45.4	19.2 43.2
			Cars	24	34	5	2	2	1
R2-	25-49	300-599	$\bar{S}$	31.2	28.0	29.1	30.4	35.2	32.0
F1	0-49	0-599	$\sigma_{\bar{S}}$	.7	.9	3.3	9.6	3.2	-
			$\bar{S}\pm3\sigma_{\bar{S}}$	29.1-33.3	25.3-30.7	19.2-39.0	1.6-59.2	25.6-44.8	- -
			Cars	20	26	3	4	3	3
R2-	25-49	300-599	$\bar{S}$	27.2	26.5	19.2	33.2	31.5	32.3
			$\sigma_{\bar{S}}$	1.1	1.2	2.4	2.2	.5	3.9
F2	50-99	600-1,199	$\bar{S}\pm3\sigma_{\bar{S}}$	23.9-30.5	22.9 30.1	12.0-26.4	26.6-39.8	30.0-33.0	20.6-44.0

Table 10 (continued)

Ramp-Freeway Category	5 Min. Volume	Equivalent Hourly Rate		Distance from Nose Point to Point of Freeway Entry, Feet					
				0-50	50-100	100-150	150-200	200-250	250-300
			Cars	13	16	2	5	2	3
R3-	50-74	600-899	$\overline{S}$	31.8	27.9	35.2	36.3	30.4	32.0
F1	0-49	0-599	$\sigma_{\overline{S}}$	2.3	1.1	3.2	1.5	1.6	1.2
			$\overline{S}\pm3\sigma_{\overline{S}}$	24.9-38.7	24.6-31.2	25.6-44.8	31.8-40.8	25.6-35.2	28.4 35.6
R3-	50-74	600-899	Cars	17	16	2	3	3	0
			$\overline{S}$	24.0	24.4	28.8	25.6	29.3	-
F2	50-99	600-1,199	$\sigma_{\overline{S}}$	1.1	1.1	3.2	1.9	1.1	-
			$\overline{S}\pm3\sigma_{\overline{S}}$	20.7-27.3	21.1-27.7	19.2 38.4	19.9-31.3	26.0-32.6	- -
			Cars	21	17	3	8	2	1
R3-	50-74	600-899	$\overline{S}$	28.0	28.0	29.9	27.4	36.0	35.2
F3	100-149	1,200-1,799	$\sigma_{\overline{S}}$	.9	.9	1.4	1.2	.8	-
			$\overline{S}\pm3\sigma_{\overline{S}}$	25.3-30.7	25.3-30.7	25.7-34.1	23.8-31.0	33.6-38.4	- -
R4-	75-99	900-1,199	Cars	12	30	8	7	1	2
F2	50-99	600-1,199	$\overline{S}$	27.7	25.0	29.2	27.1	36.8	28.8
			$\sigma_{\overline{S}}$	1.6	.7	2.0	2.1	-	3.2
			$\overline{S}\pm3\sigma_{\overline{S}}$	22.9-32.5	22.9-27.1	23.2-35.2	20.8-33.4	- -	19.2-38.4

Table 10 (continued)

Ramp-Freeway Category	5 Min. Volume	Equivalent Hourly Rate		Distance from Nose Point to Point of Freeway Entry, Feet					
				0-50	50-100	100-150	150-200	200-250	250-300
R4-	75-99	900-1,199	Cars	11	45	7	5	1	3
			$\overline{S}$	29.1	26.9	30.6	27.8	30.4	32.5
F3	100-149	1,200-1,799	$\sigma_{\overline{S}}$	1.4	.7	1.5	3.1	-	3.7
			$\overline{S}\pm3\sigma_{\overline{S}}$	24.9-33.3	24.8-29.0	26.1-35.1	18.5-37.1	- -	21.4-43.6
R5-	100-124	1,200-1,499	Cars	22	39	6	6	3	2
			$\overline{S}$	25.7	23.4	29.6	26.8	27.7	34.4
F2	50-99	600-1,199	$\sigma_{\overline{S}}$	1.3	.9	2.3	1.6	2.3	1.7
			$\overline{S}\pm3\sigma_{\overline{S}}$	21.8-29.6	20.7-26.1	22.7-36.5	22.6-31.0	20.8-34.6	29.3-39.5
R5-	100-124	1,200-1,499	Cars	26	32	10	12	4	2
			$\overline{S}$	24.8	24.6	27.2	28.4	29.0	20.8
F3	100-149	1,200-1,799	$\sigma_{\overline{S}}$	.9	.8	1.2	1.6	1.5	5.1
			$\overline{S}\pm3\sigma_{\overline{S}}$	22.1-27.5	22.2-27.0	23.6-30.8	23.6-33.2	24.5-33.5	5.5 36.1

Table 10 (continued)

63rd and I-35 Location

Ramp-Freeway Category*		Distance from Nose Point to Point of Freeway Entry, Feet																
		0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	500-550	550-600	600-650	650-700	700-750	750-800	over 800
R1-F1	Cars	0	2	3	1	2	-	1	1	-	-	-	-	4	-	1	-	1
	$\bar{S}$	-	44.0	41.1	41.6	36.8	-	56.0	44.8	-	-	-	-	45.2	-	48.0	-	38.4
	$\sigma_{\bar{S}}$	-	7.2	4.7	-	3.2	-	-	-	-	-	-	-	2.6	-	-	-	-
	$\bar{S} \pm 3\sigma_{\bar{S}}$	-	22.4-65.6	27.0-55.2	-	27.2-46.4	-	-	-	-	-	-	-	37.4-53.0	-	-	-	-
R1-F2	Cars	1	13	12	8	7	12	5	4	8	7	4	3	4	3	3	3	3
	$\bar{S}$	51.2	41.4	45.1	41.2	37.3	40.5	37.8	48.0	40.6	38.2	45.6	43.7	50.4	41.6	54.4	43.4	48.6
	$\sigma_{\bar{S}}$	-	1.8	1.2	1.6	2.6	2.4	4.2	3.0	3.3	1.8	4.2	4.0	2.4	5.5	4.2	2.6	3.8
	$\bar{S} \pm 3\sigma_{\bar{S}}$	-	36.0-46.8	41.5-48.7	36.4-46.0	29.5-45.1	33.3-47.7	25.2-50.4	41.0-57.0	30.7-50.5	32.8-43.6	33.0-58.2	31.7-55.7	43.2-57.6	25.1-58.1	41.8-67.0	35.6-51.2	37.2-60.0
R1-F3	Cars	-	6	9	6	3	6	2	-	-	1	1	3	1	-	1	-	-
	$\bar{S}$	-	36.3	37.5	38.7	33.6	39.7	45.7	-	-	48.0	43.2	48.5	49.6	-	32.0	-	-
	$\sigma_{\bar{S}}$	-	4.8	2.1	3.2	8.8	2.8	2.4	-	-	-	-	4.7	-	-	-	-	-
	$\bar{S} \pm 3\sigma_{\bar{S}}$	-	21.9-50.7	31.2-43.8	32.1-45.3	7.2-60.0	31.3-48.1	38.5-52.9	-	-	-	-	34.4-62.6	-	-	-	-	-

*See Table 3

Table 11

Average Speed of Passenger Cars Observed in Each Freeway Traffic Lane for Each Ramp Volume-Freeway Volume Category.

Ramp Volume	Freeway Volume	Volume Category	Average Freeway Speed, Mph		
			Inside Lane	Center Lane	Outside Lane
				18th and I-35 Location	
0-24	0-49	R1-F1	51.8	50.4	40.5
25-49	0-49	R2-F1	51.3	48.1	43.2
25-49	50-99	R2-F2	51.3	44.9	39.5
50-74	0-49	R3-F1	55.0	47.0	44.0
50-74	50-99	R3-F2	47.5	44.8	37.1
50-74	100-149	R3-F3	51.2	45.7	37.4
75-99	50-99	R4-F2	50.0	46.2	34.4
75-99	100-149	R4-F3	51.7	48.3	39.9
100-124	50-99	R5-F2	50.3	46.6	36.4
100-124	100-149	R5-F3	53.2	47.9	33.9
				63rd and I-35 Location*	
0-24	0-49	R1-F1	67.0		58.0
0-24	50-99	R2-F2	63.1		53.9
0-24	100-149	R3-F3	60.8		51.7

*4-Lane Freeway

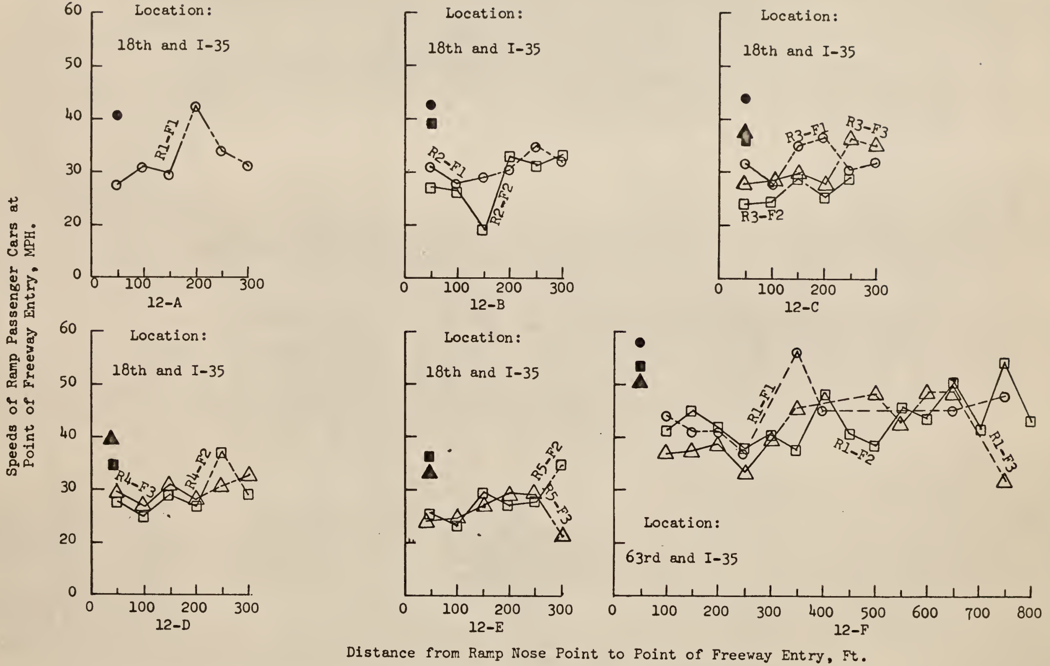

Figure 12. Average entering speeds $\overline{S}$ at point of freeway entry for each 50 ft. increment of acceleration lane (⊙, □, △) and average speed in the outside freeway lane (●, ■, ▲) for the 18th and I-35 location (12-A to 12-E) and the 63rd and I-35 location (12-F).

Plots were made of the average entering speed, $\bar{S}$, and the $\bar{S} \pm 3\sigma_{\bar{s}}$ limits for all ramp volume-freeway volume categories at both locations studied. These plots are presented in Figure 13. The plots of the $\bar{S} \pm 3\sigma_{\bar{s}}$ limits indicate a considerable overlapping of the intervals within which the average speeds, $\bar{S}$, may be expected to lie 99.765 percent of the time due to chance variation alone.

<u>18th and I-35 Location</u>

The speed data for the 18th and I-35 location are presented in Table 10 and in Figures 12-A through 12-E. The data show that speeds of ramp passenger cars at point of entry onto the freeway decreased slightly for simultaneously increasing freeway and ramp volumes. However, discounting isolated data points, the general shapes of the curves were similar and, considering the $\bar{S} \pm 3\sigma_{\bar{s}}$ limits on average entering speeds, could not be said to be significantly different. The curves also indicate a trend for entering speeds to increase gradually as a greater length of the acceleration lane was used before entering the freeway.

It was shown earlier in this report, in the section on <u>Length of Acceleration Lane Used by Passenger Cars</u>, that the first 200 feet from the nose point was used by the largest percentage of ramp passenger cars. The majority of ramp passenger cars in all the ramp volume-freeway volume categories, which entered the freeway between stations 0 + 00 and 2 + 00, did so at speeds between twenty-five and thirty-two mph. The few passenger cars that entered the freeway between stations 2 + 00 and 3 + 00 entered at speeds averaging only two to three mph higher.

It is of significance also to compare the speeds of ramp passenger cars at time of freeway entry with speeds of vehicles in the outer lane of the

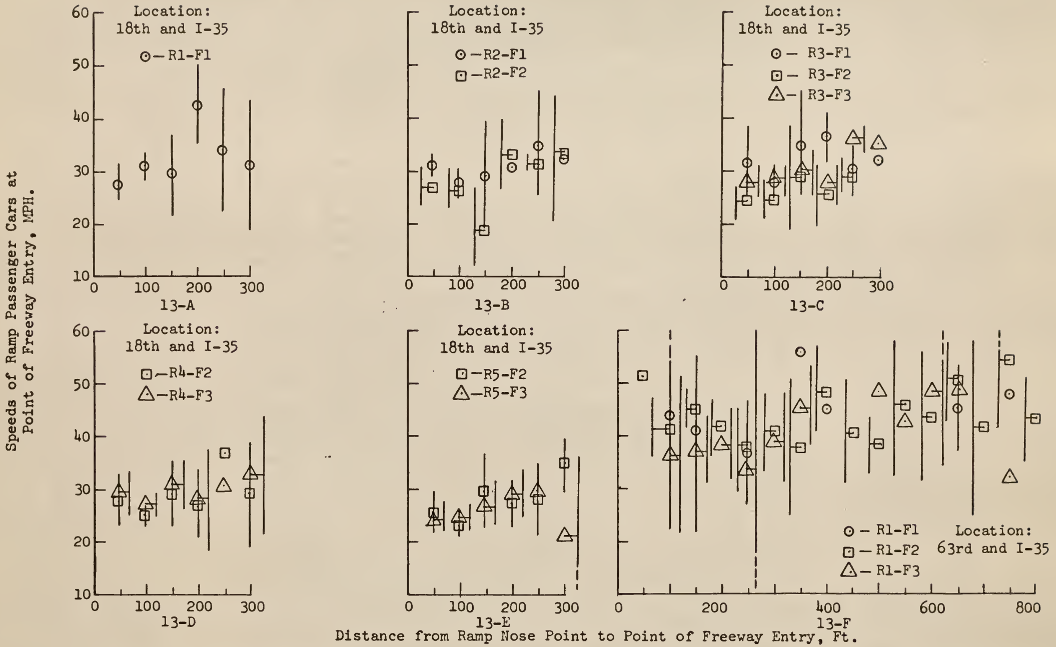

Figure 13. Average entering speed $\overline{S}$ and $\overline{S} \pm 3\sigma_{\overline{S}}$ limits at point of freeway entry for each 50 ft. increment of acceleration lane for the 18th and I-35 location (13-A to 13-E) and the 63rd and I-35 location (13-F).

freeway. The points representing average freeway speeds are plotted on Figures 12-A through 12-E where a comparison with ramp passenger car speeds entering within 100 feet of the ramp nose point shows the cars entering the freeway do so at speeds which are frequently as much as fifteen mph below the speed on the outer freeway lane.

The average speeds of vehicles in each freeway lane, as presented in Table 11, show increasingly higher lane speeds from outer lane to middle lane to inner lane. While outer lane speeds tended to range between thirty-five and forty mph, middle lane speeds were more consistent and averaged approximately forty-five mph, and inner lane speeds were equally consistent at approximately fifty mph.

63rd and I-35 Location

The speed data for the 63rd and I-35 location are presented in Table 10 and in Figure 12-F. The data indicate that speeds at the point of freeway entry were ten to fifteen mph higher than similar speeds at the 18th and I-35 location. The curves indicate that the speeds of ramp passenger cars at point of freeway entry increased as the length of acceleration lane used before freeway entry increased.

Because ramp volumes were very light at this location, drivers could enter the freeway at practically any speed they desired. This is evident in the generally erratic curves plotted in Figure 12-F and from the $\bar{S} \pm 3\sigma_{\bar{s}}$ limits for $\bar{S}$ shown in Figure 13-F. These limits show that essentially there were no significant differences between average entering speeds, for a given entry point, which could be attributed to differences in ramp and freeway volumes.

Speeds of vehicles in the outside lane of the freeway and of passenger cars entering from the acceleration lane differed by as much as fifteen to twenty mph. Also, as ramp passenger cars used a greater length of the acceleration lane before entry onto the freeway, their entering speeds approached those of vehicles in the outside lane of the freeway.

Freeway Lane Distribution

During the periods when data were collected at the study sites, observations were made of the numbers of vehicles in each freeway lane as traffic approached the merging area with the acceleration lane. As ramp and freeway volumes increased, it was observed that the percentage of freeway vehicles using the center and inside lane increased considerably. Apparently anticipating the entry of acceleration lane vehicles onto the freeway, a high percentage of the vehicles in the outside lane moved to the center or inside lane prior to the nose point of the acceleration lane. Only slower moving vehicles tended to stay in the outside lane. It was concluded that freeway volumes might be relatively less important than acceleration lane volumes in determining the vehicle operational characteristics on acceleration lanes since the number of vehicles using the outside lane did not increase in equal proportion to the increased freeway volume.

In order to verify the above observations, the percentage distribution of freeway traffic volumes by lane as the traffic approached the merging area with the acceleration lane was computed for each ramp volume-freeway volume category. These data are presented in Table 12 for both study locations. Also presented in Table 12 are the equivalent freeway and outside lane volume (vehicles per hour). These data were included so that the

Table 12

Freeway Distribution by Lane at Approach to Merging Area

Ramp Volume (veh/5min)	Freeway Volume (veh/5min)	Equivalent Freeway Volume (veh/hr)	Volume Category	Outside Lane (%)	Outside Lane Volume (veh/hr)	Center Lane (%)	Inside Lane (%)
			Location: 18th and I-35				
0- 24	0- 49	336	R1-F1	40.6	136	43.4	16.0
25- 49	0- 49	464	R2-F1	25.9	120	55.1	19.0
25- 49	50- 99	762	R2-F2	21.6	165	52.0	26.4
50- 74	0- 49	528	R3-F1	31.3	165	45.5	22.7
50- 74	50- 99	1056	R3-F2	19.3	204	42.0	38.7
50- 74	100-149	1380	R3-F3	13.9	192	47.0	39.1
75- 99	50- 99	984	R4-F2	12.2	120	48.8	39.0
75- 99	100-149	1428	R4-F3	10.9	156	54.6	34.5
100-124	50- 99	1164	R5-F2	24.7	288	42.3	33.0
100-124	100-149	1380	R5-F3	18.3	253	41.7	40.0
			Location: 63rd and I-35*				
0- 24	0- 49	456	R1-F1	62.9	287		37.1
0- 24	50- 99	920	R1-F2	57.4	528		43.6
0- 24	100-149	1386	R1-F3	49.4	685		50.6

*Four lane freeway

actual outside lane volume for each ramp volume-freeway volume category could be compared.

The data which show the freeway lane distribution at the 18th and I-35 location clearly indicate that the percentage of vehicles using the outside lane decreased substantially for a constant ramp volume and increasing freeway volumes. In most of the ramp volume categories a small decrease in the percentage of vehicles using the center lane accompanied the decrease in the outside lane. The percentage of vehicles using the outside lane at the highest ramp volume-freeway volume category (R5-F3) was less than half the percentage using the lane at the lowest ramp volume-freeway volume category (R1-F1).

The equivalent vehicles per hour data for the outside freeway lane indicated the freeway volume using this lane in the highest ramp volume-freeway volume category was almost double the volume using the lane at the lowest ramp volume-freeway volume category. However, the volumes in this lane were very light in comparison to the lane capacity. As mentioned previously in the section on Study Sites, a signalized intersection was located at the beginning of westbound I-35, 1.4 miles east of the study site. The vehicles were able to disperse from platoons before they arrived at the study site, but the instantaneous merging rate at the acceleration lane was much higher than the volumes indicate. The platooning of freeway vehicles caused momentary scarcity of gaps and increased the pressure for ramp passenger vehicles to accept the first available gaps in the traffic stream.

The data which show the freeway lane distribution at the 63rd and I-35 location indicate that a much higher volume of vehicles used the outside lane when compared with the 18th and I-35 location. This was primarily due to the fact that I-35 was a four lane freeway at this location, compared to six lanes at 18th and I-35.

At the lowest freeway volume, only two thirds as many vehicles used the inside lane as used the outside lane. At the higher freeway volume, the percentage of vehicles using each lane was approximately the same. The volume using the outside lane at the higher freeway volume level was more than double the volume using the lane at the lower freeway volume level.

CONCLUSIONS

The following conclusions are based on analyses of the data collected for this study and are subject to the limitations imposed by the geometric designs of the study locations, the relatively light traffic volumes observed during the time data were being collected, and by the manner in which the measurements were made.

1. The freeway traffic volumes at both study locations were low relative to possible freeway capacity. Near capacity ramp volumes were observed for the 18th and I-35 location for only the highest ramp volume category. The volumes at the 63rd and I-35 location were especially low in comparison to possible ramp capacity.
2. Ramp and freeway volumes, at the volume levels observed, for both locations studied, had no significant influence on the location beyond the ramp nose point at which passenger cars entered the freeway from the acceleration lane.
3. The average speeds of ramp passenger cars at the point of freeway entry were not significantly influenced by the observed ramp and freeway traffic volume levels.
4. Speeds of vehicles in the outer lane of the freeway and of passenger cars entering this lane from the acceleration lane differed by as much as fifteen to twenty mph.
5. As ramp passenger cars used a greater length of the acceleration lane before entry onto the freeway, their entering speeds increased slightly but were still well below the speeds of vehicles in the outer freeway lane.

6. It was not possible to determine from the data collected whether either ramp volumes or freeway volumes were important in determining vehicle operational characteristics on acceleration lanes, since neither had a significant influence on vehicle operational characteristics at the volume levels observed.

RECOMMENDATIONS FOR FURTHER STUDY AND RESEARCH

Because the time-lapse photography method of obtaining data provides a permanent record for a detailed study and analysis, the method has numerous applications in studies similar to the present one. For example, this method can be used for obtaining the spacing (vehicle gap or headway) between vehicles in the through lanes of the freeway. These data can be used for studying the acceptance and rejection of these gaps by entering ramp vehicles. Since available gaps are dependent on the percentage of vehicles using each freeway lane, the influence of ramp and freeway volume levels on freeway lane changes prior to acceleration lanes can also be studied by the photography method. At the present time, few studies of this type have been made. If future studies are made to facilitate further comparison, it is recommended that the time-lapse photography method of obtaining data be used.

It was observed during the analysis of film for the present study that as ramp volumes increased vehicles queued behind slow moving vehicles. Impatient drivers in the queue would dart out into the freeway lanes at a reduced speed and shortly beyond the nose point of the acceleration lane. It is recommended that a study be made for various ramp and freeway volume levels to determine if the movement has an adverse effect on freeway traffic. Possibly in conjunction with the same study, a curb could then be placed between the through freeway lanes and the parallel design acceleration lane for a distance of 100 to 150 feet beyond the nose point. It is assumed that this would eliminate the darting movements and would be helpful in forcing vehicles to use a greater length of the acceleration lane and enter the freeway at a speed which coincided with that of the outer through lane traffic. An alternative to the construction of a curb would be to use traffic markings.

Another study is recommended for locations where high ramp volumes merge with low freeway volumes. By proper signing, freeway traffic in the vicinity of interchanges could be prohibited from using the outer lane. This would allow the high ramp volumes complete freedom of entry location and would eliminate the adverse effect of low entering speeds. A study of the ramp and freeway volumes levels at which such a system would cease to operate efficiently is recommended.

It is also recommended that time-lapse photography be used to study locations where traffic volumes are at, or exceed, computed capacity to determine the usefulness of the facilities at these higher traffic volumes.

Based on the experience gained from the present study, a more efficient statistical design is recommended for use in future similar studies which desire to compare the effect of different ramp and freeway volume levels on vehicle operational characteristics.

Analysis of Variance
Fixed Effects Model for a Completely
Randomized Design
3 x 3 Factorial

Ramp Volumes, R	Freeway Volumes, F		
	F1 (Low)	F2 (Medium)	F3 (High)
R1 (Low)	X	X	X
R2 (Medium)	X	X	X
R3 (High)	X	X	X

Analysis model: $Y_{ijk} = \mu + F_i + R_j + (FxR)_{ij} + O_k \text{ in}(FxR)_{ij}$

Y_{ijk}	= the measurement for the kth sample within the ith freeway volume level and the jth ramp volume level. This measurement could be either the length of freeway used before vehicle entry onto the freeway or entering speed at this location.
μ	= the grand average of all conceivable Y_{ijk} for these specific ramp volume and freeway volume levels.
F_i	= the true average effect of the ith freeway volume level relative to μ with these specific ramp volume levels.
R_j	= the true average, effect of this jth ramp volume level relative to μ with these specific freeway volume levels.
$(FxR)_{ij}$	= the potential effect of combining the ith freeway volume level with the jth ramp volume level relative to μ.
O_k in$(FxR)_{ij}$	= the error in the kth sample unit under the ith sample freeway volume level and in the jth ramp volume level.

Analysis of Variance

Effect	Degrees of Freedom
Freeway Volumes, F	2
Ramp Volumes, R	2
FxR Interaction, FxR	4
Observations within FxR, O in FxR	9(n-1)*

* n observations in each ramp volume level-freeway volume level cell.

A sufficient number of observations should be taken for each ramp volume-freeway volume cell to reduce the standard deviation to a desirable level. Each ramp volume-freeway volume cell should be based on an equal number of observations for ease in computations. The observations in any particular ramp volume-freeway volume cell should be obtained by a random sampling of vehicles from time intervals. The freeway-ramp volume levels selected for study should be as nearly equally spaced as possible and are assumed to represent the relationship that exists for all combinations of freeway and ramp volumes. The following table illustrates this point.

Ramp Volume Level	Freeway Volume Level (vehicles per lane per hour) 500	1000	1500
200	F1xR1	F2xR1	F3xR1
500	F1xR2	F2xR2	F3xR2
800	F1xR3	F2xR3	F3xR3

Within the FxR interaction cells in the above table, n observations would be taken. In order to allow detection of significant differences of a predetermined size among the means for the FxR cells for a selected level of α, n must be large enough. The probability of calling an observed difference between two FxR cell means significant when, for the universe from which the sample means came, they are not significant is called α.

The number of observations within each FxR cell may be determined for any selected value of α, desired difference = d to be declared significant, and assumed or observed value of standard deviation = σ among observations within cells.

$$n = \frac{2\,\sigma^2\, t^2_{\alpha,\nu}}{d^2}$$

ν = degrees of freedom = 2(n-1)

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Appendix A

Presentation of Ramp and Freeway Five Minute Volume Counts

For purposes of analysis, ramp and freeway passenger cars, single unit vehicles, and combination vehicles were counted and the respective volumes totaled at the end of each five minute interval. This data is presented for the 18th and I-35 location in Table 1 and the 63rd and I-35 location in Table 2.

The five minute ramp volume and accompanying freeway volumes were then identified as belonging in light ramp-light freeway, light ramp-medium freeway, etc., categories. The range of five minute ramp and freeway traffic volumes in each category, chosen primarily as a convenient way of grouping data for analysis, are shown in the section on PRESENTATION AND DISCUSSION OF DATA, Table 3.

Analyzing the data obtained by time-lapse photography was a slow and tedious process. Because a limited time was available, not all the film was analyzed. The procedure described below was followed in order that data could be obtained on the combinations of ramp-freeway volume categories selected for study.

At the 63rd and I-35 location, all of the film was analyzed because of the small number of vehicles using the acceleration lane. At the 18th and I-35 location all five minute intervals were tabled under their proper ramp volume-freeway volume category. A random sample of five minute intervals was obtained from each ramp volume grouping in such a way that enough intervals were analyzed to provide approximately the same number of vehicles in each ramp volume category. Only passenger cars were included in this analysis because of the few trucks observed and their erratic behavior. The five minute intervals selected for study in each ramp volume-freeway volume category are presented for both locations studied in Table 3.

Table 1

5 Minute Volume Counts of Passenger Cars, Single Unit Vehicles, and Combination Vehicles

Location: 18th and I-35

Time Interval (a.m.)*	Acceleration Lane				Outside Lane				Center Lane				Inside Lane				Total Freeway Volume
	Cars	S. U. Veh.	Comb. Veh.	Total	Cars	S. U. Veh.	Comb. Veh.	Total	Cars	S. U. Veh.	Comb. Veh.	Total	Cars	S. U. Veh.	Comb. Veh.	Total	
7:00-7:05	20	5	2	27	2	1	0	3	6	0	2	8	3	0	0	3	14
7:05-7:10	27	4	1	32	9	3	2	14	22	1	0	23	3	1	0	4	41
7:10-7:15	38	7	2	47	7	5	0	12	19	2	0	21	16	3	0	19	52
7:15-7:20	22	7	0	29	10	2	2	14	13	3	0	16	8	1	1	10	40
7:20-7:25	44	6	2	52	9	1	1	11	15	1	1	17	6	0	0	6	34
7:25-7:30	34	6	0	40	9	5	1	15	17	6	2	25	11	0	0	11	51
7:30-7:35	43	6	1	50	12	1	1	14	29	1	0	30	5	0	0	5	49
7:35-7:40	63	6	1	70	4	1	1	6	28	2	0	30	19	3	0	22	58
7:40-7:45	42	7	2	51	11	1	2	14	20	0	0	20	7	3	0	10	44
7:45-7:50	43	8	2	53	9	1	0	10	21	5	1	27	11	1	0	12	49
7:50-7:55	26	7	2	35	6	1	0	7	24	1	1	26	12	1	0	13	46
7:55-8:00	23	5	0	28	5	3	1	9	22	4	1	27	5	2	0	7	43
8:00-8:05	34	6	0	40	10	1	1	12	17	3	0	20	4	0	0	4	36
8:05-8:10	25	10	3	38	8	3	0	11	16	3	0	19	9	0	0	9	39
8:10-8:15	21	5	1	27	3	6	1	10	16	3	1	20	11	1	0	12	42
8:15-8:20	17	4	2	23	6	1	1	8	12	3	0	15	4	0	0	4	27
8:20-8:25	23	8	3	34	8	1	0	9	14	1	0	15	5	0	0	5	29
8:25-8:30	15	6	3	24	3	3	0	6	8	3	1	12	3	0	0	3	21
8:30-8:35	15	4	0	19	2	2	6	10	6	3	1	10	1	0	0	1	21
8:35-8:40	16	3	1	20	6	3	3	12	7	1	3	11	5	0	0	5	28
8:40-8:45	10	5	2	17	8	8	4	20	8	3	0	11	5	1	0	6	37
8:45-8:50	18	4	0	22	5	6	1	12	12	5	2	19	6	2	0	8	39
8:50-8:55	17	4	2	23	9	3	0	12	7	4	0	11	6	1	0	7	30
8:55-9:00	10	6	3	19	5	3	3	11	7	0	1	8	1	1	0	2	21

* 7:00 a.m. to 9:00 a.m.
Thursday, April 14, 1965

Table 1 (continued)

Time Interval (p.m.)*	Acceleration Lane				Outside Lane				Center Lane				Inside Lane				Total Freeway Volume
	Cars	S. U. Veh.	Comb. Veh.	Total	Cars	S. U. Veh.	Comb. Veh.	Total	Cars	S. U. Veh.	Comb. Veh.	Total	Cars	S. U. Veh.	Comb. Veh.	Total	
3:45-3:50	41	4	0	45	14	2	0	16	31	1	0	32	16	1	0	17	65
3:50-3:55	61	6	0	67	5	5	0	10	24	4	0	28	17	0	0	17	55
3:55-4:00	42	4	1	47	7	2	0	9	34	3	2	39	16	2	0	18	66
4:00-4:05	31	8	0	39	16	2	0	18	21	5	0	26	12	2	0	14	58
4:05-4:10	50	3	2	55	12	1	0	13	20	4	0	24	16	1	0	17	54
4:10-4:15	64	4	0	68	10	6	3	19	32	7	0	39	30	2	0	32	90
4:15-4:20	67	8	0	75	13	3	0	16	28	5	0	33	23	2	0	25	74
4:20-4:25	53	5	1	59	14	3	0	17	33	4	0	37	32	2	0	34	88
4:25-4:30	67	5	3	75	14	1	1	16	29	5	0	34	22	0	0	22	72
4:30-4:35	55	6	0	61	20	5	1	26	35	2	1	38	26	2	0	28	92
4:35-4:40	70	11	4	85	4	6	0	10	35	5	0	40	29	3	0	32	82
4:40-4:45	63	4	0	67	9	3	0	12	37	3	0	40	32	1	0	33	85
4:45-4:50	91	11	0	102	18	6	0	24	36	5	0	41	31	1	0	32	97
4:50-4:55	81	9	1	91	18	2	0	20	35	5	1	41	26	1	0	27	88
4:55-5:00	83	8	0	91	22	2	0	24	53	5	0	58	37	4	0	41	123
5:00-5:05	50	6	0	56	17	4	0	21	44	4	0	48	32	1	0	33	102
5:05-5:10	66	4	1	71	14	2	0	16	48	6	0	54	42	3	0	45	115
5:10-5:15	87	11	1	99	15	1	0	16	51	4	1	56	42	1	0	43	115
5:15-5:20	91	11	0	102	18	2	1	21	43	5	0	48	42	4	0	46	115
5:20-5:25	84	5	0	89	18	2	1	21	47	3	1	51	48	2	0	50	122
5:25-5:30	69	8	2	79	28	1	0	29	56	7	2	65	44	3	0	47	141
5:30-5:35	82	7	0	89	12	1	2	15	42	2	4	48	44	2	0	46	109
5:35-5:40	76	6	0	82	23	1	0	24	53	6	1	60	53	2	0	55	139
5:40-5:45	96	1	1	98	16	0	2	18	60	3	0	63	44	3	0	47	128
5:45-5:50	81	3	1	85	13	0	0	13	62	3	0	65	39	2	0	41	119
5:50-5:55	67	6	0	73	15	1	0	16	41	5	1	47	35	2	0	37	100
5:55-6:00	54	3	0	57	10	2	0	12	30	4	2	36	28	1	0	29	77
6:00-6:05	61	3	0	64	17	3	0	20	37	3	0	40	25	4	0	29	89

* 3:45 p.m. to 6:05 p.m.
Friday, April 16, 1965

Table 2

5 Minute Volume Counts of Passenger Cars, Single Unit Vehicles, and Combination Vehicles

Location: 63rd and I-35

Time Interval (a.m.)*	Acceleration Lane				Outside Lane				Inside Lane				Total Freeway Volume
	Cars	S. U. Veh.	Comb. Veh.	Total	Cars	S. U. Veh.	Comb. Veh.	Total	Cars	S. U. Veh.	Comb. Veh.	Total	
7:00-7:05	5	2	0	7	20	3	1	24	12	3	0	15	39
7:05-7:10	2	0	0	2	23	2	0	25	13	0	0	13	40
7:10-7:15	3	2	0	5	34	5	1	40	18	1	0	19	59
7:15-7:20	6	1	0	7	39	6	4	49	29	6	0	35	84
7:20-7:25	11	3	0	14	34	5	0	39	22	3	0	25	64
7:25-7:30	6	0	0	6	25	13	0	38	19	3	0	22	60
7:30-7:35	2	2	0	4	24	6	0	30	28	4	0	32	62
7:35-7:40	7	1	0	8	44	12	0	56	34	1	0	35	91
7:40-7:45	9	1	0	10	46	7	1	54	38	1	1	40	94
7:45-7:50	7	1	0	8	35	6	1	42	34	2	0	36	78
7:50-7:55	8	0	0	8	30	7	2	39	33	5	0	38	77
7:55-8:00	7	1	0	8	25	7	2	34	19	3	0	22	56
8:00-8:05	6	2	0	8	17	6	0	23	15	3	0	18	41
8:05-8:10	4	2	0	6	17	4	2	23	9	1	0	10	33

* 7:00 a.m. to 8:10 a.m.
Thursday, April 15, 1965

Table 2 (continued)

Time Interval (p.m.)*	Acceleration Lane				Outside Lane				Inside Lane				Total Freeway Volume
	Cars	S. U. Veh.	Comb. Veh.	Total	Cars	S. U. Veh.	Comb. Veh.	Total	Cars	S. U. Veh.	Comb. Veh.	Total	
4:15-4:20	4	3	0	7	40	5	2	47	37	1	1	39	86
4:20-4:25	3	1	0	4	27	8	1	36	10	3	1	14	50
4:25-4:30	2	0	0	2	43	9	1	53	63	4	0	67	120
4:30-4:35	8	1	0	9	40	6	1	47	31	1	0	32	79
4:35-4:40	5	1	0	6	42	7	3	52	47	3	0	50	102
4:40-4:45	9	3	0	12	40	8	2	50	43	3	0	46	96
4:45-4:50	6	1	1	8	49	5	2	56	46	4	1	51	107
4:50-4:55	4	1	0	5	44	8	1	53	53	7	0	60	113
4:55-5:00	7	0	0	7	52	4	1	57	53	8	0	61	118
5:00-5:05	7	1	0	8	41	12	2	55	51	5	0	56	111
5:05-5 10	4	0	1	5	46	4	1	51	41	3	1	45	96
5:10-5:15	8	2	0	10	41	7	3	51	45	2	0	47	98
5:15-5:20	6	1	0	7	64	5	3	72	60	4	0	64	136
5:20-5:25	3	0	0	3	50	7	1	58	58	1	0	59	117

* 4:15 p.m. to 5:25 p.m.
Thursday, April 15, 1965

Table 3

5 Minute Intervals Selected for Study in Each Ramp Volume-Freeway Volume Category

Location: 18th and I-35

Volume Category		5 Min. Intervals	5 Min. Volume Ramp	5 Min. Volume Freeway
R1-F1		8:15-8:20	23	27
		8:25-8:30	24	21
		8:30-8:35	19	21
		8:35-8:40	20	28
		8:40-8:45	17	37
		8:45-8:50	22	39
		8:50-8:55	23	30
		8:55-9:00	19	21
	Totals		167	224
R2-F1		7:05-7:10	32	41
		7:50-7:55	35	46
		8:20-8:25	34	29
	Totals		101	116
R2-F2		3:55-4:00	47	66
		4:00-4:05	39	58
	Totals		86	124
R3-F1		7:40-7:45	51	44
R3-F2		4:20-4:25	59	88
R3-F3		5:05-5:10	71	115
R4-F2		4:35-4:40	85	82
R4-F3		5:45-5:50	85	119
R5-F2		4:45-4:50	102	97
R5-F3		5:15-5:20	102	115

Table 3 (continued)

5 Minute Intervals Selected for Study in Each Ramp Volume-Freeway Volume Category

Location: 63rd and I-35

Volume Category	5 Min. Intervals	5 Min. Volume Ramp	5 Min. Volume Freeway
R1-F1	7:00-7:05	7	39
	7:05-7:10	2	38
	8:00-8:05	8	41
	8:05-8:10	6	33
Totals		23	151
R1-F2	7:10-7:15	5	59
	7:15-7:20	7	84
	7:20-7:25	14	64
	7:25-7:30	6	60
	7:30-7:35	4	62
	7:35-7:40	8	91
	7:40-7:45	10	94
	7:45-7:50	8	78
	7:50-7:55	8	77
	7:55-8:00	8	56
	4:15-4:20	7	86
	4:20-4:25	4	50
	4:30-4:35	9	79
	4:40-4:45	12	96
	5:05-5:10	5	96
	5:10-5:15	10	98
Totals		125	1230
R1-F3	4:25-4:30	2	120
	4:35-4:40	6	102
	4:45-4:50	8	107
	4:50-4:55	5	113
	4:55-5:00	7	118
	5:00-5:05	8	111
	5:15-5:20	7	136
	5:20-5:25	3	117
Totals		46	924

APPENDIX - B

Presentation of Ramp and Freeway Passenger Car Speed Data

Table 1

Entering Speeds, mph, of Ramp Passenger Cars and Distance from Nose Point to Point of Freeway Entry, ft., by 5 Minute Intervals

18th and I-35 Location

Entering Speed, mph.	Point of Entry, ft.
7:05 - 7:10, a.m.	
24.0	500+
24.0	500+
32.0	60
33.6	40
32.0	90
25.6	60
30.4	125
24.0	90
28.8	130
33.6	40
32.0	30
32.0	80
16.0	70
24.0	90
32.0	90
32.0	40
30.4	60
22.4	500+
24.0	60
31.7	140
38.4	230
27.2	25
32.0	30
27.2	30
44.8	320
40.0	190
7:40 - 7:45, a.m.	
22.4	40
35.2	30
25.6	70
28.8	60
30.4	55
38.4	170
32.0	260
35.2	180
7:40 - 7:45, a.m. continued	
27.2	80
35.2	270
28.8	280
28.8	70
20.8	80
32.0	40
35.2	30
28.8	80
40.0	160
32.0	105
27.2	40
32.0	210
28.0	70
35.2	20
27.2	40
31.2	170
30.4	40
24.0	90
32.0	30
35.2	60
30.4	60
33.6	70
27.2	300+
27.2	90
19.2	60
41.6	30
28.8	30
30.4	20
35.2	30
36.8	180
28.8	230
25.6	80
38.4	115
32.0	70

Table 1 (continued)

Entering Speed, mph.	Point of Entry, ft.
7:50 - 7:55, a.m.	
32.0	30
27.2	70
25.6	130
32.0	80
28.8	140
28.8	40
38.4	20
32.0	20
27.2	70
28.8	40
32.0	60
32.0	30
27.2	90
32.0	240
20.8	180
20.8	60
35.2	300+
25.6	70
36.8	40
28.8	40
27.2	300+
22.4	80
25.6	60
28.8	90
28.8	70
38.4	60
8:15 - 8:20, a.m.	
24.0	30
25.6	40
32.0	20
32.0	135
27.2	70
32.0	70
28.8	30
38.4	80
25.6	70
30.4	130
24.0	70
30.4	70
32.0	260
8:15 - 8:20, a.m. continued	
24.0	300+
34.4	70
28.8	60
32.0	400+
8:20 - 8:25, a.m.	
32.0	260
32.0	35
22.4	70
25.6	40
30.4	35
33.6	35
32.0	45
28.8	35
35.2	60
32.0	60
36.8	35
22.4	80
24.0	60
27.2	60
28.8	180
24.0	85
24.0	40
27.2	35
24.0	60
35.2	60
35.2	35
28.8	90
36.8	80
8:25 - 8:30, a.m.	
30.4	30
32.0	40
32.0	40
28.8	80
36.8	30
32.0	40
35.2	260
32.0	70

Table 1 (continued)

Entering Speed, mph.	Point of Entry, ft.
8:25 - 8:30, a.m. continued	
28.8	70
35.2	90
43.2	30
28.8	110
14.4	70
19.2	70
24.0	30
8:30 - 8:35, a.m.	
41.6	20
24.0	230
38.4	20
28.8	90
35.2	300+
22.4	30
30.4	40
32.0	30
40.0	210
40.0	180
25.6	130
30.4	90
28.8	500+
36.8	60
32.0	210
8:35 - 8:40, a.m.	
34.4	40
25.6	40
27.2	60
32.0	60
24.0	80
35.2	60
22.4	70
38.4	400+
38.4	400+
30.4	90
28.8	40
36.8	40
11.2	120
8:35 - 8:40, a.m. continued	
40.0	400+
32.0	90
36.8	40
8:40 - 8:45, a.m.	
28.8	90
25.6	60
40.0	230
28.8	500+
36.0	--
32.0	90
27.2	120
28.8	40
36.8	80
32.0	80
8:45 - 8:50, a.m.	
28.8	40
9.6	40
35.2	60
25.8	60
36.8	300+
24.0	40
28.8	70
40.0	70
25.6	60
27.2	60
33.6	40
28.8	70
32.0	70
43.2	110
32.0	70
28.8	70
35.2	60
8:50 - 8:55, a.m.	
36.8	300+
35.2	80

Table 1 (continued)

Entering Speed, mph.	Point of Entry, ft.	Entering Speed, mph.	Point of Entry, ft.
8:50 - 8:55, a.m. continued		3:55 - 4:00, p.m. continued	
33.6	40	36.8	400+
32.0	70	27.2	40
—	60	35.2	300+
36.8	70	27.2	260
30.4	80	28.8	300+
32.0	40	40.0	60
35.2	110	32.0	80
44.8	180	32.0	220
32.0	70	30.4	60
32.0	30	—	300+
44.8	85	17.6	125
28.8	80	24.0	20
20.8	40	27.2	60
32.0	70	30.4	40
		30.4	160
8:55 - 9:00, a.m.		28.8	150
		27.2	60
28.8	140	24.0	80
30.4	500+	28.8	300+
32.0	130	35.2	400+
27.2	90	38.4	170
38.4	90	30.4	70
28.8	70	25.6	60
28.8	40	22.4	300+
27.2	30	27.2	80
32.0	40	36.8	90
		24.0	35
3:55 - 4:00, p.m.		27.2	30
25.6	40	4:00 - 4:05, p.m.	
28.8	80		
30.4	80	16.0	70
32.0	40	24.0	110
22.4	80	17.6	80
22.4	30	28.8	35
25.6	300+	32.0	20
16.0	70	28.8	60
16.0	90	32.8	300+
16.0	110	30.4	210
29.6	290	20.8	40
27.2	55	32.0	300+

Table 1 (continued)

Entering Speed, mph.	Point of Entry, ft.
4:00 - 4:05, p.m. continued	
24.0	40
27.2	40
25.6	60
30.4	60
28.8	40
32.0	30
19.2	400+
32.0	220
40.0	260
27.2	60
40.0	30
25.6	40
28.8	70
35.2	180
22.4	60
28.8	70
20.8	90
20.8	30
30.4	40
20.8	40
4:20 - 4:25, p.m.	
17.6	40
25.6	110
22.4	170
30.4	220
24.0	30
28.8	70
24.0	40
28.8	500+
28.8	30
28.8	500+
32.0	500+
24.0	300+
35.2	500+
30.4	210
25.6	40
25.6	160
9.6	85
22.4	30
27.2	60
32.0	110
4:20 - 4:25, p.m. continued	
22.4	70
27.2	210
25.6	70
22.4	40
25.6	70
25.6	80
24.0	40
25.6	40
25.6	60
24.0	40
25.6	40
25.6	60
36.8	300+
19.2	40
24.0	40
24.0	90
28.8	160
27.2	20
24.0	80
32.0	300+
25.6	60
38.4	400+
30.4	40
30.4	30
25.6	60
25.6	80
25.6	500+
36.8	300+
12.8	20
28.8	400+
24.0	90
25.6	55
4:35 - 4:40, p.m.	
24.0	60
32.0	60
35.2	170
25.6	80
25.6	60
28.8	90
32.0	110
24.0	55

Table 1 (continued)

Entering Speed, mph.	Point of Entry, ft.	Entering Speed, mph.	Point of Entry, ft.
4:35 - 4:40, p.m. continued		4:35 - 4:40, p.m. continued	
32.2	160	32.0	40
22.4	180	30.4	110
19.2	70	22.4	60
19.2	140	28.8	30
20.8	40	27.2	60
24.0	170	28.8	60
38.4	110	28.8	90
27.2	40	32.0	30
32.0	300+	36.8	400+
27.2	140	32.0	300+
24.0	--	40.0	500+
24.0	60	35.2	400+
20.8	30	19.2	170
32.0	120	19.2	400+
22.4	70	24.0	90
28.8	120	19.2	90
27.2	65	24.0	60
22.4	70	27.2	170
25.6	90	30.4	40
36.8	240	25.6	40
29.6	160	25.6	60
33.6	80		
27.2	70	4:45 - 4:50, p.m.	
32.0	290		
27.2	60	24.0	90
22.4	60	27.2	40
25.6	500+	32.0	60
25.6	60	30.4	60
25.6	110	35.2	60
16.0	70	32.0	190
16.0	60	36.8	290
20.8	--	28.8	80
19.2	40	24.0	70
24.0	60	26.4	160
27.2	40	22.4	70
28.8	80	40.0	110
25.6	260	24.0	210
30.4	300+	17.6	70
32.0	30	28.3	--
28.8	90	30.4	40
36.8	40	20.8	70

Table 1 (continued)

Entering Speed, mph.	Point of Entry, ft.	Entering Speed, mph.	Point of Entry, ft.
4:45 - 4:50, p.m. continued		4:45 - 4:50, p.m. continued	
22.4	90	28.8	90
19.2	60	25.6	90
28.8	170	27.2	120
24.0	300+	30.4	110
32.0	20	40.0	30
16.0	30	35.2	40
19.2	60	28.8	90
19.2	40	16.0	80
20.8	30	25.6	500+
20.8	40	24.0	160
28.8	90	16.0	90
32.0	240	20.8	40
32.0	300+	20.8	70
20.8	180	24.0	80
19.2	40	27.2	90
24.0	40	32.0	290
19.2	30	22.4	60
20.8	60	22.4	70
25.6	60	30.4	40
20.8	60	24.0	500+
—	160	24.0	500+
20.8	40	27.2	210
24.0	70	24.0	60
12.8	70	20.8	40
17.6	90	25.6	60
24.0	140	27.2	40
28.8	160	24.0	70
27.2	30	24.0	20
32.0	30	20.8	80
—	300+	28.8	20
28.8	140	27.2	70
27.2	140		
24.0	60	5:05 - 5:10, p.m.	
24.0	70		
19.2	60	27.2	40
24.0	300+	25.6	30
19.2	300+	28.8	30
27.2	90	28.8	155
27.2	70	24.0	90
28.8	40	19.2	300+
30.4	500+	27.2	400+

Table 1 (continued)

Entering Speed, mph.	Point of Entry, ft.	Entering Speed, mph.	Point of Entry, ft.
5:05 - 5:10, p.m. continued		5:05 - 5:10, p.m. continued	
30.4	130	25.6	20
36.8	220	30.4	40
30.4	60	30.4	40
35.2	260	33.6	40
30.4	40	28.8	40
32.0	60	28.8	70
32.0	40	28.8	70
27.2	40	32.0	160
28.8	190	22.4	40
24.0	300+	28.8	70
—	400+	35.2	300+
24.0	90	24.0	400+
25.6	400+	25.1	—
25.6	190	27.2	90
32.0	400+	19.2	20
25.6	60	27.2	40
25.6	80	35.2	230
28.8	160	24.0	40
22.4	70		
24.0	400+	5:15 - 5:20, p.m.	
35.2	70		
27.2	40	22.4	60
30.4	400+	28.8	110
33.6	60	24.0	65
24.0	20	25.6	60
28.8	40	28.8	170
36.8	20	22.4	130
28.8	90	28.8	215
32.0	120	19.2	190
36.0	90	19.2	260
27.2	110	22.4	270
20.8	190	16.0	60
28.8	180	19.2	90
25.6	190	24.0	70
24.0	70	20.0	90
33.6	40	22.4	90
27.2	500+	25.6	160
24.0	70	20.8	180
32.0	500+	16.0	70
24.0	40	16.0	45

Table 1 (continued)

Entering Speed, mph.	Point of Entry, ft.	Entering Speed, mph.	Point of Entry, ft.
5:15 - 5:20, p.m. continued		5:15 - 5:20, p.m. continued	
16.0	30	40.0	500+
27.2	140	28.8	90
19.2	35	28.8	230
22.4	40	28.8	60
25.6	240	30.4	70
24.0	55	30.4	70
28.8	70	30.4	80
22.4	60	20.8	40
28.8	120	32.0	140
27.2	110	30.4	110
25.6	40	32.0	170
24.0	60	35.2	170
20.8	60	32.8	230
28.8	110	25.6	40
24.0	90	24.0	300+
24.0	90	24.0	80
22.4	40	30.4	15
27.2	170	20.8	60
28.8	170	24.0	85
20.8	30	32.0	30
20.8	500+	24.0	170
30.4	20	24.0	40
20.8	60	28.8	165
33.6	170	36.8	160
19.2	140	20.8	40
25.6	400+	34.4	40
20.8	30	25.6	30
19.2	70	28.8	25
20.8	70	28.8	70
22.4	30		
20.8	40	5:45 - 5:50, p.m.	
25.6	30		
33.6	400+	36.8	140
24.0	80	32.8	70
27.2	130	33.6	40
25.6	45	28.8	90
28.8	30	30.4	60
30.4	40	32.0	400+
28.8	45	27.2	90
27.2	30	35.2	60
30.4	60	40.0	260

Table 1 (continued)

Entering Speed, mph.	Point of Entry, ft.	Entering Speed, mph.	Point of Entry, ft.
5:45 - 5:50, p.m. continued		5:45 - 5:50, p.m. continued	
39.4	140	27.2	60
22.4	90	30.4	80
11.2	80	33.6	45
25.6	30	30.4	110
30.4	70	28.8	30
27.2	70	28.8	120
28.8	45	30.4	400+
32.0	120	30.4	300+
33.6	60	30.4	60
28.8	70	28.8	300+
27.2	40	28.8	290
22.4	40	30.4	130
28.8	70	24.0	70
28.8	260	20.8	60
28.8	--	20.8	80
32.0	80	33.6	30
32.0	170	24.0	60
30.4	60	22.4	60
25.6	40	24.0	40
27.2	190	--	190
36.8	40	24.0	110
27.2	80	24.0	90
32.0	60	30.4	220
40.0	60	27.2	70
27.2	60	25.6	80
19.2	190	25.6	80
22.4	70	30.4	80
19.2	80	30.4	55
20.8	90	25.6	60
25.6	80	27.2	70
32.0	80		
--	300+		
27.2	90		
28.8	90		
36.8	160		
24.0	90		
24.0	60		
22.4	60		
33.6	400+		
22.4	65		
24.0	190		

Table 2

Entering Speeds, mph, of Ramp Passenger Cars and Distance from Nose Point to Point of Freeway Entry, ft., by 5 Minute Intervals

63rd and I-35 Location

Entering Speed, mph.	Point of Entry, ft.
7:00 - 7:05, a.m.	
41.6	200
41.6	650
51.2	625
36.8	75
40.0	650
7:05 - 7:10, a.m.	
56.0	350
43.2	150
7:10 - 7:15, a.m.	
40.0	100
38.4	525
40.0	325
7:15 - 7:20, a.m.	
51.2	40
60.8	710
46.4	340
43.2	450
43.2	210
33.6	260
7:20 - 7:25, a.m.	
41.6	70
40.0	790
51.2	130
48.0	390
36.8	485
41.6	770
44.8	640
48.6	780
56.0	385
36.8	340
43.2	110
7:25 - 7:30, a.m.	
43.2	130
41.6	295
51.2	670
46.4	460
40.0	420
49.6	130
7:30 - 7:35, a.m.	
36.8	240
41.6	60
7:35 - 7:40, a.m.	
48.0	165
43.2	130
32.0	265
57.6	540
52.8	295
32.0	240
33.6	280
7:40 - 7:45, a.m.	
43.2	310
38.4	160
33.6	490
41.6	160
54.4	620
35.2	490
52.8	290
44.8	429
54.4	60
7:45 - 7:50, a.m.	
44.8	800
41.6	135
44.8	440

Table 2 (continued)

Entering Speed, mph.	Point of Entry, ft.
7:45 - 7:50, a.m. continued	
57.6	710
51.2	380
35.2	410
36.8	480
7:50 - 7:55, a.m.	
48.0	170
46.4	365
54.4	610
36.8	130
56.1	800
48.0	240
40.0	180
44.8	730
7:55 - 8:00, a.m.	
51.2	590
44.8	95
40.0	210
43.2	110
28.8	220
32.0	245
46.4	90
8:00 - 8:05, a.m.	
48.0	710
33.6	205
40.0	220
32.0	140
48.0	145
8:05 - 8:10, a.m.	
48.0	610
51.2	70
44.8	370
4:15 - 4:20, p.m.	
35.2	460
48.0	440
48.0	420
32.0	110
4:20 - 4:25, p.m.	
40.0	435
38.4	580
22.4	330
4:25 - 4:30, p.m.	
49.6	620
19.2	90
4:30 - 4:35, p.m.	
46.4	140
40.0	100
46.4	95
41.6	680
41.6	580
40.0	100
46.4	135
38.4	300
4:35 - 4:40, p.m.	
27.2	270
35.2	135
41.6	590
43.2	510
40.0	90
4:40 - 4:45, p.m.	
43.2	310
40.0	100
36.8	270

Table 2 (continued)

Entering Speed, mph.	Point of Entry, ft.	Entering Speed, mph.	Point of Entry, ft.
4:40 - 4:45, p.m. continued		5:05 - 5:10, p.m.	
35.2	290	44.8	110
40.0	290	32.0	660
35.2	290	43.2	490
25.6	440	40.0	180
38.4	170		
44.8	540	5:10 - 5:15, p.m.	
4:45 - 4:50, p.m.		35.2	160
		48.0	620
		35.2	80
44.8	80	32.0	660
30.4	130	25.6	90
32.0	115	54.4	270
33.6	160	41.6	380
38.4	120	41.6	80
38.4	280	41.6	550
4:50 - 4:55, p.m.		5:15 - 5:20, p.m.	
43.2	120	43.2	265
46.4	580	57.6	560
49.6	160	32.0	470
46.4	260	41.6	110
		28.8	90
4:55 - 5:00, p.m.		28.8	190
48.0	470	5:20 - 5:25, p.m.	
41.6	440		
16.0	210	33.6	170
40.0	260	48.0	340
35.2	130	35.2	230
49.6	135		
44.8	160		
5:00 - 5:05, p.m.			
32.0	720		
46.4	80		
43.2	260		
41.6	90		
48.0	290		

Table 3

Individual Speeds of Passenger Cars in Each Freeway Traffic Lane, by 5 Minute Intervals

18th and I-35 Location

Speed		
Outside Lane	Center Lane	Inside Lane
7:05 - 7:10, a.m.		
44.8	51.2	56.0
46.4	40.0	48.0
43.2	64.0	51.2
38.4	62.4	59.2
44.8	56.0	
42.4	56.0	
41.6	22.4	
41.6	57.6	
24.8	49.6	
	48.0	
	57.6	
	48.0	
	44.8	
	44.8	
	41.6	
	49.6	
	52.8	
	52.8	
	48.0	
	44.8	
	40.8	
7:40 - 7:45, a.m.		
44.8	44.8	60.8
43.2	45.6	49.6
35.2	44.8	60.8
67.2	43.2	52.8
46.4	46.4	57.6
46.4	44.8	56.0
32.0	48.0	54.4
38.4	48.0	48.0
44.8	44.0	
46.4	43.2	
48.0	48.0	
35.2	56.0	
7:40 - 7:45, a.m. continued		
	48.0	
	48.0	
	51.2	
	46.4	
	44.8	
	51.2	
7:50 - 7:55, a.m.		
44.8	48.0	48.0
40.0	49.6	59.2
36.0	40.0	40.0
39.2	48.0	52.8
48.0	48.0	48.0
49.6	43.2	49.6
	48.0	56.0
	51.2	28.8
	48.0	70.4
	52.8	
	44.8	
	43.2	
	48.0	
	54.4	
	51.2	
	54.4	
	46.4	
	54.4	
	49.6	
	41.6	
	36.0	
	41.6	
	43.2	

Table 3 (continued)

Speed		
Outside Lane	Center Lane	Inside Lane
	<u>8:15 - 8:20</u>, a.m.	
40.0	40.0	56.0
36.0	54.4	49.6
48.0	57.6	67.2
38.4	43.2	
45.6	41.6	
	51.2	
	49.6	
	40.0	
	48.0	
	44.8	
	40.8	
	48.0	
	<u>8:20 - 8:25</u>, a.m.	
44.8	56.0	
51.2	52.8	
46.4	65.6	
49.6	52.8	
52.8	41.6	
36.8	36.8	
	52.8	
	36.8	
	37.6	
	56.0	
	48.0	
	43.2	
	44.8	
	48.0	
	<u>8:25 - 8:30</u>, a.m.	
44.0	56.0	52.8
28.0	52.8	32.0
	51.2	60.8
	38.4	
	32.0	
	56.0	
	70.4	

Speed		
Outside Lane	Center Lane	Inside Lane
	<u>8:30 - 8:35</u>, a.m.	
45.6	51.2	
52.8	48.0	
	46.4	
	48.0	
	56.0	
	<u>8:35 - 8:40</u>, a.m.	
42.4	64.0	44.8
47.2	54.4	
56.0	51.2	
48.0	49.6	
54.4	57.6	
44.0	48.0	
64.0		
	<u>8:40 - 8:45</u>, a.m.	
36.0	52.8	62.4
24.0	51.2	70.4
38.4	41.6	
36.0	46.4	
40.8	40.0	
41.6	57.6	
48.0	49.6	
	60.8	
	56.0	
	57.6	
	<u>8:45 - 8:50</u>, a.m.	
48.0	64.0	48.0
46.4	41.6	60.8
41.6	64.0	38.4
40.0	59.2	64.0
52.8	56.0	
48.0	60.8	
	41.6	
	44.8	

Table 3 (continued)

	Speed	
Outside Lane	Center Lane	Inside Lane
	8:50 - 8:55, a.m.	
40.0	48.0	60.8
41.6	59.2	32.0
62.4	32.0	
36.0		
40.8		
	8:55 - 9:00, a.m.	
57.6	56.0	41.6
27.2	52.8	44.8
64.0	36.8	
	48.0	
	50.4	
	52.8	
	3:55 - 4:00, p.m.	
36.8	38.4	49.6
40.0	40.0	44.8
37.6	44.0	41.6
32.0	48.0	44.8
39.2	35.2	64.0
39.2	27.2	51.2
39.4	48.0	54.4
	44.8	46.4
	57.6	59.2
	51.2	49.6
	51.2	51.2
	52.8	54.4
	50.4	49.6
	51.2	
	52.8	
	43.2	
	44.8	
	44.8	
	44.8	
	48.0	
	38.4	
	41.6	
	45.6	
	48.0	
	46.4	
	51.2	

	Speed	
Outside Lane	Center Lane	Inside Lane
	3:55 - 4:00, p.m. continued	
	44.0	
	42.4	
	40.0	
	43.2	
	4:00 - 4:05, p.m.	
48.0	49.6	46.4
40.0	41.6	64.0
33.6	48.0	59.2
28.8	54.4	51.2
46.4	27.2	52.8
48.0	46.4	54.4
40.0	44.8	52.8
39.2	44.8	52.8
40.0	56.0	57.6
59.2	44.0	45.6
40.0	46.4	42.4
43.2	41.6	43.2
41.6	51.2	
24.8	28.8	
32.0	44.8	
	44.8	
	44.8	
	48.0	
	44.0	
	36.0	
	4:20 - 4:25, p.m.	
44.8	34.4	44.8
34.4	42.4	34.4
37.6	48.0	49.6
37.6	48.8	52.8
33.6	41.6	51.2
38.4	44.8	59.2
32.0	46.4	48.0
32.0	36.8	51.2
32.8	56.0	51.2
35.2	48.0	48.0
48.0	48.0	48.0
38.4	54.4	30.4

Table 3 (continued)

	Speed	
Outside Lane	Center Lane	Inside Lane
	4:20 - 4:25, p.m. continued	
42.4	35.2	56.0
32.0	41.6	44.8
	44.8	56.0
	46.4	48.0
	43.2	40.0
	42.4	48.0
	40.0	48.0
	54.4	48.0
	44.8	46.4
	40.0	60.8
	48.0	44.0
	37.6	40.0
	54.4	48.0
	52.8	42.4
	44.6	34.4
	44.8	36.8
	43.2	52.8
	32.0	46.4
		45.6
		43.2
	4:35 - 4:40, p.m.	
30.4	56.0	32.0
36.8	33.6	48.0
36.0	41.6	52.8
34.4	44.8	51.2
	48.0	64.0
	48.0	51.2
	41.6	38.4
	44.8	54.4
	48.0	56.0
	48.0	56.0
	48.0	52.8
	44.8	56.0
	48.0	57.6
	40.0	56.0
	41.6	49.6
	44.8	48.8
	49.6	49.6
	60.8	46.4

	Speed	
Outside Lane	Center Lane	Inside Lane
	4:35 - 4:40, p.m. continued	
	52.8	40.0
	40.0	51.2
	42.4	35.2
	44.0	46.4
	51.2	54.4
	46.4	48.0
	44.8	46.4
	48.0	49.6
	32.0	52.8
	44.0	56.0
	48.0	44.8
	46.4	46.4
	52.8	59.2
	52.8	
	4:45 - 4:50, p.m.	
30.4	35.2	37.6
36.8	28.8	52.8
37.6	40.0	49.6
32.0	44.8	49.6
32.0	51.2	52.8
41.6	56.0	48.0
36.0	51.2	57.6
33.6	43.2	52.8
44.8	64.0	57.6
37.6	54.4	36.8
32.0	49.6	43.2
41.6	36.8	49.6
36.8	42.4	49.6
34.4	43.2	48.0
32.0	51.2	44.8
32.0	48.0	48.0
33.6	43.2	46.4
41.6	44.8	44.8
44.8	38.4	51.2
	35.2	47.2
	40.0	54.4
	48.0	57.6
	48.0	54.4
	49.6	52.8

Table 3 (continued)

Speed Outside Lane	Speed Center Lane	Speed Inside Lane
4:45 - 4:50, p.m. continued		
	54.4	51.2
	52.8	56.0
	51.2	48.0
	48.0	57.6
	59.2	59.2
	40.0	49.6
	44.8	
	59.2	
	41.6	
5:05 - 5:10, p.m.		
24.0	24.0	34.4
29.6	48.0	56.0
36.0	41.6	44.0
48.0	51.2	49.6
35.2	43.2	49.6
43.2	44.0	57.6
29.6	40.0	52.8
33.6	44.8	44.8
46.4	39.2	54.4
36.8	43.2	46.4
48.0	52.8	59.2
38.2	40.0	56.0
36.0	49.6	30.4
	41.6	46.4
	51.2	44.8
	62.4	40.0
	54.4	64.0
	48.0	57.6
	40.0	54.4
	46.4	60.8
	57.6	56.0
	48.0	62.4
	49.6	54.4
	54.4	51.2
	44.8	52.8
	46.4	51.2
	46.4	51.2

Speed Outside Lane	Speed Center Lane	Speed Inside Lane
5:05 - 5:10, p.m. continued		
	46.4	56.0
	56.0	51.2
	48.0	64.0
	40.0	45.6
	40.0	48.8
	41.6	48.0
	43.2	51.2
	46.4	57.6
	36.8	52.8
	46.4	52.8
	40.0	46.4
	46.4	49.6
	48.0	49.6
	52.8	41.6
	36.8	
	42.4	
	44.8	
	46.4	
	46.4	
5:15 - 5:20, p.m.		
24.0	51.2	48.0
25.6	48.0	56.0
28.0	56.0	43.2
35.2	43.2	51.2
33.6	59.2	56.0
30.4	48.0	44.0
43.2	56.0	44.8
48.0	52.8	48.0
28.0	33.6	48.0
44.8	40.8	44.8
40.0	43.2	40.0
21.6	40.0	51.2
36.0	36.8	54.4
36.0	56.0	57.6
32.0	38.4	60.8
36.0	43.2	51.2
	36.8	49.6

Table 3 (continued)

	Speed			Speed	
Outside Lane	Center Lane	Inside Lane	Outside Lane	Center Lane	Inside Lane
5:15 - 5:20, p.m. continued			5:45 - 5:50, p.m. continued		
	39.2	64.0	35.2	44.8	49.6
	43.2	48.0	28.0	52.8	51.2
	52.8	59.2	34.4	49.6	59.2
	47.2	56.0		40.0	64.0
	60.8	43.2		44.8	57.6
	52.8	60.8		43.2	54.4
	48.0	67.2		38.4	59.2
	54.4	64.0		56.0	51.2
	60.8	64.0		46.4	51.2
	51.2	48.0		48.0	49.6
	54.4	52.8		59.2	57.6
	56.0	54.4		48.8	54.4
	52.8	51.2		67.2	49.6
	49.6	64.0		49.6	48.0
	48.0	52.8		52.8	52.8
	38.4	64.0		51.2	54.4
	48.0	52.8		44.8	41.6
	38.4	64.0		51.2	52.8
	65.6	56.0		51.2	47.2
	59.2	54.4		44.8	56.0
	43.2	46.4		48.0	60.8
	54.4	43.2		38.4	49.6
	48.0	59.2		43.2	49.6
	28.8	54.4		44.8	40.8
	34.4	52.8		43.2	43.2
	36.0			36.8	40.8
	51.2			48.0	46.4
				43.2	46.4
5:45 - 5:50, p.m.				42.4	
				56.0	
44.0	54.4	62.4		59.2	
46.4	64.0	52.8		52.8	
51.2	49.6	57.6		48.0	
42.4	56.0	51.2		44.8	
35.2	52.8	52.8		56.0	
35.2	51.2	49.6		48.0	
34.4	51.2	49.6		49.6	
32.8	49.6	48.0		40.0	
59.2	48.0	48.0		51.2	

Table 3 (continued)

Speed		
Outside Lane	Center Lane	Inside Lane
	5:45 - 5:50, p.m. continued	
	40.0	
	36.8	
	40.0	
	40.0	
	48.0	
	43.2	
	43.2	
	46.4	
	56.0	
	52.8	

Table 4

Individual Speeds of Passenger Cars in Each Freeway Traffic Lane, by 5 Minute Intervals

63rd and I-35 Location

Speed: Outside Lane	Speed: Inside Lane
7:00 - 7:05, a.m.	
67.2	67.2
49.9	56.8
59.6	69.4
56.8	73.6
52.8	64.0
48.0	71.2
61.4	60.3
65.1	63.0
59.8	75.8
67.2	75.2
50.7	54.0
56.4	69.4
42.0	
60.8	
59.2	
63.5	
54.8	
68.3	
51.2	
7:05 - 7:10, a.m.	
63.6	72.0
67.8	65.6
65.1	69.4
52.8	49.3
79.2	53.4
59.2	58.7
68.3	64.6
43.5	80.0
34.6	60.0
54.0	69.4
45.4	78.9
56.0	68.8
64.8	65.6
63.0	69.4
7:05 - 7:10, a.m. continued	
56.4	
44.8	
84.3	
52.8	
60.0	
7:10 - 7:15, a.m.	
63.0	74.2
51.2	80.1
57.1	68.8
61.2	73.6
61.6	67.2
63.6	66.7
61.5	69.4
65.6	65.6
57.6	72.0
68.8	64.0
65.6	66.2
59.6	75.2
51.7	55.0
54.0	71.0
64.6	68.8
58.2	63.5
65.1	
69.9	
65.6	
50.8	
72.0	
64.0	
41.6	
48.0	
67.2	
47.6	
53.2	
7:10 - 7:15, a.m. continued	
54.0	
50.8	
48.6	
50.4	
58.8	
68.8	
63.6	
56.4	
7:15 - 7:20, a.m.	
49.9	50.8
56.0	61.9
49.9	74.4
48.0	67.2
40.6	62.4
53.2	56.6
57.2	56.0
45.8	55.2
46.7	71.5
47.7	72.6
48.0	55.2
48.8	71.5
53.6	56.0
45.6	64.0
49.2	65.2
54.4	65.6
57.2	58.7
57.2	69.4
67.8	68.3
42.2	71.0
66.4	72.0
58.4	56.2
57.6	61.2
71.0	65.1

Table 4 (continued)

Speed		Speed		Speed	
Outside Lane	Inside Lane	Outside Lane	Inside Lane	Outside Lane	Inside Lane
7:15 - 7:20, a.m. continued		7:20 - 7:25, a.m. continued		7:30 - 7:35, a.m. continued	
39.2	53.9	70.4		64.0	65.6
46.0	64.6	67.8		58.7	67.8
41.6	73.6	63.0		42.2	67.2
48.0	63.0	72.6		44.0	64.0
54.8	76.8	46.7		49.2	65.1
63.0	59.2	72.0		52.5	76.0
59.2	69.4	55.2		65.6	76.0
63.5	55.6	64.6		41.6	64.6
55.5		65.6		37.8	66.2
57.1		49.1		73.6	58.2
53.6		53.2		50.6	69.6
48.4				72.0	63.0
55.5		7:25 - 7:30, a.m.		54.4	65.6
47.2				48.4	50.4
		57.1	57.2	44.1	64.0
7:20 - 7:25, a.m.		44.4	60.3	68.3	71.0
		62.0	76.8	50.0	64.0
49.6	81.6	60.8	64.6	57.2	67.8
50.4	68.3	82.7	70.4	56.0	74.2
64.8	58.2	52.8	54.4	47.2	64.6
65.6	64.8	52.0	67.4	58.0	71.5
65.1	66.2	66.7	59.2	51.2	63.0
62.4	67.8	60.0	64.6	50.4	66.7
56.0	61.2	58.8	66.2	51.6	
63.2	76.8	57.6	68.9	51.6	
49.2	63.0	52.4	63.0	58.0	
62.4	68.8	55.6	67.8		
55.2	63.5	56.0	67.8	7:35 - 7:40, a.m.	
63.0	56.8	37.8	72.0		
71.2	70.4	47.2	61.2	49.9	61.9
65.1	69.4	52.8	64.0	55.6	63.0
47.6	71.5	49.0	64.6	61.9	58.7
56.0	75.2	58.7	62.4	48.0	59.8
46.0	64.0	45.6	48.4	53.3	50.0
64.8	71.2	49.2		54.4	69.4
64.0	70.4	60.8		49.2	65.1
53.6	59.6	51.6		47.2	68.8
59.6	66.7			63.2	68.8
57.6		7:30 - 7:35, a.m.		46.8	46.4
49.6				57.1	80.0
60.8		40.3	64.6	58.1	70.4
58.7		55.6	73.6	50.1	61.6

Table 4 (continued)

Speed		Speed		Speed	
Outside Lane	Inside Lane	Outside Lane	Inside Lane	Outside Lane	Inside Lane
7:35 - 7:40, a.m. continued		7:40 - 7:45, a.m. continued		7:45 - 7:50, a.m.	
				47.6	56.8
43.8	65.6	48.0	64.6	61.6	64.6
33.9	52.4	49.2	54.8	53.4	66.7
30.7	54.8	50.4	56.6	68.8	62.4
34.6	59.2	42.8	59.8	65.6	68.3
63.5	48.8	49.6	64.6	54.4	65.1
48.0	68.5	65.1	52.8	63.5	66.2
56.6	58.8	47.2	53.6	63.2	80.0
48.0	74.2	47.2	61.9	52.3	59.2
48.8	62.4	49.2	72.0	55.5	61.9
54.4	64.0	40.3	68.8	50.8	59.8
57.6	56.8	40.8	55.5	69.4	60.8
41.0	63.0	42.7	61.4	72.6	58.4
54.8	63.0	51.2	59.8	60.8	74.2
48.4	71.5	50.0	67.2	48.6	68.8
49.6	66.7	46.8	65.1	56.0	58.8
59.2	64.6	50.8	65.1	52.4	65.1
58.8	65.1	61.2	61.9	65.1	64.0
58.4	68.3	55.6	67.8	44.4	54.4
52.0	61.9	50.4	64.6	40.0	73.6
54.4	59.6	57.2	57.6	45.8	68.3
43.5	75.2	48.5	64.0	54.4	62.0
33.6	68.3	46.4	63.5	50.0	60.3
52.0	69.4	67.8	64.0	51.6	68.8
56.0		46.8	68.8	61.2	63.5
50.8		46.4	68.8	49.6	65.1
54.4		70.4	69.4	44.5	60.3
56.6		56.4	58.4	57.6	76.8
58.4		42.9	58.4	64.0	
		39.5	66.4	65.1	
7:40 - 7:45, a.m.		42.7	79.5	58.7	
		51.6	67.2	60.8	
60.8	69.9	49.6		54.4	
59.8	67.8	75.8		62.4	
60.3	61.9	37.8		45.1	
46.0	67.8	43.6		44.0	
57.6	69.4	61.6		63.5	
46.0	63.0	61.4		54.8	
46.7	68.8	66.2		57.0	
59.2	70.4			60.8	
				64.4	

Table 4 (continued)

Speed		Speed		Speed	
Outside Lane	Inside Lane	Outside Lane	Inside Lane	Outside Lane	Inside Lane
7:50 - 7:55, a.m.		7:55 - 8:00, a.m.		8:00 - 8:05, a.m. continued	
65.1	66.7	54.4	65.1		
71.0	71.0	48.4	65.6	60.3	65.6
65.1	74.2	51.7	67.2	54.0	72.0
65.1	63.5	59.2	58.7	59.2	72.0
61.2	69.6	52.8	60.8	76.3	59.8
46.4	77.6	54.4	64.8	56.8	65.6
35.2	65.6	66.7	60.8	42.2	65.6
43.5	57.6	60.0	54.4	51.2	67.2
45.1	77.4	58.0	48.8	58.7	68.8
55.6	63.0	45.6	61.2	59.2	72.6
61.9	74.7	57.6	58.7	58.7	70.4
58.2	69.4	57.6	61.4	67.8	81.1
55.5	61.9	52.8	71.0	55.2	71.5
67.2	65.6	37.1	70.4		
47.2	63.0	65.6	54.4	8:05 - 8:10, a.m.	
52.4	68.3	63.0	63.6		
57.6	65.6	61.4	65.2	54.0	70.4
61.6	65.6	62.4	67.8	60.8	67.2
45.1	58.2	53.6	73.6	49.0	64.6
70.4	81.1	51.6		58.2	70.4
64.0	74.7	58.2		68.8	72.6
30.7	67.2	62.4		70.4	79.5
56.0	57.6	62.4		44.2	73.1
45.2	62.4	65.6		62.4	66.2
61.4	62.4	50.8		66.2	54.4
59.8	66.7			64.6	
46.0	58.2	8:00 - 8:05, a.m.		60.3	
60.3	60.3			56.6	
52.8	61.9	53.6	61.9	66.7	
56.0	59.8	59.8	66.2	63.2	
72.0	59.8	41.0	60.8	43.5	
73.1	59.8	61.9	54.4	50.8	
				50.4	

Table 4 (continued)

Speed		Speed		Speed	
Outside Lane	Inside Lane	Outside Lane	Inside Lane	Outside Lane	Inside Lane
4:15 - 4:20, p.m.		4:20 - 4:25, p.m.		4:25 - 4:30, p.m. continued	
64.0	71.5	48.0	67.8		
45.2	62.4	42.0	55.5	49.3	63.5
60.0	65.1	56.6	61.4	43.6	65.1
56.6	56.6	42.6	49.2	46.1	60.8
64.0	51.2	49.9	57.2	53.2	60.3
50.8	60.0	51.2	67.2	56.6	54.4
52.0	58.7	52.0	60.3	52.8	57.1
57.6	57.2	44.0	47.4	49.2	62.4
58.8	61.9	43.2	54.8	57.1	65.1
63.0	58.7	44.8	47.6	55.2	61.4
48.0	53.2	47.5	70.4	41.9	61.9
59.2	59.2	60.3		45.1	65.6
37.6	56.0	47.4		48.4	54.4
54.4	55.5	38.7		44.0	62.4
46.8	69.4	43.8		45.2	60.8
48.4	59.2	43.2		51.7	63.0
37.2	47.2	59.6		38.4	60.3
59.2	57.6	48.8		38.4	57.6
53.2	44.8	51.2		44.8	55.2
57.2	49.6	52.8		43.7	59.2
67.8	67.8	53.2		46.4	56.0
34.2	68.8	50.8		57.6	60.0
39.6	59.2	49.0		40.5	56.6
43.5	52.8	45.4		46.0	50.7
48.0	53.2	58.4		51.2	52.8
47.7	64.6			53.4	52.4
57.6	54.4	4:25 - 4:30, p.m.		59.2	50.1
68.3	56.0			62.4	48.6
62.4	61.2	46.0	66.7		45.2
62.8	63.0	37.1	64.0		44.3
53.2	60.3	47.6	61.9		45.6
44.8	61.4	47.7	55.6		43.8
50.8	73.1	66.2	71.0		53.9
42.2	64.0	50.8	63.0		53.4
48.0		45.8	74.4		58.2
57.6		50.0	60.3		58.2
48.0		48.8	62.4		58.2
52.8		48.8	64.6		60.8

Table 4 (continued)

Speed		Speed		Speed	
Outside Lane	Inside Lane	Outside Lane	Inside Lane	Outside Lane	Inside Lane
4:25 - 4:30, p.m. continued		4:30 - 4:35, p.m. continued		4:35 - 4:40, p.m. continued	
	62.4	65.6	76.3	54.0	66.2
	57.1	60.3	64.0	57.6	64.0
	60.8	55.6	69.2	55.5	56.8
	57.6	56.8	66.4	43.8	58.7
	55.5	41.6	61.4	46.4	68.3
	56.6	50.4	55.6	52.0	64.6
	58.2	54.4	56.0	57.6	62.4
	62.4	67.8	66.7	58.4	54.4
	46.4	29.6	62.4	52.4	56.0
	53.2	48.0	58.4	52.4	49.9
	56.6	39.4	64.0	54.4	49.2
	62.4	49.2	58.2	56.0	48.0
	63.5	56.0	59.8	53.2	59.2
	56.0	53.4	49.2	39.7	61.4
	60.4	52.4	61.2	52.8	60.8
	64.0	50.8	65.6	50.8	55.5
	64.0	53.2		60.8	57.6
				56.4	49.2
4:30 - 4:35, p.m.		4:35 - 4:40, p.m.		56.0	60.8
				49.6	60.8
60.0	56.0	53.9	58.7	62.0	56.8
45.6	67.2	51.7	61.9	54.0	56.6
37.8	63.0	60.0	61.4	52.8	57.1
51.2	60.3	52.4	63.5		54.0
52.0	59.8	52.0	66.4		56.0
55.2	46.4	54.4	64.0		61.4
37.6	57.2	53.6	55.5		
56.8	56.0	47.4	63.5	4:40 - 4:45, p.m.	
64.0	56.0	44.8	61.9		
43.8	56.8	45.4	63.5	54.8	59.8
38.4	59.2	53.4	61.9	46.4	60.3
43.2	60.8	58.7	66.7	47.7	70.4
54.0	64.0	45.6	56.6	58.7	53.6
57.2	64.6	46.4	57.6	56.0	35.2
56.6	55.6	54.0	62.4	41.6	62.4
48.4	58.7	66.2	63.2	68.8	69.9
57.6	60.3	50.4	60.8	52.8	57.6
55.5	44.8	49.2	59.2	53.2	66.7
74.1	68.0	54.4	57.6	52.0	61.4
49.2	63.5	57.1	65.1	54.4	63.0

Table 4 (continued)

Speed		Speed		Speed	
Outside Lane	Inside Lane	Outside Lane	Inside Lane	Outside Lane	Inside Lane
4:40 - 4:45, p.m. continued		4:45 - 4:50, p.m. continued		4:45 - 4:50, p.m. continued	
49.6	54.8	45.9	67.8	51.6	
50.0	59.2	46.4	64.6	47.0	
54.8	73.6	44.4	54.4	59.2	
59.2	61.2	47.4	62.4		
44.4	52.4	50.4	63.2	4:50 - 4:55, p.m.	
52.4	56.8	50.0	59.2		
43.5	61.4	48.0	64.0	45.6	60.8
68.3	65.1	50.8	54.0	39.7	62.4
74.7	52.8	37.1	62.4	52.3	64.6
62.4	57.6	40.3	58.2	60.3	60.8
64.6	46.4	43.8	59.8	40.3	55.5
66.7	59.2	41.9	59.2	46.4	64.0
51.2	65.1	53.2	58.2	63.0	52.0
45.3	61.4	48.0	59.8	61.6	55.2
50.0	55.5	52.4	82.2	48.8	61.6
51.2	60.8	54.0	75.8	50.8	65.6
48.8	52.0	42.2	56.4	51.6	59.2
52.0	65.1	54.8	63.5	53.3	61.9
52.8	59.8	54.8	59.8	59.8	50.4
49.1	57.9	60.8	61.9	50.8	63.0
52.0	56.4	57.6	58.2	65.1	67.2
46.8	56.6	56.0	61.4	57.6	67.8
56.0	57.6	60.8	63.5	62.0	64.6
37.8	63.0	58.2	49.2	43.2	66.2
49.9	69.4	55.2	56.8	52.4	62.4
50.4	45.1	45.6	58.4	58.2	71.0
	50.1	47.6	74.7	56.6	60.8
	56.8	58.0	64.0	52.0	63.0
	53.6	55.2	63.2	52.8	59.2
	52.0	60.8	59.2	47.4	58.7
	54.8	57.1	54.0	46.7	57.1
	56.8	39.4	57.6	48.0	55.6
		50.4	62.4	48.0	56.0
4:45 - 4:50, p.m.		50.2	63.2	49.0	56.0
		52.0	62.0	53.6	53.6
63.0	63.5	48.8	64.6	50.8	72.0
50.4	53.2	49.0	63.5	46.8	61.4
54.0	57.6	44.8		44.4	61.4
47.6	60.3	47.2		44.2	68.8
56.8	68.3	40.0		50.4	57.6
55.5	63.0	41.3		64.8	58.2

Table 4 (continued)

Speed		Speed		Speed	
Outside Lane	Inside Lane	Outside Lane	Inside Lane	Outside Lane	Inside Lane
4:50 - 4:55, p.m. continued		4:55 - 5:00, p.m. continued		5:00 - 5:05, p.m. continued	
66.2	64.6	54.4	71.0	53.6	66.4
54.4	52.4	52.4	64.0	56.8	67.2
50.1	58.2	50.8	64.0	46.1	63.0
51.2	63.0	46.4	69.9	54.4	60.8
60.3	71.0	42.6	46.8	41.3	49.6
46.7	55.0	49.2	53.6	42.7	58.7
51.7	68.3	52.0	58.0	55.5	64.6
55.0	63.5	56.0	53.2	59.8	66.2
54.0	68.3	45.9	64.6	51.7	74.2
52.0	65.6	52.4	68.9	59.6	62.4
54.4	60.3	51.2	69.4	45.6	66.7
54.4	59.8	51.2	64.0	46.7	62.4
59.8	65.1	45.4	62.4	60.3	60.3
		54.0	57.1	50.1	61.6
4:55 - 5:00, p.m.		65.1	70.4	44.8	61.4
		59.2	68.8	59.2	55.2
57.1	64.0	49.2	64.0	54.4	54.4
54.8	63.2	57.2	63.5	49.1	62.4
55.0	61.4	54.4	56.8	49.6	62.4
50.6	61.4	43.6	61.4	41.6	65.1
48.0	62.4	42.4	60.8	53.2	72.0
51.6	61.4	49.2	62.4	52.8	48.8
51.2	54.8	54.8	68.3	57.6	54.4
49.3	58.4	44.2		54.4	50.1
57.1	57.6	56.0		53.9	48.0
53.2	63.0	52.0		49.2	56.6
50.4	62.4	41.0		65.1	63.6
38.7	56.0	48.4		42.1	54.4
47.2	64.0	63.0		42.8	57.6
55.5	50.4	55.2		51.7	65.6
47.7	60.3			53.9	66.2
46.4	59.2	5:00 - 5:05, p.m.		61.9	61.4
51.2	58.7			38.4	56.0
58.8	59.2	47.6	66.2	53.6	58.2
55.5	56.0	52.4	55.5		60.0
56.0	46.9	43.6	46.1		60.3
45.4	52.8	46.8	59.8		56.6
46.4	63.0	49.1	51.6		64.0
37.6	62.0	51.2	55.2		67.8
48.6	63.0	49.2	67.2		63.0

Table 4 (continued)

Speed		Speed		Speed	
Outside Lane	Inside Lane	Outside Lane	Inside Lane	Outside Lane	Inside Lane
5:05 - 5:10, p.m.		5:10 - 5:15, p.m.		5:15 - 5:20, p.m.	
45.1	57.6	54.4	56.6	55.2	65.1
61.4	64.0	48.0	56.8	45.3	61.9
55.2	65.6	57.6	64.0	52.4	61.2
57.1	67.2	60.8	60.8	52.0	54.4
55.5	58.7	57.1	64.0	45.9	60.4
54.4	57.1	36.8	65.6	47.6	61.9
56.6	63.0	41.6	68.8	54.4	55.6
52.8	64.0	51.6	69.4	52.8	60.0
55.5	67.2	101.6	49.6	54.4	60.8
46.4	63.5	51.2	66.2	56.0	66.7
61.4	63.0	57.6	76.3	51.2	62.4
60.4	65.1	52.4	65.1	60.8	60.0
52.0	68.8	52.4	69.6	44.5	64.0
83.3	69.4	52.3	71.0	49.6	68.3
64.0	64.0	50.8	57.6	66.4	67.8
55.2	59.8	51.2	62.4	54.4	60.3
48.4	64.0	48.0	60.8	54.4	59.2
48.0	66.2	52.8	60.8	57.2	59.2
58.4	67.2	58.2	57.1	58.8	62.4
57.6	48.0	58.4	64.0	46.7	77.9
57.6	64.0	48.8	64.0	50.0	55.5
52.0	56.6	48.0	60.8	59.2	59.8
51.2	64.0	54.0	62.4	50.8	61.4
49.2	64.6	53.6	57.1	58.7	55.5
41.6	67.2	63.0	63.2	52.3	57.1
51.2	67.2	65.6	59.8	46.4	55.5
47.4	63.0	54.4	61.9	46.8	55.6
66.7	48.0	44.5	60.4	44.0	55.6
55.0	64.6	37.8	71.0	56.8	63.0
50.4	65.1	48.8	58.7	51.6	64.0
45.6	59.6	52.0	63.0	51.7	61.4
48.0	61.9	50.4	60.3	48.4	62.0
52.3	67.2	50.0	65.1	46.0	61.4
46.4	63.0	44.0	56.0	47.6	59.2
44.4	66.7	50.0	51.2	51.6	60.8
52.0	75.2	52.8	50.1	48.0	58.8
65.1	62.0	53.2	48.0	46.4	65.1
47.6	65.6	55.2	61.9	48.8	62.8
54.8	60.8	54.4	63.5	47.2	60.3
60.8	63.0	51.2	62.4	39.7	65.6
61.9	69.9	55.2	66.2	40.0	67.8
56.8		66.7	63.0	42.0	50.7
57.2		48.3	56.6		
		56.4			

Table 4 (continued)

Speed		Speed	
Outside Lane	Inside Lane	Outside Lane	Inside Lane
5:15 - 5:20, p.m. continued		5:20 - 5:25, p.m. continued	
54.4	64.0	54.4	63.0
56.4	63.0	57.1	59.2
58.2	65.1	53.9	60.0
47.6	59.8	52.0	63.5
48.8	47.2	45.6	71.0
59.2	53.6	55.5	63.0
45.6	58.0	59.6	64.6
52.0	48.0	57.6	65.6
49.2	56.8	62.8	64.0
52.0	53.6	53.9	61.4
44.5	57.2	55.2	63.0
52.8	63.5	55.5	79.0
51.7	66.2	57.2	64.0
39.5	67.2	49.2	64.0
42.2		48.8	66.2
50.4		58.8	60.3
55.0		58.0	59.8
50.4		59.2	60.8
49.2		56.0	67.8
53.4		72.0	68.8
54.8		55.6	65.6
54.4		59.8	66.2
		46.4	58.7
5:20 - 5:25, p.m.		54.4	63.0
		50.7	66.7
55.0	60.8	50.1	63.0
40.4	65.1	52.0	59.8
44.8	56.0	54.4	57.1
58.8	65.6	52.4	64.0
56.4	59.8	52.3	63.0
59.6	61.6	62.4	64.0
53.6	61.9	54.4	64.0
58.8	63.5	62.4	64.0
52.4	66.2	59.2	57.6
61.9	61.4		60.8
58.2	59.2		61.6
46.1	60.8		69.6
48.8	54.4		64.0
64.0	64.0		61.6
59.2	63.5		70.4
63.5	77.6		70.4

INTERACTION OF DRIVER BEHAVIOR; GEOMETRIC DESIGN;
AND VEHICLE MOVEMENT ON ACCELERATION LANES ON
URBAN FREEWAYS IN KANSAS

by

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ABSTRACT

The purpose of this study was to determine whether the length of acceleration lane used by ramp passenger cars when entering a freeway was affected by either ramp and freeway traffic volumes or by the geometry of the acceleration lane. The study was limited to two locations on Interstate Route 35 near Kansas City, Kansas. Data were collected for the following: the distance from ramp nose point to point of freeway entry; the speeds of ramp passenger cars when entering the freeway; the speeds of passenger cars on the freeway by freeway lane; the volume of ramp passenger cars by five-minute intervals; and, the volumes of vehicles in each freeway lane by five-minute intervals. All the data were obtained with a sixteen mm time-lapse camera and an analysis projector.

The data indicated that the freeway traffic volumes, as well as the ramp traffic volumes, were well below practical operating capacity. Neither freeway nor ramp traffic volumes had any significant effect on the length of acceleration lane used by ramp passenger cars or speeds of ramp passenger cars—for the low levels of traffic volumes observed.

The speeds of passenger cars entering the freeway were as much as fifteen to twenty mph lower than speeds of passenger cars in the outer lane of the freeway. As ramp passenger cars used a greater length of the acceleration lane before entry onto the freeway, their entering speeds increased slightly but were still well below the speeds of vehicles in the outer freeway lane.