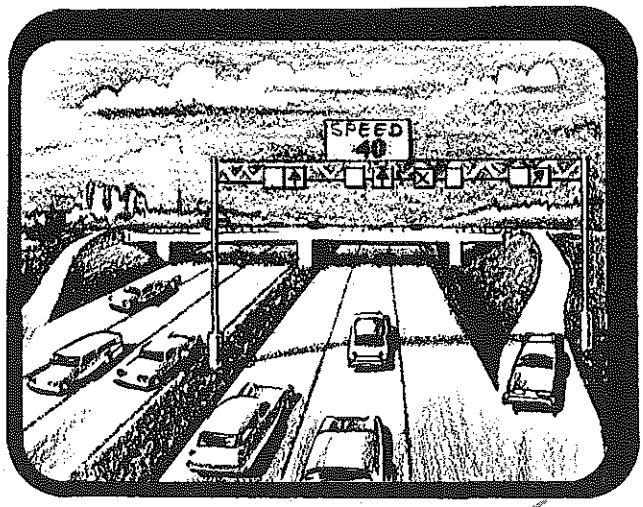
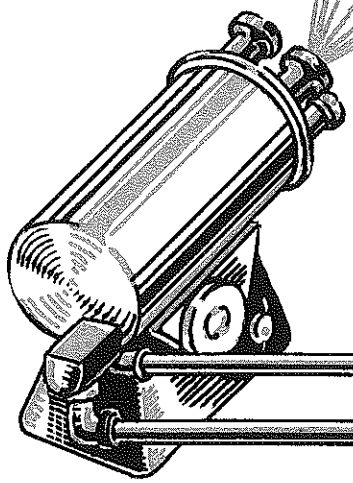
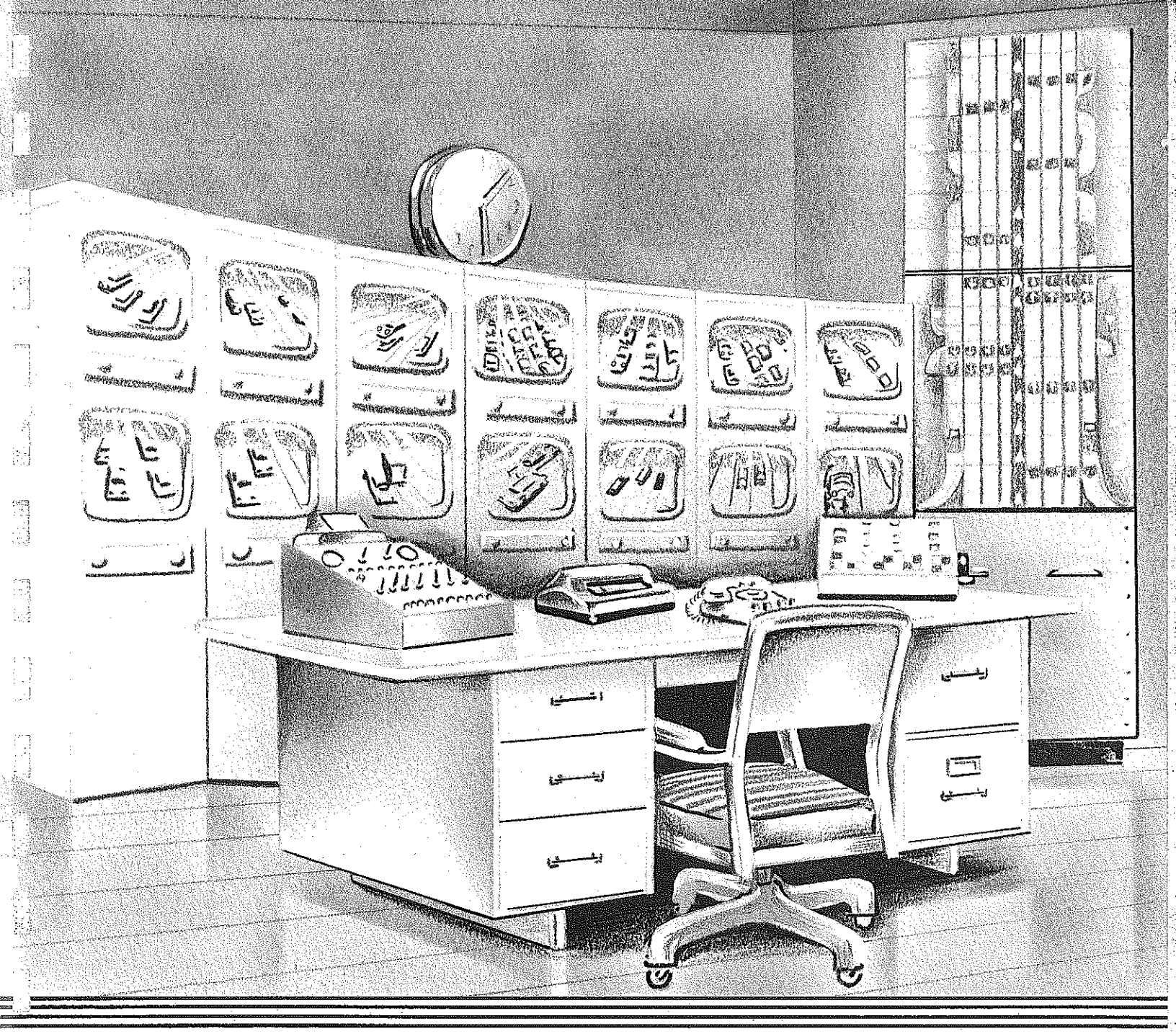
JOHN C. LODGE FREEWAY TRAFFIC SURVEILLANCE and CONTROL RESEARCH PROJECT



LANE CHANGES ON AN URBAN FREEWAY





FREEWAY SURVEILLANCE CONTROL CENTER

JOHN C. LODGE

FREEWAY TRAFFIC SURVEILLANCE AND CONTROL RESEARCH PROJECT

A Project of the
Michigan State Highway Department
Jointly With The
Wayne County Road Commission
City of Detroit, Department of Streets and Traffic
In Cooperation With the
U.S. Bureau of Public Roads

LANE CHANGES ON AN URBAN FREEWAY

A Report of the
Project Technical Committee

By

Jean W. Clinton
Wayne County Road Commission

August, 1962

FREEWAY TRAFFIC SURVEILLANCE AND CONTROL RESEARCH PROJECT

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This project consists of the establishment of a comprehensive system of surveillance and control on an urban freeway. The purposes of the project are to evaluate the use of surveillance, traffic control and sensing equipment; to investigate the characteristics of the freeway traffic flow which may be determined and treated by such equipment; to improve freeway traffic operation and safety by these means, as well as to conduct basic research into freeway operations by making use of this specialized equipment. For the first time, it has become possible to assemble the specialized equipment required to carry on a project of this scope.

The project is sponsored jointly by the Michigan State Highway Department, Wayne County Road Commission, and City of Detroit, Department of Streets and Traffic, in cooperation with the United Stated Bureau of Public Roads. The following report pertains to one of a number of individual studies to be performed. Each of the studies will be reported separately as it is completed and each will contribute to the overall objective of this study.

INDEX OF TABULATIONS AND FIGURES

FREEWAY TRAFFIC SURVEILLANCE AND CONTROL RESEARCH PROJECT

LANE CHANGES ON AN URBAN FREEWAY

Introduction

Lane change is defined as the transfer of a vehicle from one traffic lane to another traffic lane. Lane change movements are either forced or optional. Forced lane change is caused by a stopped or slower moving vehicle ahead. Other lane changes are optional.[1] The purpose of this study is to determine and analyze vehicle lane changes on an urban freeway.

The efficiency of any traffic facility, particularly a freeway, depends in part on the amount of lane changing. The proper location of entrance and exit ramps and adequate weaving distance between ramps can minimize the conflict between vehicles changing lanes on a freeway. Findings in this report should be of value in freeway traffic control operations and design of future freeways and other traffic facilities.

Study Analysis

The purpose of this study is to determine and analyze vehicle lane changes by section in the 3.2 mile length of the John C. Lodge Freeway between the Davison Freeway Interchange and the Edsel B. Ford Freeway Interchange in the City of Detroit. The John C. Lodge Freeway is an urban freeway with an ADT at the midpoint of the 3.2 mile length of 145,000 vehicles. Another study, "Freeway Volume Characteristics", will give more detailed volume information. This 3.2 mile length of the John C. Lodge Freeway has been placed under television surveillance and divided into fourteen sections which coincide with the visual areas of fourteen television cameras. The cameras were installed on bridge structures

[1]Matson, Smith and Hurd: Traffic Engineering, McGraw-Hill Book Company, Inc., New York, 1955, Pg. 136.

and connected to a central control room where traffic is observed on television monitors. Traffic is under observation by trained observers during critical periods. Present schedule is from 6:00AM to 8:00PM weekdays.

Lane changes were observed in thirteen of the fourteen camera sections on television monitors. The fourteenth camera, located at the south end of the study area immediately north of the Edsel B. Ford Freeway Interchange, is situated at a point where traffic interchanges between the two freeways and was not used in this study. Most of the camera sections for both the northbound and southbound directions were divided into two fields of observation to view adequately the section. The telephoto camera lens (designated T on Figure II) was used to view the farthest field and the regular camera lens (designated R on Figure II) was used to view the field close to the camera.

All lane changes, by type of vehicle, were observed in each field by trained observers for two 1-hour periods. Observations were made during week days for an off-peak hour and a peak hour. Morning peak hours were observed in the southbound (inbound to the central business district) direction and the afternoon peak hours were observed in the northbound (outbound from the central business district) direction. Volumes of traffic, by type of vehicle, were also viewed on the television monitors by trained observers and recorded manually for each field on a comparable week day for the same 1-hour periods

Study Analysis (Cont'd)

Although the same traffic generally uses the freeway going to and returning from work and other places, the northbound direction will be considered as a separate road from the southbound direction for analysis. The beginnings and ends of the 3.2 mile length are basically the same since right entrance and exit ramps and left entrance and exit ramps are located at the interchanges at each end. Excluding the end interchanges, the northbound roadway has four entrance ramps and five exit ramps, and the southbound roadway has five entrance ramps and four exit ramps.

The John C. Lodge Freeway is primarily a six lane freeway with three lanes in each direction. There are eight lane sections in this study area as shown on Figure 1. Shown on Camera Field Plan (Figure II) are camera locations, section designation, entrance and exit ramps, horizontal and vertical curve locations, and the portion of the freeway study area which is not visible on television monitors. The elimination of camera section 14 from this study because of traffic interchange activity and blind spots, including curve view obstructions in sections 5 and 7, reduce the visible length of the study area to 2.5 miles in the southbound direction and 2.4 miles in the northbound direction. Analysis of the study area reveals that 66% of both directions of the length of the study area is three lane, and 34% is four lane. Inasmuch as the lane changing characteristics in three lane and four lane sections vary, the three lane and four lane sections are analyzed separately. There are six types of lane changing movements possible in a three lane section and twelve types of lane changing movements possible in a four lane section.

FREEWAY TRAFFIC SURVEILLANCE AND CONTROL RESEARCH PROJECT

ON

JOHN C. LODGE FREEWAY
DETROIT, MICHIGAN

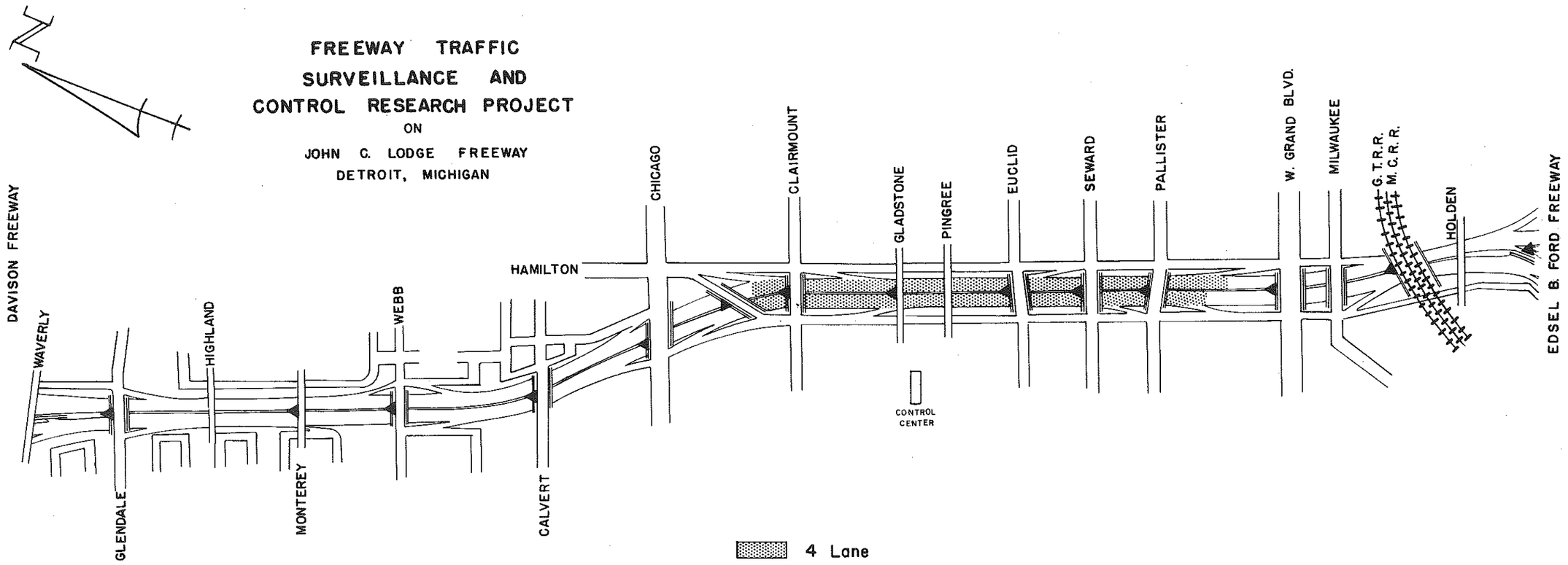


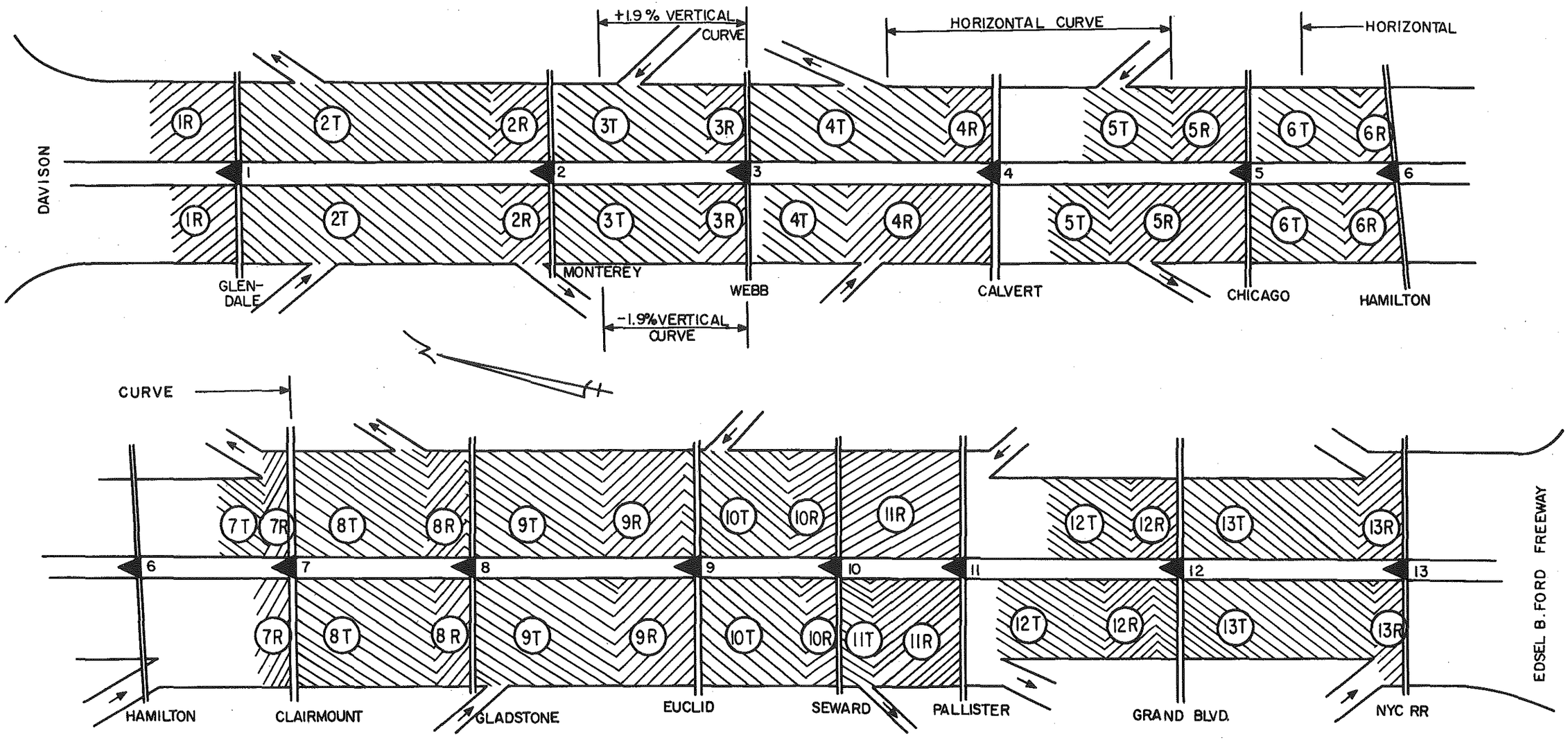
FIGURE I

FREEWAY STUDY AREA PLAN

12-18-61 B.R.

FIGURE II

CAMERA FIELD PLAN



5-15-62

Study Analysis (Cont'd)

Inasmuch as the length of roadway required for a lane change depends upon several factors, lane change movements were recorded in the field in which they were started. The length of roadway required for lane change and location of the end of the lane change was not considered in this study.

Location of the lane change movement depends in part upon the location of the directional signs. Standard Interstate System overhead white on green directional signs are provided in this study area. Three directional signs are provided for each exit ramp. At each exit ramp, two signs are provided, one sign with the ramp name and a directional slant arrow and the other sign has the name of the exit with "Next Exit" message under the name. The third sign which gives the name of next exit and "Keep Right" message under the name is provided about 1000 feet in advance of the exit. Additional ground level signs are installed at ramps. White on green "Exit" sign with slant arrow is provided at gore of exit ramps and standard black on yellow diamond warning "Merging Traffic" signs are provided at the entrance ramps.

Table I shows the number of lane changes per hour. 10, 148 total vehicles changed lanes in two one-hour periods in the southbound direction of which 54.7% changed lanes during the off-peak hour. 8.780 vehicles changed lanes in two one-hour periods in the northbound direction. There were only two northbound lane change movements more in the off-peak hour than there were in the peak hour. Table I also shows the length of the camera fields. From this information, lane changes per mile per hour are determined and shown on Table II for comparison purposes. The lane changes per mile per field will also be evaluated with respect to volume

TABLE I

NUMBER OF LANE CHANGES PER HOUR

Southbound Direction				Northbound Direction			
Camera Field	Field In Ft.	Peak Hour	Off-Peak Hour	Camera Field	Field In Ft.	Peak Hour	Off-Peak Hour
1R	400	103	243	1R	500	49	82
2T	1450	524	826	2T	1400	252	374
2R	300	153	126	2R	350	298	153
3T	915	204	273	3T	865	184	213
3R	250	52	48	3R	225	71	91
4T	500	119	154	4T	1120	221	259
4R	820	42	94	4R	300	65	131
5T	350	122	164	5T	500	71	172
5R	800	104	131	5R	425	61	93
6T	550	62	217	6T	595	40	135
6R	300	88	107	6R	200	49	77
7R*	200	216	177	7T	250	125	73
8T*	860	409	363	7R*	150	516	45
8R*	200	146	152	8T*	810	436	257
9T*	800	605	495	9R*	200	113	133
9R*	450	132	245	9T*	805	534	377
10T*	625	323	197	8R*	450	138	123
10R*	200	153	137	10T*	625	300	346
11T*	505	358	352	10R*	200	84	174
11R*	200	86	186	11R*	775	178	293
12T	500	184	255	12T	450	74	244
12R	400	92	133	12R	300	98	99
13T	1120	207	273	13T	950	166	307
13R*	200	108	208	13R*	250	266	140
One Hour Totals		4,592	5,556			4,389	4,391
Direction Totals		10,148				8,780	
Study Area Totals			18,928				

R = Near Camera Field
T = Far Camera Field
* = 4 Lane Section

LANE CHANGES PER MILE PER HOUR — TABLE II

Southbound Direction			Northbound Direction		
Camera Field	Peak Hour	Off-Peak Hour	Camera Field	Peak Hour	Off-Peak Hour
1R	1360	3215	1R	520	866
2T	1905	3010	2T	950	1410
2R	2690	2220	2R	4500	2320
3T	1180	1580	3T	1120	1300
3R	1100	1015	3R	1670	2140
4T	1255	1630	4T	1040	1240
4R	270	606	4R	1150	2310
5T	1840	2480	5T	750	1760
5R	686	868	5R	760	1160
6T	582	2085	6T	354	1200
6R	1545	1875	6R	1300	2040
7R	5700	4675	7T	2640	1540
8T	2550	2230	7R	18200	1580
8R	3855	4020	8T	2850	1660
9T	3985	3250	8R	2980	3510
9R	1550	2560	9T	3500	2480
10T	2680	1665	9R	1620	1450
10R	4040	3620	10T	2540	2930
11T	3759	3696	10R	2220	4280
11R	2270	4910	11R	1220	2000
12T	1940	2695	12T	865	2855
12R	1210	1755	12R	1730	1740
13T	976	1290	13T	925	1710
13R	2850	5500	13R	5615	2950

to determine the average number of lane changes per vehicle-mile (Table VIII).

Tables IIIA and IIIB show the lane changes by lane for southbound direction in three lane and four lane sections respectively. Tables IVA and IVB show the lane changes by lane for northbound direction in three and four lane sections respectively. Lane 1 is the lane nearest the center island. The other lanes are numbered consecutively to the shoulder. A change from lane 2 to lane 3 in three lane and four lane sections is different because a vehicle in a three lane section changing lanes from lane 2 to lane 3 would be entering the lane nearest the shoulder, which is the normal procedure for exiting traffic, whereas a vehicle in a four lane section changing lanes from lane 2 to lane 3 would not be entering the lane nearest the shoulder.

Analysis of this data reveals that 328 lane changes or 1.7% of the lane changing traffic in both directions changed more than one lane at a time. Further analysis reveals that 72% of the multiple lane changes occurred during the off-peak hour when traffic volumes are lower. Of the multiple lane changes, 31% occurred in southbound field 1R and 2T during the off-peak hour. Field 1R is located just south of the Davison Freeway. Field 2T is located just south of Field 1R. Traffic from the Glendale entrance ramp enters field 2T. Trucks account for 13 of the 24 multiple lane change vehicles in Field 1R and 26 of 79 multiple lane change vehicles in Field 2T. They enter the southbound Lodge Freeway in lane 1 from the Davison Freeway via a left entrance ramp to work their way to lane 3 to comply with the City of Detroit ordinance which

TABLE IIIA

SOUTHBOUND LANE CHANGES

IN THREE LANE SECTIONS

Peak Hour

Camera Field	Lane 1 to 2	Lane 2 and 3	Lane 3 to 2	Lane 2 to 1	Multiple Lanes
1R	42 (41)	7 (7)	42 (41)	10 (10)	2 (1)
2T	91 (17)	35 (7)	219 (42)	168 (32)	8 (2)
2R	26 (17)	31 (20)	46 (30)	48 (31)	2 (2)
3T	43 (21)	42 (21)	48 (24)	68 (33)	3 (1)
3R	17 (32)	10 (19)	9 (17)	16 (32)	0
4T	30 (25)	15 (13)	40 (34)	34 (28)	0
4R	8 (19)	5 (12)	12 (29)	17 (40)	0
5T	13 (11)	39 (32)	32 (26)	38 (31)	0
5R	30 (29)	29 (28)	27 (26)	18 (17)	0
6T	10 (16)	33 (53)	12 (19)	6 (10)	1 (2)
6R	23 (26)	28 (32)	17 (19)	20 (23)	0
12T	36 (20)	26 (14)	68 (37)	54 (29)	0
12R	20 (22)	16 (17)	29 (32)	26 (28)	1 (1)
13T	53 (26)	56 (27)	43 (21)	54 (26)	1 (-)
1-Hour Totals	442 (21.6)	372 (18.2)	644 (31.3)	577 (28)	18 (0.9)

Off-Peak Hour

Camera Field	Lane 1 to 2	Lane 2 to 3	Lane 3 to 2	Lane 2 to 1	Multiple Lanes
1R	96 (40)	26 (11)	63 (26)	34 (14)	24 (8)
2T	154 (19)	68 (8)	264 (32)	261 (32)	79 (9)
2R	18 (14)	28 (22)	43 (34)	37 (30)	0
3T	57 (21)	62 (23)	55 (20)	89 (33)	10 (3)
3R	9 (19)	11 (23)	9 (19)	19 (39)	0
4T	30 (19)	19 (12)	30 (19)	68 (44)	5 (6)
4R	23 (25)	18 (19)	19 (20)	32 (34)	2 (2)
5T	50 (30)	31 (19)	37 (23)	46 (28)	0
5R	28 (21)	34 (26)	30 (23)	39 (30)	0
6T	43 (20)	103 (47)	50 (23)	21 (10)	0
6R	24 (22)	40 (37)	20 (19)	23 (22)	0
12T	53 (21)	33 (13)	79 (31)	82 (32)	8 (3)
12R	20 (15)	21 (16)	47 (35)	45 (34)	0
13T	87 (32)	77 (28)	38 (14)	68 (25)	3 (1)
1-Hour Totals	692 (22.7)	571 (18.8)	784 (25.7)	864 (28.5)	131 (4.3)
2-Hour Totals	1134 (22.3)	943 (18.5)	1428 (28.1)	1441 (28.2)	149 (2.9)

( ) = % of total

\- = Less than 0.5%

TABLE IIIB

SOUTHBOUND LANE CHANGES

IN FOUR LANE SECTIONS

Peak Hour

Camera Field	Lane 1 to 2	Lane 2 to 3	Lane 3 to 4	Lane 4 to 3	Lane 3 to 2	Lane 2 to 1	Multiple Lanes
7R	24 (11)	73 (34)	47 (22)	35 (16)	26 (12)	8 (4)	3 (1)
8T	77 (19)	100 (24)	73 (18)	55 (13)	56 (14)	48 (12)	0
8R	16 (11)	42 (29)	23 (16)	8 (5)	24 (16)	33 (23)	0
9T	66 (11)	72 (12)	45 (7)	212 (35)	111 (18)	86 (14)	13 (2)
9R	25 (19)	25 (19)	16 (12)	20 (16)	23 (17)	23 (17)	0
10T	44 (14)	40 (12)	35 (11)	59 (18)	81 (25)	52 (16)	12 (4)
10R	24 (15)	27 (18)	18 (12)	29 (19)	26 (17)	29 (19)	0
11T	52 (14)	69 (19)	44 (12)	45 (13)	67 (19)	81 (23)	0
11R	14 (16)	21 (24)	3 (4)	13 (16)	14 (16)	21 (24)	0
13R	29 (27)	41 (39)	0	0	19 (17)	19 (17)	0
1-Hour Totals	371 (14.7)	510 (20)	304 (12)	476 (18.8)	447 (17.6)	400 (15.8)	28 (1.1)

Off-Peak Hour

Camera Field	Lane 1 to 2	Lane 2 to 3	Lane 3 to 4	Lane 4 to 3	Lane 3 to 2	Lane 2 to 1	Multiple Lanes
7R	23 (13)	57 (32)	35 (20	26 (15)	19 (11)	17 (9)	0
8T	73 (20)	135 (37)	60 (16)	17 (5)	39 (11)	37 (10)	2 (1)
8R	30 (20)	38 (25)	20 (13)	12 (8)	33 (22)	19 (12)	0
9T	66 (13)	119 (24)	80 (16)	97 (20)	52 (1)	64 (13)	18 (4)
9R	30 (12)	44 (18)	40 (16)	43 (18)	48 (20)	38 (15)	2 (1)
10T	26 (13)	39 (20)	12 (6)	18 (9)	48 (24)	47 (24)	7 (4)
10R	26 (19)	26 (19)	8 (6)	16 (12)	33 (24)	26 (19)	2 (1)
11T	56 (16)	53 (15)	45 (13)	59 (17)	61 (17)	72 (20)	6 (2)
11R	27 (14)	26 (14)	13 (7)	46 (25)	39 (21)	35 (19)	0
13R	32 (16)	42 (20	12 (6)	61 (29)	30 (14)	31 (15)	0
1-Hour Totals	389 (15.5)	579 (23)	325 (13)	395 (15.7)	402 (16)	386 (15.4)	37 (1.4)
2-Hour Totals	760 (15.1)	1089 (21.5)	629 (12.5)	871 (17.3)	849 (16.8)	786 (15.5)	65 (1.3)

TABLE IVA

NORTHBOUND LANE CHANGES

IN THREE LANE SECTIONS

Peak Hour

Camera Field	Lane 1 to 2	Lane 2 to 3	Lane 3 to 2	Lane 2 to 1	Multiple Lanes
1R	18 (37)	12 (25)	9 (18)	10 (20)	0
2T	61 (24)	100 (40)	50 (20)	41 (16)	0
2R	79 (26)	108 (36)	52 (18)	58 (20)	1 (-)
3T	65 (35)	56 (30)	32 (18)	30 (16)	1 (1)
3R	13 (18)	17 (24)	24 (34)	17 (24)	0
4T	51 (23)	115 (52)	32 (15)	22 (10)	1 (-)
4R	15 (23)	20 (31)	13 (20)	16 (25)	1 (1)
5T	18 (25)	7 (10)	26 (37)	20 (28)	0
5R	15 (25)	19 (31)	12 (19)	15 (25)	0
6T	7 (18)	10 (25)	9 (22)	14 (35)	0
6R	5 (10)	17 (14)	27 (56)	9 (18)	2 (2)
7T	9 (17)	7 (6)	79 (63)	30 (24)	0
12T	21 (28)	22 (30)	14 (19)	17 (23)	0
12R	28 (29)	14 (14)	26 (26)	28 (29)	2 (2)
13T	47 (28)	29 (17)	35 (21)	54 (33)	1 (1)
1-Hour Totals	452 (24.6)	553 (30.1)	440 (24)	381 (20.8)	9 (0.5)

Off-Peak Hour

Camera Field	Lane 1 to 2	Lane 2 to 3	Lane 3 to 2	Lane 2 to 1	Multiple Lanes
1R	19 (23)	6 (7)	16 (20)	40 (49)	1 (1)
2T	90 (24)	121 (32)	70 (19)	85 (23)	8 (2)
2R	28 (18)	49 (32)	45 (30)	31 (20)	0
3T	49 (23)	85 (40)	29 (14)	36 (17)	14 (6)
3R	15 (16)	30 (33)	16 (18)	30 (33)	0
4T	48 (19)	97 (37)	60 (23)	49 (19)	5 (2)
4R	20 (15)	34 (26)	40 (31)	37 (28)	0
5T	45 (26)	37 (22)	50 (29)	39 (23)	1 (-)
5R	21 (22)	28 (31)	23 (25)	21 (22)	0
6T	22 (16)	39 (29)	38 (29)	34 (25)	2 (2)
6R	20 (26)	14 (18)	27 (35)	16 (21)	0
7T	20 (27)	16 (22)	21 (29)	16 (22)	0
12T	48 (20)	49 (20)	65 (27)	80 (32)	2 (1)
12R	21 (21)	19 (19)	34 (35)	25 (25)	0
13T	86 (28)	79 (26)	51 (17)	90 (29)	1 (-)
1-Hour Totals	552 (22.1)	703 (28.1)	585 (23.3)	629 (25.1)	34 (1.4)
2-Hour Totals	1004 (23.1)	1256 (28.8)	1025 (23.7)	1010 (23.4)	43 (1.0)

( ) = % of total
- = Less than 0.5%

TABLE IVB

NORTHBOUND LANE CHANGES BY LANE

IN FOUR LANE SECTIONS

Peak Hour

Camera Field	Lane 1 to 2	Lane 2 to 3	Lane 3 to 4	Lane 4 to 3	Lane 3 to 2	Lane 2 to 1	Multiple Lanes
7R	0	3 (-)	0	475 (93)	34 (7)	4 (-)	0
8T	25 (6)	25 (6)	33 (8)	115 (26)	149 (34)	80 (18)	9 (2)
8R	5 (4)	7 (6)	17 (15)	29 (26)	34 (30)	21 (19)	0
9T	31 (6)	51 (10)	39 (7)	156 (29)	158 (30)	81 (15)	18 (3)
9R	7 (5)	16 (12)	14 (10)	45 (33)	34 (25)	20 (14)	2 (1)
10T	15 (5)	55 (18)	61 (20)	59 (19)	74 (25)	30 (10)	6 (3)
10R	12 (15)	16 (19)	3 (4)	10 (9)	24 (29)	19 (23)	0
11R	3 (2)	19 (11)	43 (24)	70 (39)	31 (17)	12 (7)	0
13R	58 (22)	30 (11)	7 (3)	83 (31)	55 (21)	32 (12)	1 (-)
1-Hour Totals	156 (6.2)	222 (8.6)	217 (8.5)	1042 (40.5)	593 (23.2)	299 (11.6)	36 (1.4)

Off-Peak Hour

Camera Field	Lane 1 to 2	Lane 2 to 3	Lane 3 to 4	Lane 4 to 3	Lane 3 to 2	Lane 2 to 1	Multiple Lanes
7R	19 (42)	9 (20)	0	4 (9)	10 (22)	3 (7)	0
8T	30 (12)	41 (16)	47 (18)	30 (12)	52 (20)	47 (18)	10 (4)
8R	17 (13)	17 (13)	11 (8)	16 (12)	46 (34)	26 (20)	0
9T	48 (13)	79 (21)	50 (13)	55 (14)	70 (19)	66 (17)	9 (3)
9R	28 (23)	19 (15)	10 (8)	13 (11)	29 (24)	24 (19)	0
10T	58 (17)	70 (20)	50 (14)	19 (6)	66 (19)	73 (21)	10 (3)
10R	31 (18)	30 (17)	26 (15)	20 (11)	34 (20)	33 (19)	0
11R	19 (6)	26 (9)	40 (14)	123 (42)	54 (18)	25 (9)	6 (2)
13R	36 (26)	21 (15)	0	5 (4)	41 (29)	37 (26)	0
1-Hour Totals	286 (15.1)	312 (16.5)	234 (12.4)	285 (15.1)	402 (21.2)	334 (17.7)	35 (2)
2-Hour Totals	442 (9.9)	534 (12)	451 (10.1)	1327 (29.8)	995 (22.4)	633 (14.2)	71 (1.6)

() = % of total
- = Less than 0.5%

requires that "Trucks Slow Vehicles Keep Right". On the other hand, 43 of the 79 multiple lane change vehicles in field 2T were passenger vehicles that changed from lane 3 to lane 1.

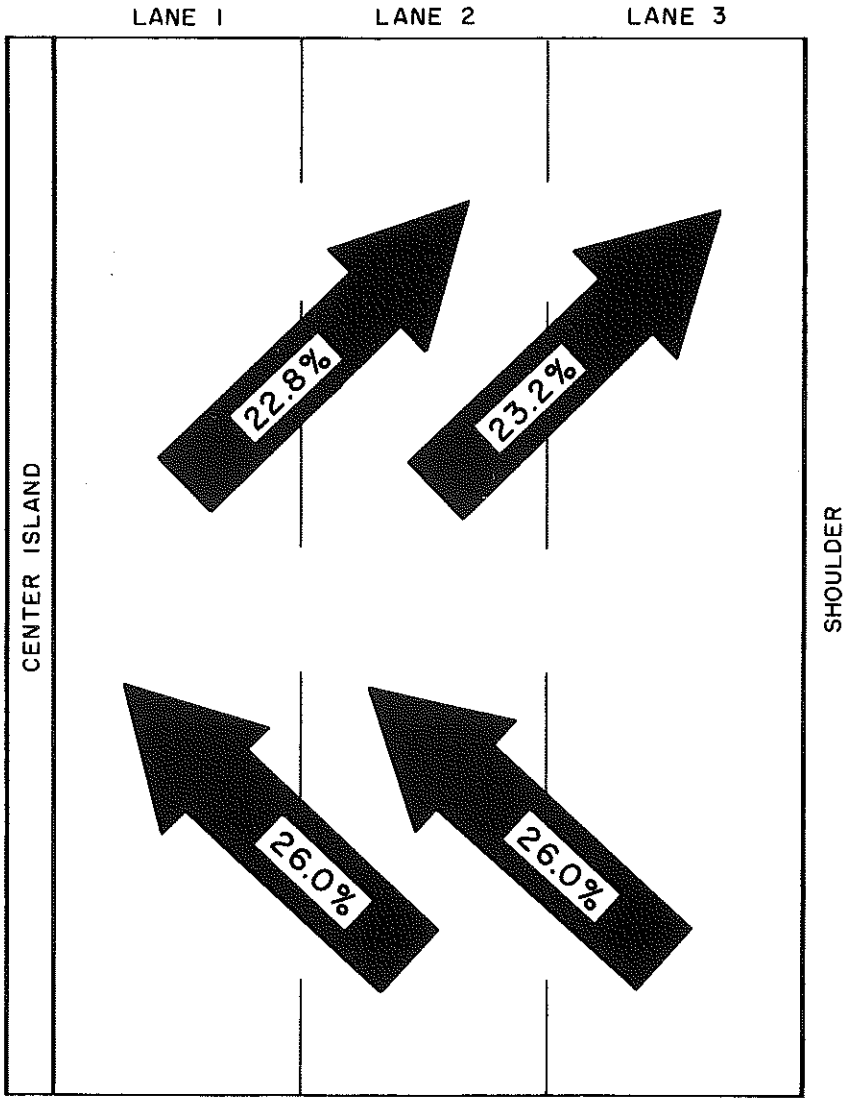
Figures IIIA and IIIB show the percent of total lane changes by lane in three lane and four lane sections respectively. Of course, all lane change traffic in the three lane sections use lane 2, while in the four lane sections 66% of lane change traffic use lane 2 and 72% of lane change traffic use lane 3.

Figure IV shows the comparison of direction of percent of lane changes by groups of sections. This reveals that 55.8% of the lane changing traffic in all groups combined changed lanes from the shoulder side toward the center island side. Since the study area is about the middle area of the Lodge Freeway, between the Central Business District and the end of the Freeway at James Couzens Highway in northwest Detroit, the heavier movement toward the center island does not appear to be significant. However, there is a decided difference in the percent of lane change traffic changing lanes from the shoulder side toward the center island side in the northbound direction during the peak hour. During the peak hour, 45% of lane change traffic in the northbound three lane sections and 77.3% of the lane change traffic in the northbound four lane sections change lanes from the shoulder side toward the center island side. This 32.3% difference may be caused in part by the fact that the four lane field are in the south half of the study area. Northbound peak traffic apparently changes lanes in the four lane field to enter the through traffic lanes.

Tables VA and VB show the total lane changes by type of vehicle for southbound and northbound directions respectively. Percent of total lane change by type of vehicle is shown in table VI where some

FIGURE III A

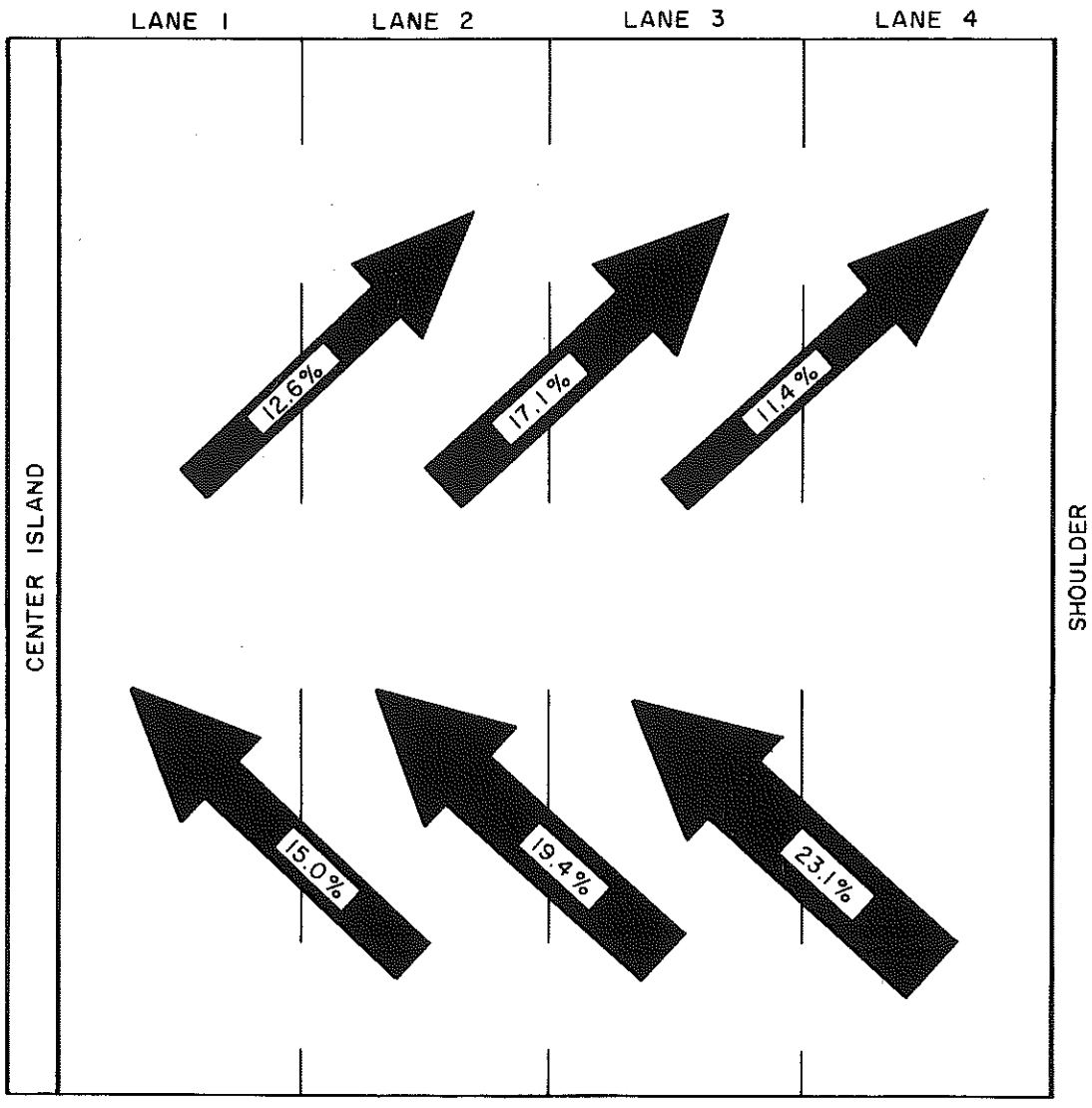
PERCENT OF TOTAL LANE CHANGES IN 3 LANE SECTIONS BY LANE



NOTE: 2% Multiple Lane Changes

FIGURE IIIB

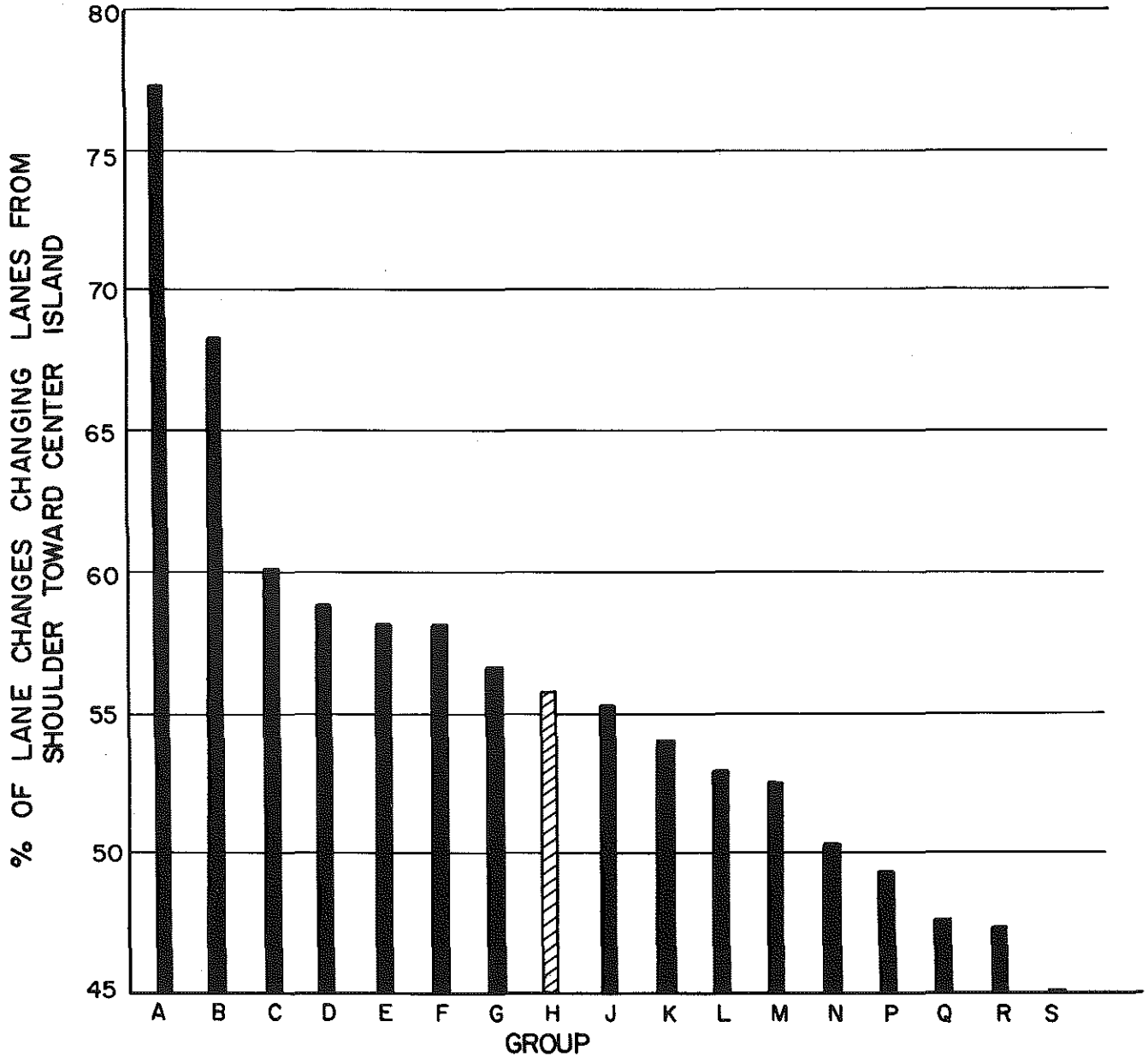
PERCENT OF TOTAL LANE CHANGES IN 4 LANE SECTIONS BY LANE



NOTE: 1.4% Multiple Lane Changes

FIGURE IV

DIRECTION OF PERCENT OF LANE CHANGES BY GROUPS OF SECTIONS



A - 4 LANE NB PEAK HOUR
B - 4 LANE NB TOTAL
C - 3 LANE SB PEAK HOUR
D - 4 LANE TOTAL
E - NB TOTAL
F - 3 LANE SB TOTAL
G - 3 LANE SB OFF PEAK HOUR
H - TOTAL STUDY AREA
J - 4 LANE NB OFF PEAK HOUR
K - SB TOTAL
L - 3 LANE TOTAL
M - 4 LANE SB PEAK HOUR
N - 4 LANE SB TOTAL
P - 3 LANE NB OFF PEAK HOUR
Q - 4 LANE SB OFF PEAK HOUR
R - 3 LANE NB TOTAL
S - 3 LANE NB PEAK HOUR

vehicle types are combined. Passenger vehicles accounted for 91.5% of the lane changes, 95% in the peak hour and 88% in the off-peak hour. Percent of total lane change by passenger vehicles is compared with percent of total volume by passenger vehicles in Figure X.

Hourly volumes of traffic by location for comparable periods of time when the lane changes were made are shown in Table VII. Daily and hourly volume variations account for the differences in volumes in sections where there appears to be no other reason, such as entrance or exit ramp, for a difference in volume. Of course, peak hour volumes are always heavier than off-peak volumes in each field, although not as heavy as might be expected. The peak hour varies from 53.7% of the two-hour volume total in southbound field 3T and 3R to 67.4% of the two-hour volume total in northbound field 2T.

Table VIII shows the number of lane changes per vehicle-mile. The number is computed by dividing the number of lane changes per mile in Table II by volume in Table VII. Except for southbound field 10T and northbound fields 2R, 7T, 7R, 8T, and 13R, the lane change rate during the off-peak hour is always higher. The off-peak hour percent of combined two hour number of lane changes per vehicle-mile is shown in Figure V. The off-peak hour percent is computed by dividing the lane change rate per off-peak hour by the combined peak and off-peak hour rates in Table VIII for each field. The average off-peak hour percent per field was 63%. Of the 48 field, 65% of the fields were within 10% $\pm$ of the average and 94% of the fields were within 20% $\pm$ of the average. Of the 29 three-lane fields, 25 fields were within 28% (off-peak %; 59% to 86%). Of the 19 four lane fields, 14 fields were within 23% (off peak %; 44% to 66%). The off-peak hour percent varies from 86% of the two-hour

TABLE VA

TOTAL SOUTHBOUND LANE CHANGES BY TYPE OF VEHICLE

Camera Field	Peak Hour (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	Off-Peak Hour (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1R	68	0	5	2	8	18	2	0	169	18	5	8	22	30	0	0
2T	444	23	24	15	10	5	3	0	671	22	22	36	44	30	1	0
2R	123	11	11	3	3	2	0	0	86	9	2	10	6	13	0	0
3T	174	10	5	7	2	5	0	1	208	16	15	9	10	15	0	0
3R	37	9	5	1	0	0	0	0	37	6	1	1	1	2	0	0
4T	96	8	9	1	3	2	0	0	117	13	6	10	5	2	1	0
4R	34	6	1	0	0	0	0	1	71	11	4	5	1	1	0	1
5T	105	9	3	2	1	2	0	0	145	5	2	4	5	3	0	0
5R	89	9	0	2	1	1	2	0	117	2	2	5	4	1	0	0
6T	50	5	3	3	0	0	1	0	159	12	17	16	6	6	1	0
6R	81	3	2	1	0	1	0	0	93	9	4	4	1	1	0	0
7R	183	22	7	1	3	0	0	0	154	10	3	5	3	2	0	0
8T	321	41	24	10	1	12	0	0	285	34	7	20	9	8	0	0
8R	114	12	11	1	0	8	0	0	132	6	2	9	2	1	0	0
9T	499	58	19	17	11	0	1	0	400	40	20	18	10	6	2	0
9R	119	4	4	2	3	0	0	0	209	13	9	8	4	2	0	0
10T	268	23	19	9	3	0	1	0	179	15	4	7	5	1	1	0
10R	94	26	14	17	0	2	0	0	121	6	1	4	1	4	0	0
11T	278	26	22	7	19	3	1	2	286	17	6	24	15	3	1	0
11R	70	5	4	3	1	2	1	0	145	9	6	11	6	9	0	0
12T	130	25	11	2	11	4	1	0	200	22	6	9	10	8	7	0
12R	75	9	4	1	1	1	1	0	113	1	4	10	3	2	0	0
13T	166	17	10	3	10	1	0	0	195	28	9	12	22	7	0	0
13R	79	15	8	3	3	0	0	0	170	10	5	12	8	3	0	0
1-Hour Totals	3697	376	225	113	94	69	14	4	4462	334	162	257	203	160	14	1

(1) = Standard passenger vehicle
(2) = Compact passenger vehicle
(3) = Small passenger vehicle
(4) = Panel and pick-up truck
(5) = Single axle truck
(6) = Combination truck
(7) = Bus
(8) = Motorcycle

TABLE VB

TOTAL NORTHBOUND LANE CHANGES BY TYPE OF VEHICLE

Camera Field	Peak Hour								Off-Peak Hour							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1R	47	0	1	1	0	0	0	0	54	14	2	5	4	1	1	1
2T	219	8	12	8	4	0	0	1	299	16	8	19	25	6	0	1
2R	266	13	11	4	3	0	1	0	128	2	8	5	9	1	0	0
3T	162	12	6	1	3	0	0	0	172	17	8	5	10	1	0	0
3R	71	0	0	0	0	0	0	0	68	6	6	5	3	3	0	0
4T	191	15	8	0	1	4	1	1	204	15	11	8	13	6	1	1
4R	63	0	1	0	1	0	0	0	95	10	5	8	5	8	0	0
5T	59	6	4	2	0	0	0	0	130	16	8	9	5	2	1	1
5R	48	8	2	2	0	0	1	0	70	2	4	6	3	8	0	0
6T	31	5	1	3	0	0	0	0	101	13	5	3	7	6	0	0
6R	45	2	1	0	0	1	0	0	58	9	5	3	1	1	0	0
7T	113	7	5	0	0	0	0	0	56	7	1	2	5	2	0	0
7R	426	43	26	7	8	1	5	0	33	3	2	3	3	1	0	0
8T	362	47	10	10	2	2	3	0	202	25	8	10	5	6	1	0
8R	94	12	4	0	3	0	0	0	104	13	4	7	3	2	0	0
9T	420	69	28	10	1	3	3	0	293	35	10	18	15	6	0	0
9R	128	3	5	2	0	0	0	0	98	8	8	5	1	3	0	0
10T	259	19	9	7	3	2	1	0	283	25	11	10	9	6	2	0
10R	81	1	0	1	1	0	0	0	147	3	3	5	6	10	2	0
11R	148	8	3	3	4	1	1	0	255	4	12	8	8	6	0	0
12T	59	8	12	3	2	2	2	0	185	22	9	12	10	6	0	0
12R	73	13	2	3	1	4	1	1	63	5	5	7	8	11	0	0
13T	146	5	3	4	5	3	0	0	202	20	5	19	38	19	4	0
13R	211	18	8	10	11	8	0	0	99	7	3	5	14	12	0	0
1-hour Totals	3769	322	162	81	53	31	19	3	3399	297	151	187	210	133	12	4

(1) = Standard passenger vehicle
(2) = Compact passenger vehicle
(3) = Small passenger vehicle
(4) = Panel and pick-up trucks
(5) = Single axle trucks
(6) = Combination trucks
(7) = Bus
(8) = Motorcycle

TABLE VI

PERCENT OF TOTAL LANE CHANGES BY TYPE OF VEHICLE

Southbound Direction

Camera Field	Peak Hour (1)	(2)	(3)	(4)	Off-Peak Hour (1)	(2)	(3)	(4)
1R	79	2	17	2	76	3	21	0
2T	94	3	3	-	87	4	9	-
2R	95	2	3	0	77	8	15	0
3T	92	4	4	-	87	3	10	0
3R	98	2	0	0	92	2	6	0
4T	94	1	5	0	87	7	5	1
4R	98	0	0	2	92	5	2	1
5T	96	2	2	0	93	2	5	0
5R	94	2	2	2	92	4	4	0
6T	94	4	0	2	87	7	6	-
6R	98	1	1	0	95	4	1	0
7R	98	-	2	0	94	3	3	0
8T	94	3	3	0	90	5	5	0
8R	94	1	5	0	92	6	2	0
9T	95	3	2	-	93	4	3	-
9R	96	2	2	0	94	3	3	0
10T	94	4	2	-	93	4	3	-
10R	88	11	1	0	93	3	4	0
11T	91	2	6	1	88	7	5	-
11R	93	3	3	1	86	6	8	0
12T	90	1	9	-	90	4	6	0
12R	96	1	2	1	89	8	3	0
13T	93	2	5	0	85	4	11	0
13R	94	3	3	0	89	6	5	0
Average % 1-Hr. Total	94	3	3	-	90	4	6	-
Average % Direction Total	92	3.5	4.5	-				
Average % Study Area Total	91.5	4.0	4.5	-				

Northbound Direction

Camera Field	Peak Hour (1)	(2)	(3)	(4)	Off-Peak Hour (1)	(2)	(3)	(4)
1R	98	2	0	0	85	6	6	3
2T	95	3	2	-	81	7	12	-
2R	98	1	1	-	90	7	3	0
3T	97	2	1	0	93	2	5	0
3R	100	0	0	0	89	5	6	0
4T	97	0	2	1	89	3	7	1
4R	98	0	2	0	84	6	10	0
5T	97	3	0	0	90	5	4	1
5R	94	4	0	2	82	6	12	0
6T	94	6	0	0	88	2	10	0
6R	98	0	2	0	92	5	3	0
7T	100	0	0	0	88	3	9	0
7R	96	1	2	1	86	6	8	0
8T	96	2	1	1	91	4	5	-
8R	97	0	3	0	91	5	4	0
9T	97	2	1	-	90	5	5	0
9R	98	2	0	0	93	4	3	0
10T	96	2	2	-	89	4	6	1
10R	98	1	1	0	88	3	9	0
11R	95	2	3	-	92	3	5	0
12T	91	4	5	0	88	5	7	0
12R	90	3	5	2	74	7	19	0
13T	93	3	4	0	74	6	19	1
13R	89	4	7	0	79	4	17	0
Average % 1-Hr. Total	96	2	2	-	86	7	7	-
Average % Direction Total	91	4.5	4.5	-				

(1) = Passenger vehicles (2)= Panel & pickup trucks (3) = Heavy trucks (4) = Miscellaneous (bus etc.)
- = Less than 0.5%

TABLE VII

HOURLY VOLUMES BY LOCATION

Southbound Direction			Northbound Direction		
Camera Field	Peak Hour	Off-Peak Hour	Camera Field	Peak Hour	Off-Peak Hour
1R	4989	3259	1R	5627	2831
2T	5018	4190	2T	5804	2810
2R	5018	3569	2R	5804	3815
3T	4974	4292	3T	5804	2996
3R	4974	4292	3R	5686	3202
4T	5099	3764	4T	5756	3202
4R	5552	4016	4R	5918	3397
5T	5552	4016	5T	5652	3321
5R	5301	3587	5R	5652	3321
6T	5301	4153	6T	5652	3321
6R	5301	4252	6R	5652	3321
7R	6938	4015	7T	5652	3910
8T	6165	4078	7R	6366	4225
8R	6222	4109	8T	5416	3967
9T	6971	4142	8R	5583	4169
9R	6293	4496	9T	5583	4169
10T	6612	4791	9R	5583	4169
10R	7006	4496	10T	4901	4183
11T	6465	3916	10R	4901	4232
11R	6465	4136	11R	4901	4183
12T	5988	4426	12T	4665	3532
12R	5988	4001	12R	4415	3144
13T	5988	3639	13T	4944	3694
13R	6439	3202	13R	5178	4076

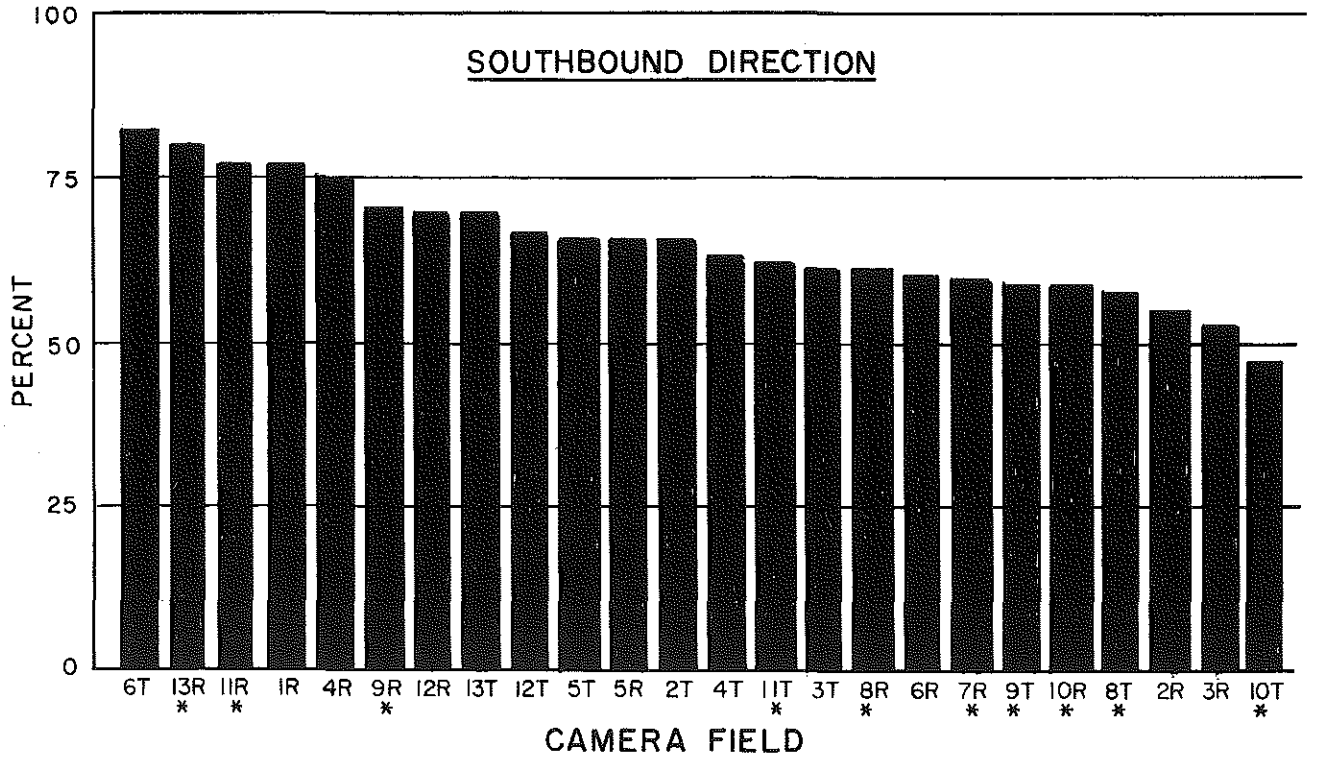
TABLE VIII

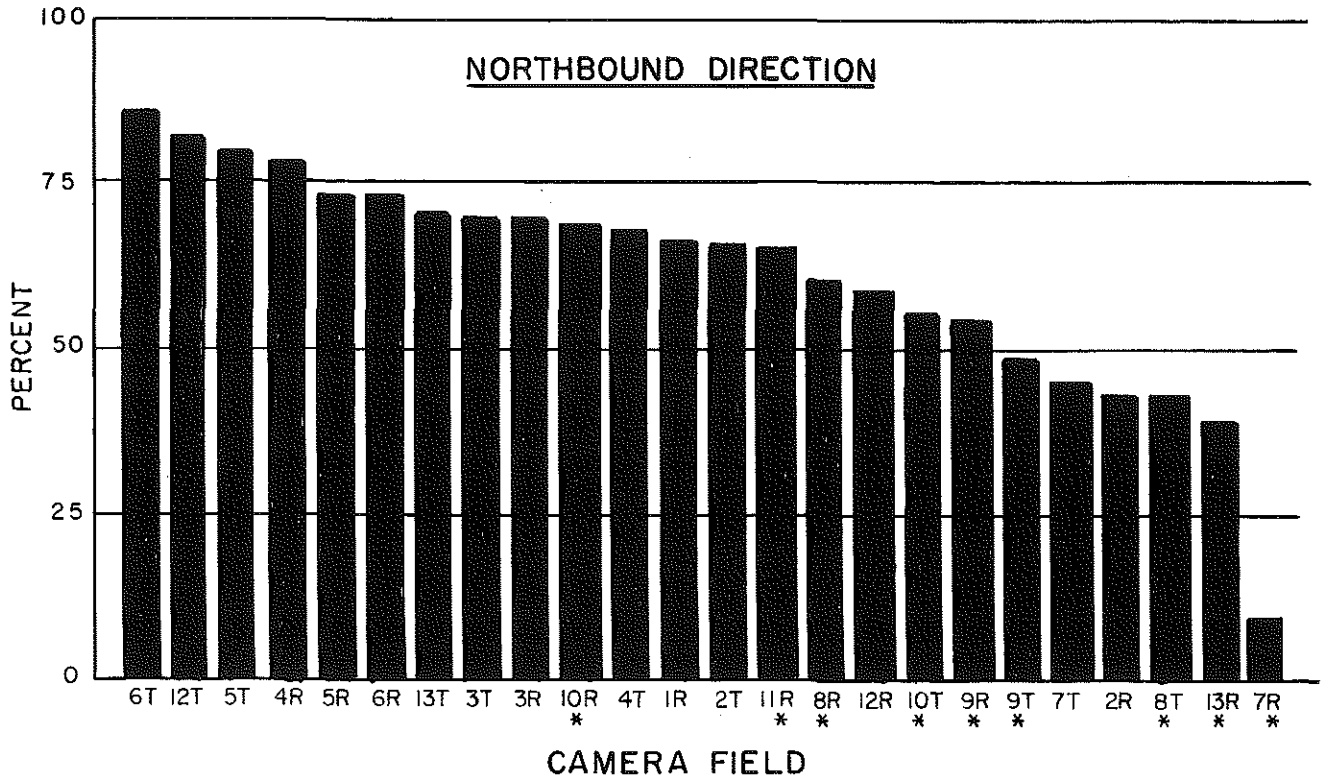
NUMBER OF LANE CHANGES PER VEHICLE-MILE

Southbound Direction			Northbound Direction		
Camera Field	Peak Hour	Off-Peak Hour	Camera Field	Peak Hour	Off-Peak Hour
1R	.27	.99	1R	.15	.31
2T	.38	.72	2T	.16	.31
2R	.54	.62	2R	.78	.61
3T	.24	.37	3T	.19	.44
3R	.22	.24	3R	.29	.67
4T	.25	.43	4T	.18	.39
4R	.05	.15	4R	.19	.68
5T	.33	.62	5T	.13	.53
5R	.13	.24	5R	.13	.35
6T	.11	.50	6T	.06	.36
6R	.29	.44	6R	.23	.62
7R	.82	1.16	7T	.47	.40
8T	.41	.55	7R	2.86	.37
8R	.62	.98	8T	.53	.42
9T	.57	.79	8R	.53	.84
9R	.25	.57	9T	.63	.60
10T	.41	.35	9R	.29	.35
10R	.58	.81	10T	.52	.70
11T	.58	.94	10R	.45	1.01
11R	.35	1.08	11R	.25	.48
12T	.32	.61	12T	.18	.81
12R	.20	.44	12R	.39	.55
13T	.16	.35	13T	.19	.46
13R	/44	1.72	13R	1.09	.72

FIGURE V

OFF-PEAK HOUR PERCENT OF COMBINED TWO HOUR NUMBER OF LANE CHANGES PER VEHICLE - MILE





combined total rates in northbound field 6T to 11% of the two hour combined total rates in northbound field 7R. The very high rate of lane change in northbound field 7R was caused primarily by the reduction of one lane at the Hamilton exit ramp. Sign changes were made at this exit after the study and an after check reveals that 403 fewer lane changes in field 7R were made in a comparable peak hour. There were 392 fewer lane changes from lane 4 to lane 3 and 12 fewer lane changes from lane 3 to lane 2. The after check increased the off-peak hour percent to 37% of the two-hour combined total rate. The sign changes that were made for the Hamilton exit consisted of adding the message "Exit Only" to the overhead signs. This sign change, however, has not completely solved the problem since traffic changing lanes from lane 4 to lane 3 (83 during peak hour after check) are illegal movements.

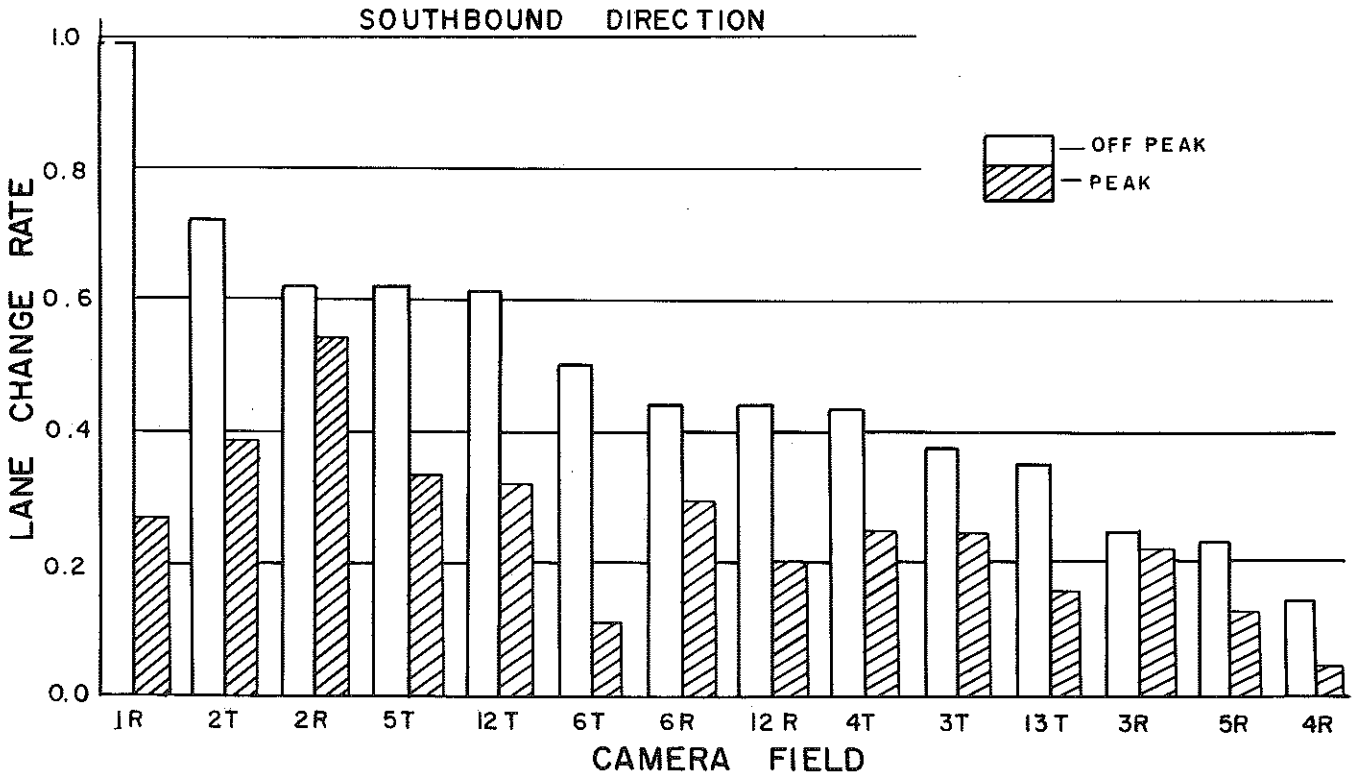
Number of lane changes per vehicle-mile in three lane sections and four lane sections are shown in Figure VI and Figure VII respectively. The lane change rates in the four lane sections are generally higher than in the three lane sections.

Figure VIII shows the number of lane changes per vehicle-mile by groups of sections. As shown the number of lane changes per vehicle-mile for the study area is .48. The four lane northbound peak hour group has the highest rate of .84 lane changes per vehicle-mile and all three lane peak hour groups have the lowest rate of .24 lane changes per vehicle mile.

Figure IX shows the comparison of combined rate of lane changes per vehicle mile for one peak and one off-peak hour with respect to entrance and exit ramps, horizontal and vertical curves, and three

FIGURE VI

NUMBER OF LANE CHANGES PER VEHICLE-MILE IN THREE LANE SECTIONS



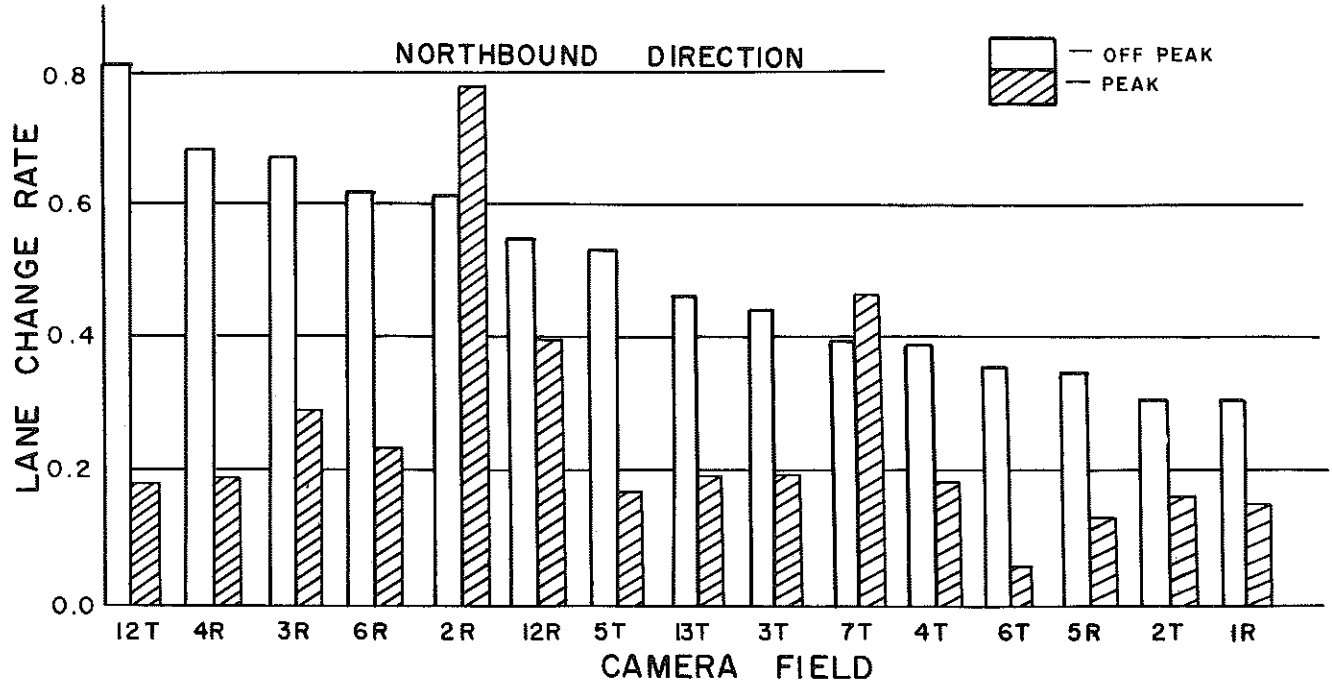
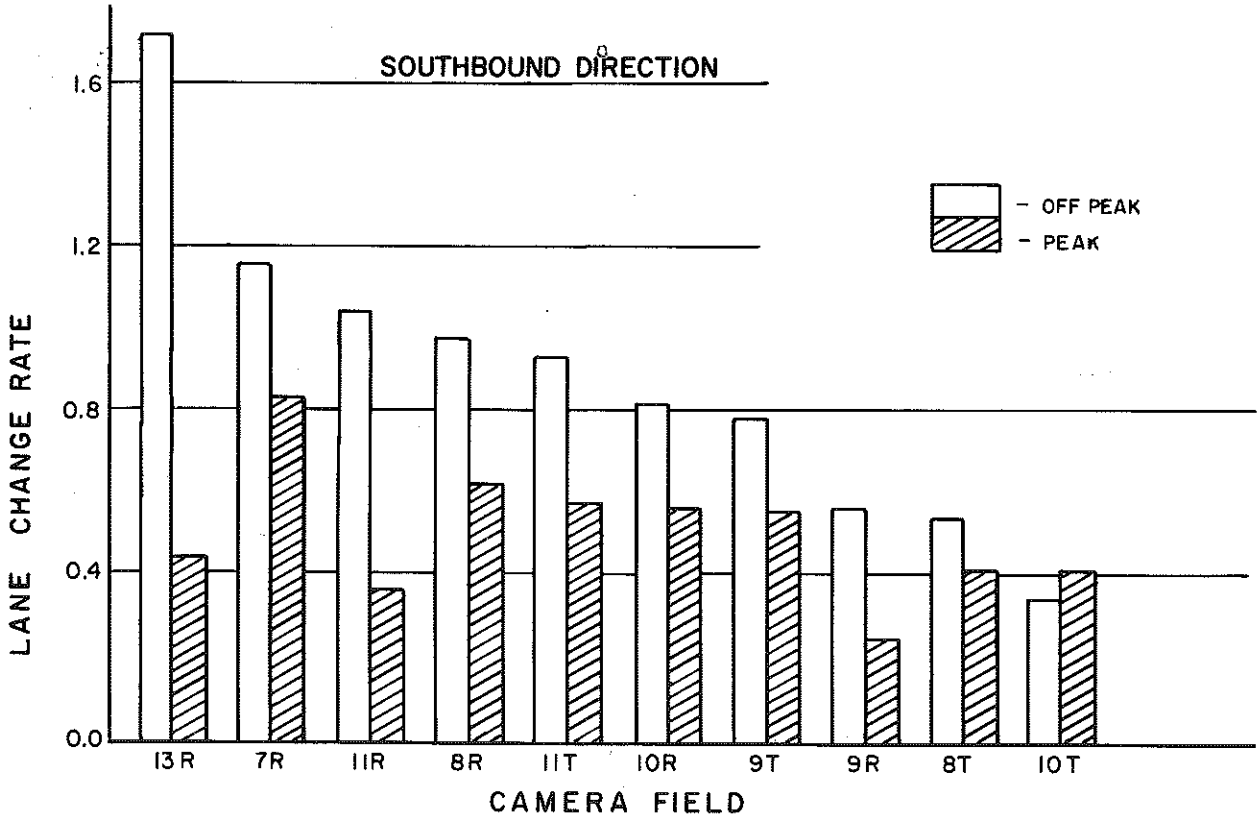


FIGURE VII

NUMBER OF LANE CHANGES PER VEHICLE-MILE IN FOUR LANE SECTIONS



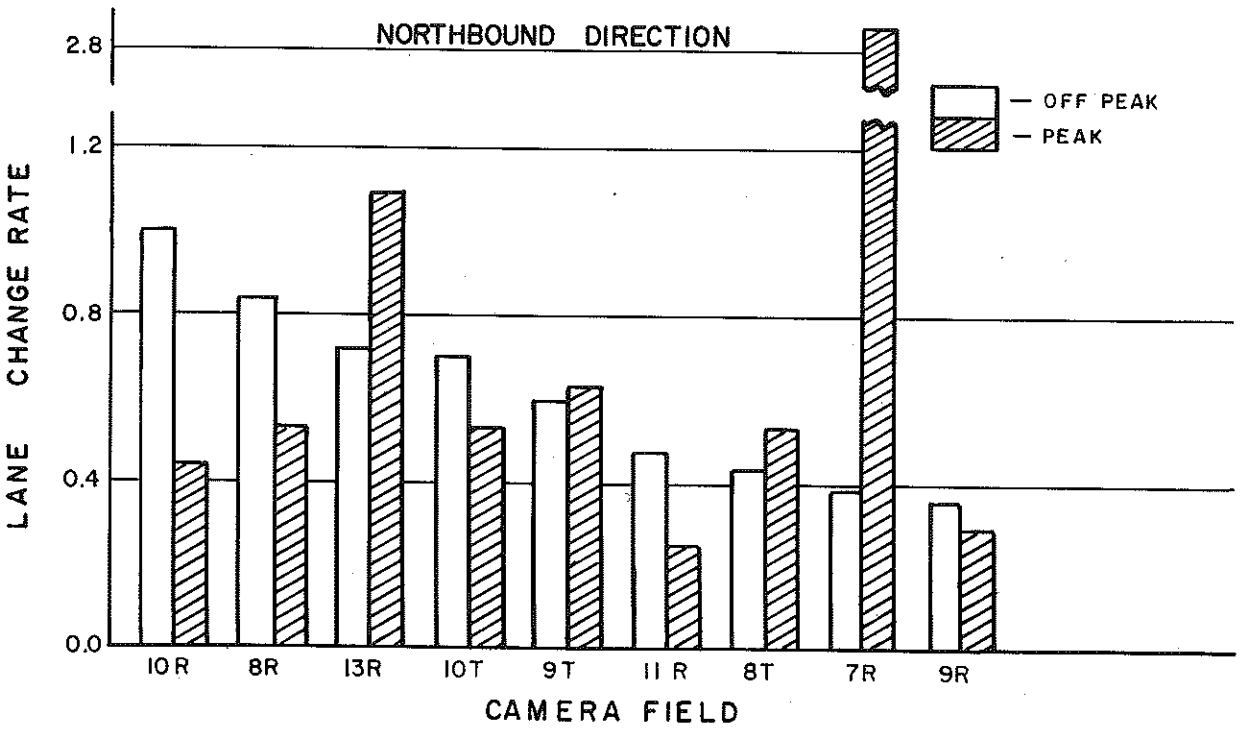
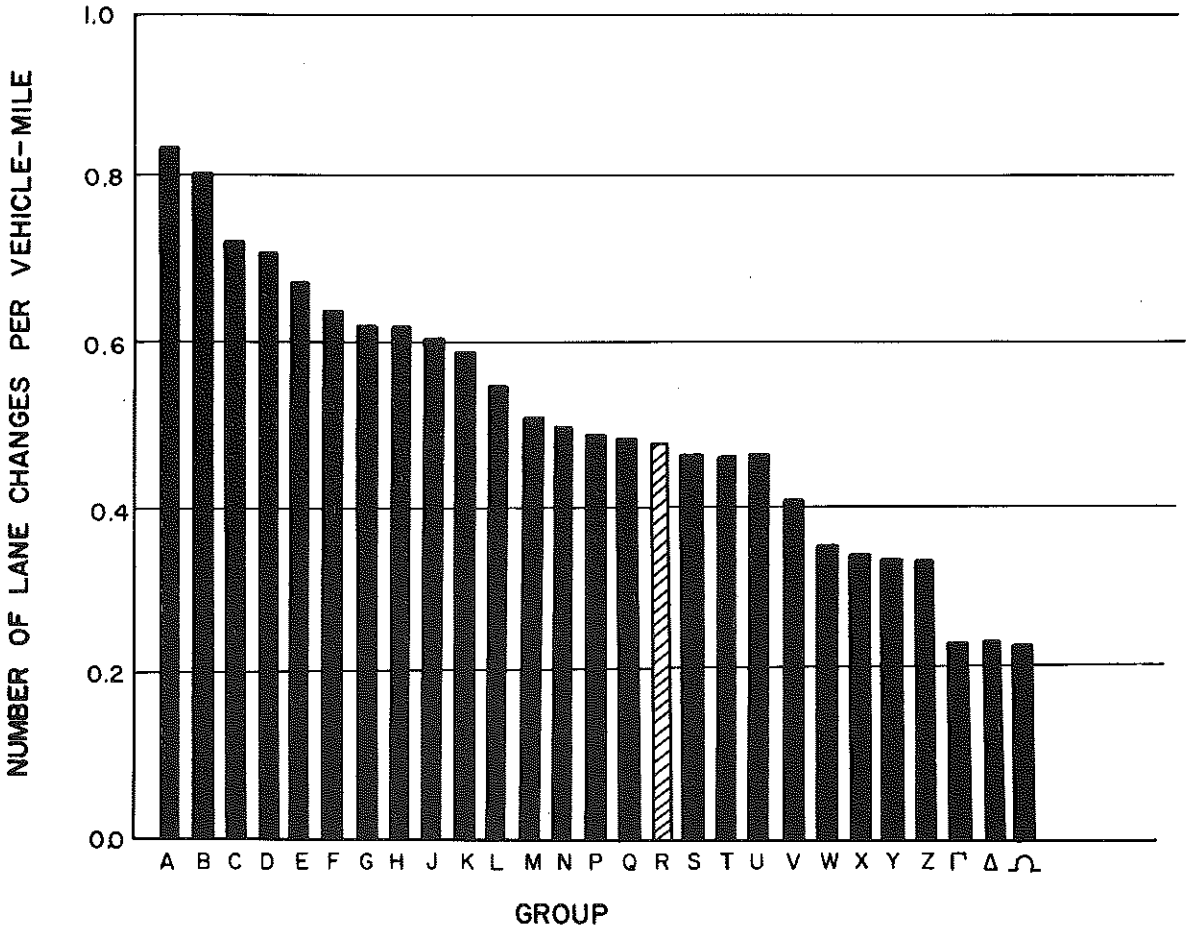


FIGURE VIII

NUMBER OF LANE CHANGES PER VEHICLE MILE BY GROUPS OF SECTIONS



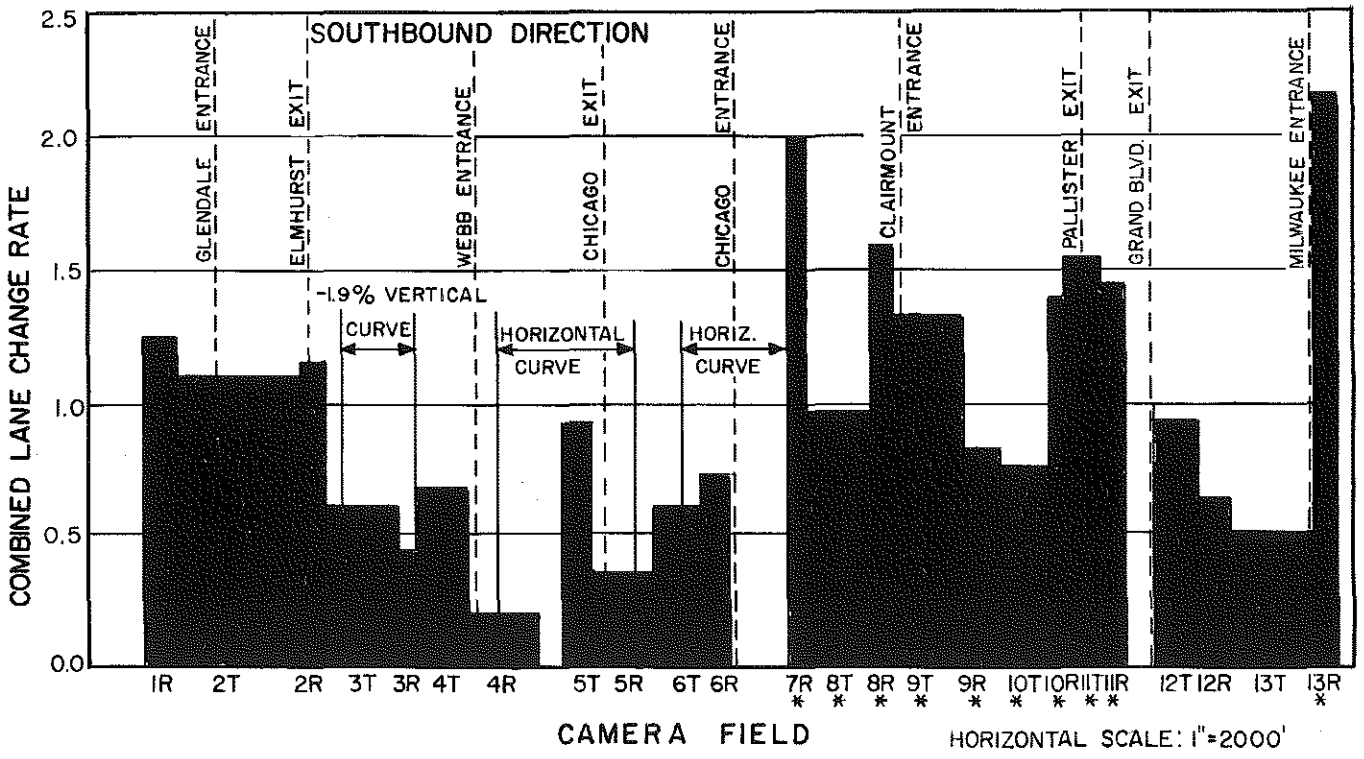
A - 4 LANE NB PEAK HOUR
B - 4 LANE SB OFF PEAK HOUR
C - 4 LANE OFF PEAK HOUR TOTAL
D - 4 LANE NB TOTAL
E - 4 LANE TOTAL
F - 4 LANE PEAK HOUR TOTAL
G - SB OFF PEAK HOUR TOTAL
H - 4 LANE SB TOTAL
J - 4 LANE NB OFF PEAK HOUR
K - OFF PEAK HOUR TOTAL
L - NB OFF PEAK HOUR TOTAL
M - 3 LANE NB OFF PEAK HOUR
N - NB TOTAL
P - 4 LANE SB PEAK HOUR
Q - 3 LANE OFF PEAK HOUR TOTAL
R - TOTAL STUDY AREA
S - SB TOTAL
T - 3 LANE SB OFF PEAK HOUR
U - NB PEAK HOUR TOTAL
V - PEAK HOUR TOTAL
W - SB PEAK HOUR TOTAL
X - 3 LANE NB TOTAL
Y - 3 LANE TOTAL
Z - 3 LANE SB TOTAL
Γ - 3 LANE PEAK HOUR TOTAL
Δ - 3 LANE SB PEAK HOUR
⎍ - 3 LANE NB PEAK HOUR

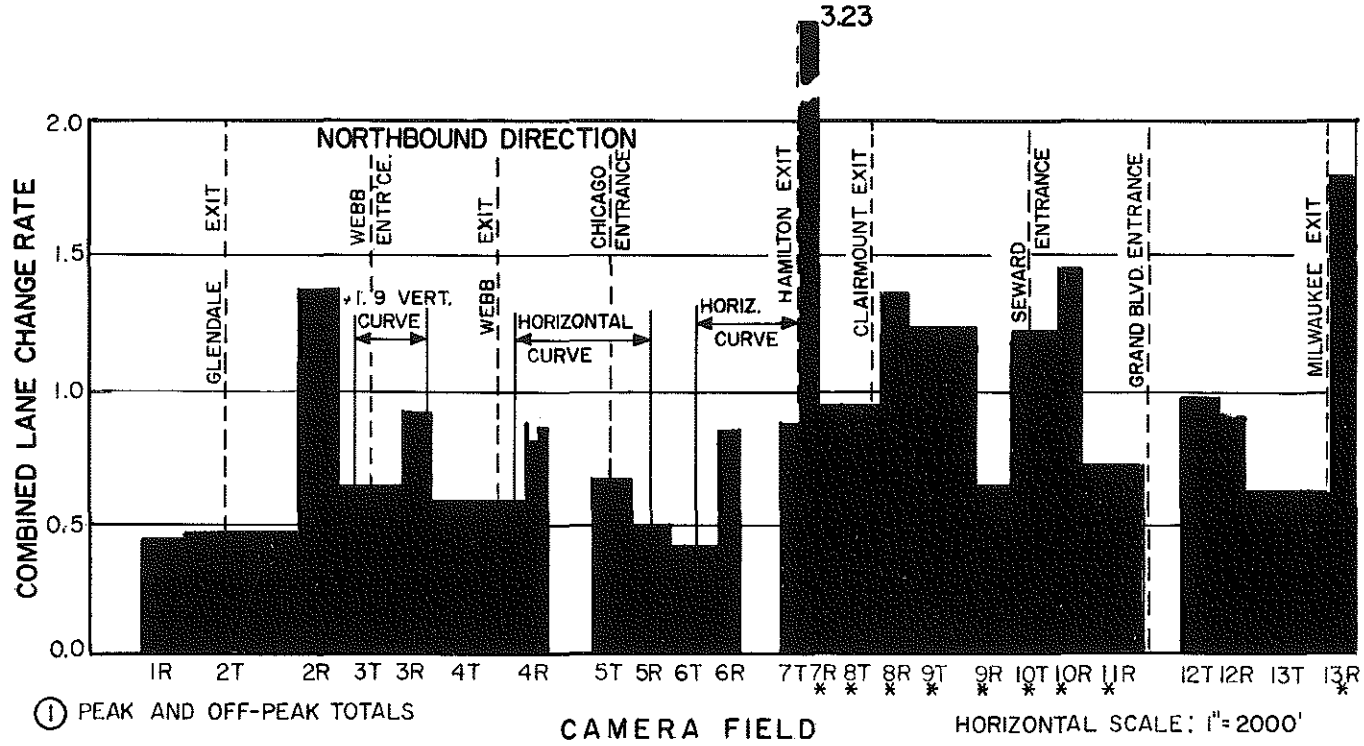
and four lane sections. As expected, there was generally an increased rate in the vicinity of entrance and exit ramps. There does not appear to be a rate increase in the vicinity of the horizontal curves attributable to the horizontal curves alone. Rate increases in horizontal curve fields appear to be caused by adjacent entrance and exit ramps. The horizontal curve in camera fields 4 and 5 has a degree of curvature of 2^{o} 45', and the horizontal curve in camera fields 6 and 7 has a 30^{o} 10' degree of curvature. The superelevated twelve foot wide lanes apparently accommodate traffic well through the curve sections. However, 32% of the curve in section 7 and 35% of curve in section 5 in northbound direction and 46% of the curve in section 7 and 21% of the curve in section 5 in southbound direction were not visible on the television monitors and therefore not surveyed. The increased lane change rate in northbound field 3R may be caused in part by the + 1.9% vertical grade. The maximum vertical grade in the remainder of the study area is 0.8%. In southbound field 4T and northbound fields 12R and 5T, there are rate increases before entrance ramps. The rate increases may be caused in part by motorists changing lanes to avoid merging traffic. In some fields such as southbound field 12T there does not appear to be a specific explanation for the rate increase.

Total volumes by type of vehicle are shown in Table IX. The percent of total volume by type of vehicle is shown in Table X. This reveals that 92.1% of the total volume is passenger vehicles and compares with 91.5% of lane changing which is done by passenger vehicle (Table VI). Percent of total volume by passenger vehicles is within 2.2% of percent of lane changes by passenger vehicles during peak, as well as off-peak hours for both directions.

FIGURE IX

COMPARISON OF COMBINED ① RATE OF LANE CHANGES PER VEHICLE-MILE TO GEOMETRIC FEATURES





① PEAK AND OFF-PEAK TOTALS

TABLE IX

TOTAL VOLUMES BY TYPE OF VEHICLE

Southbound Direction

Camera Field	Peak Hour (1)	(2)	(3)	(4)	Off-Peak Hour (1)	(2)	(3)	(4)
1R	4826	57	36	70	2874	128	153	104
2T	4821	85	36	76	3795	149	121	125
2R	4821	85	36	76	3100	154	205	110
3T	4779	83	36	76	3782	209	152	149
3R	4779	83	36	76	3782	209	152	149
4T	4915	71	66	47	3355	156	140	113
4R	5324	87	82	59	3568	171	158	119
5T	5324	87	82	59	3568	171	158	119
5R	5012	149	62	78	3185	135	113	154
6T	5012	149	62	78	3712	189	142	100
6R	5012	149	62	78	3795	181	131	145
7R	6647	136	70	85	3587	179	128	121
8T	5853	111	112	89	3572	185	218	103
8R	5957	89	85	91	3704	174	129	102
9T	6657	101	110	103	3682	201	146	113
9R	6062	74	78	79	3995	188	125	188
10T	6354	115	82	61	4227	216	144	204
10R	6607	169	136	94	4112	111	132	141
11T	6075	161	135	94	3425	197	162	132
11R	6075	161	135	94	3690	187	113	146
12T	5643	143	92	110	3977	179	112	158
12R	5643	143	92	110	3594	142	119	146
13T	5643	143	92	110	3204	161	192	82
13R	6062	158	98	121	2806	120	191	85

Northbound Direction

Camera Field	Peak Hour (1)	(2)	(3)	(4)	Off-Peak Hour (1)	(2)	(3)	(4)
1R	5409	122	51	55	2430	144	138	119
2T	5540	166	51	47	2447	147	125	91
2R	5540	166	51	47	3396	182	147	90
3T	5540	166	51	47	2713	147	138	98
3R	5428	162	49	47	2779	163	166	94
4T	5562	96	50	48	2779	163	166	94
4R	5706	102	56	54	2950	176	175	96
5T	5411	117	61	63	2994	129	183	115
5R	5411	117	61	63	2994	129	183	115
6T	5411	117	61	63	2994	129	183	115
6R	5411	117	61	63	2994	129	183	115
7T	5411	117	61	63	3478	173	155	103
7R	6100	126	70	70	3761	187	167	110
8T	5183	96	73	64	3420	147	185	115
8R	5338	99	81	65	3692	159	201	117
9T	5338	99	81	65	3692	159	201	117
9R	5338	99	81	65	3692	159	201	117
10T	4647	113	78	63	3693	183	179	128
10R	4647	113	78	63	3695	195	133	200
11R	4647	113	78	63	3693	183	179	128
12T	4368	138	69	90	3088	175	170	99
12R	4173	107	77	68	2680	184	186	124
13T	4670	97	108	69	3239	156	172	127
13R	4886	123	96	73	3547	185	200	134

(1) = Passenger vehicles
(2) = Panel and pickup trucks
(3) = Heavy trucks
(4) = Busses and miscellaneous

Study Analysis (Cont'd)

Figure X shows the comparison of percent of total lane changes by passenger vehicles to percent of total volume by passenger vehicles. Except for southbound peak-hour field 1R, southbound off-peak hour fields 1R and 2R, and northbound off-peak hour fields 12R and 13T, the percent of total lane changes by passenger vehicles is within 10% of the percent of total volume by passenger vehicles for both directions during both peak and off-peak hours. The major reason for the increase in lane changes by trucks in these fields is due to the location of the Davison and Ford Freeways left entrance ramps to the Lodge Freeway. Trucks which serve automobile manufacturers on the west end of the Ford Freeway and east end of the Davision Freeway, account in part for the increased percent of lane changing. The trucks, of course, must work their way from lane 1 to lane 3 to comply with the ordinance to keep from interfering with traffic in lanes 1 and 2.

TABLE X

PERCENT OF TOTAL VOLUME BY TYPE OF VEHICLE

Southbound Direction

Camera Field	Peak Hour (1)	(2)	(3)	(4)	Off-Peak Hour (1)	(2)	(3)	(4)
1R	97	1	0.5	1.5	88	4	5	3
2T	96	1.5	1.	1.5	91	4	2.5	2.5
2R	96	1.5	1	1.5	87	4	6	3
3T	96	1.5	1	1.5	88	5	3.5	3.5
3R	96	1.5	1	1.5	88	5	3.5	3.5
4T	97	1	1	1	89	4	4	3
4R	96	1.5	1.5	1	89	4	4	3
5T	96	1.5	1.5	1	89	4	4	3
5R	95	3	1	1	89	4	3	4
6T	95	3	1	1	89	5	3.5	2.5
6R	95	3	1	1	90	4	3	3
7R	97	2	1	1	89	5	3.5	3.5
8T	95	2	2	1	88	4	5	3
8R	96.5	1.5	1.5	1.5	90	5	3	2
9T	95	1.5	2	1.5	89	5.5	3	2.5
9R	97	1	1	1	89	4	3	4
10T	97	1	1	1	88	5	3	4
10R	95	2	2	1	92	2	3	3
11T	94	3	2	1	88	5	4	3
11R	94	3	2	1	89	5	3	3
12T	96	2	1	1	90	4	2	4
12R	96	2	1	1	90	4	2	4
13T	96	2	1	1	88	4	5	3
13R	94	2	2	2	88	4	5	3
Average % 1-Hr. Total	95.3	1.9	1.4	1.4	89.5	4.2	3.5	2.8
Average % Direction Total	92.4	3.1	2.4	2.1				
Average Study Total	92.1	3.1	2.7	2.1				

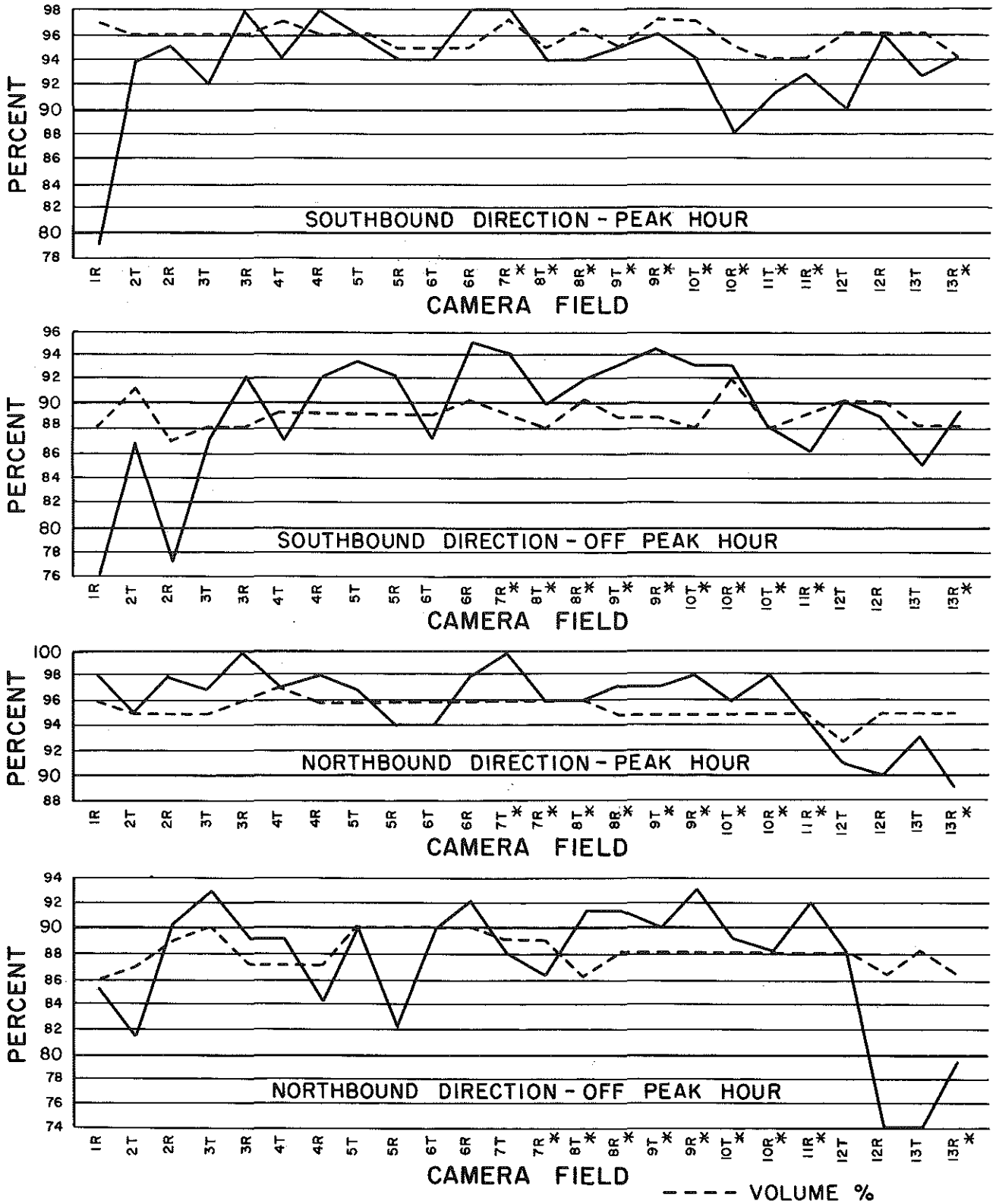
Northbound Direction

Camera Field	Peak Hour (1)	(2)	(3)	(4)	Off-Peak Hour (1)	(2)	(3)	(4)
1R	96	2	1	1	86	5	5	4
2T	95	3	1	1	87	5	5	3
2R	95	3	1	1	89	5	4	2
3T	95	3	1	1	90	4	3.5	2.5
3R	96	2	1	1	87	5	5	3
4T	97	1	1	1	87	5	5	3
4R	96	2	1	1	87	5	5	3
5T	96	2	1	1	90	3	4	3
5R	96	2	1	1	90	3	4	3
6T	96	2	1	1	90	3	4	3
6R	96	2	1	1	90	3	4	3
7T	96	2	1	1	89	4	4	3
7R	96	2	1	1	89	4	4	3
8T	96	2	1	1	86	4.5	5	3.5
8R	95	2	1.5	1.5	88	4	5	3
9T	95	2	1.5	1.5	88	4	5	3
9R	95	2	1.5	1.5	88	4	5	3
10T	95	2	1.5	1.5	88	4.5	4.5	3
10R	95	2	1.5	1.5	88	4	3	5
11R	95	2	1.5	1.5	88	4.5	4.5	3
12T	93	3	2	2	88	4.5	4.5	3
12R	95	2	1.5	1.5	86	5	5	4
13T	95	2	2	1	88	4	5	3
13R	95	2	2	1	87	5	5	3
Average % 1-Hr. Total	95.5	2.1	1.3	1.1	88.2	4.3	4.5	3.0
Average % Direction Total	91.8	3.2	2.9	2.1				

(1)= Passenger Vehicles (2)= Panel & pickup trucks (3)= Heavy trucks (4)= Busses and miscellaneous

FIGURE X

COMPARISON OF PERCENT OF TOTAL LANE CHANGES BY PASSENGER VEHICLES TO PERCENT OF TOTAL VOLUME BY PASSENGER VEHICLES



Findings

This study indicated that the percent of lane changes by passenger vehicles (91.5%) compared quite closely with the percent of total volume by passenger vehicles (92.1%). Percent of total volume by passenger vehicles was within 2.2% of percent of lane changes by passenger vehicles during peak as well as off-peak hours for both directions.

The study also revealed that 1.7% of lane change movements involved multiple lane changes. Of the multiple lane changes 72% occurred during the off-peak hours when traffic volumes were lower. All lane change movements in a three lane section, of course, involve lane 2. In the four lane sections, 66% of lane change traffic used lane 2 and 72% of lane change traffic used lane 3. Analysis showed that 55.8% of the lane change traffic changed lanes from the shoulder side to the center island side.

The number of lane changes per vehicle-mile was found to be .48 in the entire study area. The lowest rate was .05 in southbound field 4R (a 3 lane peak hour field) and the highest rate was 2.86 in northbound field 7R (a four lane peak hour field). The 2.86 rate may approach a maximum rate since northbound field 7R is located at a point where the freeway is reduced from four lanes to three lanes and the peak hour traffic makes it difficult for some traffic entering the freeway from the heavy W. Grand Boulevard entrance ramp and Seward entrance ramp to weave from lane 4 before field 7R. The 2.86 rate was reduced to a .62 rate after signs were installed requiring traffic using lane 4 to exit only via the exit ramp at the north end of field 7R. This reduction may or may not be offset by changes in other fields upstream since it would be necessary to re-survey the northbound study area further south to determine this. It has, however, indicated that sign changes

can reduce the rate of lane changes considerably at a specific point. In addition to northbound field 7R, critical sections, those with a high percentage of multiple lane changes and lane changes by trucks, appear to be those at the approach extremities of the study area where left entrance ramps from the Davison and Ford Freeways cause trucks to work their way from lane 1 to lane 3.

Lane change rates were generally higher in the four lane sections and the off-peak periods. As expected, there was usually an increased lane change rate per vehicle mile in the vicinity of entrance and exit ramps. Because of the various factors involving lane changing techniques, a lane change rate increase has usually been found a considerable distance downstream from the entrance ramp. Lane change rate increases were found before some entrance ramps. This may be caused in part by motorists changing lanes to avoid merging traffic. Although advance directional overhead signs are provided for exit ramps, the highest rate of lane change is generally in the area in advance of the ramp. There does not appear to be a rate increase in the vicinity of the horizontal curves attributable to the horizontal curves alone. However, lane changes in portions of the horizontal curves could not be viewed on the television monitors. The only vertical upgrade in excess of 0,8% in field 3R (+1.9%) shows an increased rate for no other explainable reason. There does not appear to be a specific explanation for rate increases in some fields such as southbound field 12T.

The study also showed that there appears to be a limit between the number of lane changes per vehicle-mile possible in the peak hour to the number of lane changes per vehicle-mile obtained during the off-peak

hour for a given field. The off-peak percent of combined two hour number of lane changes per vehicle-mile was higher and more consistent in three lane fields than four lane fields. Analysis showed that 86% of the three lane fields were within 28% (off-peak %; 59% to 86%) and 74% of the four lane fields were within 23% (off-peak %; 44% to 66%). Using an off-peak percent average of 72% for three lane fields and 55% for four lane fields, it may be possible to make a prediction on the number of lane changes in a field for the peak hour, given the off-peak rate and peak hour volume.

Many factors in this 3.2 mile study are, including the three and four lane sections, major freeway interchanges at each end of the study area, nine entrance or exit ramps for each direction, horizontal and vertical curves, and mixture of through and local traffic contribute to the difficulty of analyzing lane change movements. Further study remains to be done on this subject since the maximum efficiency of a freeway, or any traffic facility, is obtained when the greatest volume of traffic is maintained. Among other things, this will require a minimum of lane changing movements at points where they will least interfere with through traffic. Findings in other studies of lane changes of this project may substantiate some of the findings in this report and add further information on this subject.

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