ENGINEERING RESEARCH INSTITUTE

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FINAL REPORT

FREEWAY OPERATIONS ANALYSIS OF I-80 TO I-29 INTERCHANGE

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CONTENTS

1. Introduction

1.1. Project Scope

At the request of the Iowa State Highway Commission, the Engineering Research Institute observed the traffic operations at the Interstate 29 (I-29) and Interstate 80 (I-80) interchange in the southwest part of Council Bluffs. The general location of the site is shown in Figure 1. Before limiting the analysis to the diverging area the project staff drove the entire Council Bluffs freeway system and consulted with Mr. Philip Hassenstab (Iowa State Highway Commission, District 4, Resident Maintenance Engineer at Council Bluffs). The final study scope was delineated as encompassing only the operational characteristics of the diverge area where I-29 South and I-80 East divide and the ramp to merge area where I-80 West joins I-29 North (both areas being contained within the aforementioned interchange).

Supplementing the traffic operations scope, was an effort to delineate and document the applicability of video-tape techniques to traffic engineering studies and analyses. Documentation was primarily in the form of a demonstration video-tape.

1.2. Project Objectives

The research activity was directed toward achieving the following objectives:

1.2.1. The magnitude and character of present traffic conflicts are quantified at each study site.

1.2.2. The magnitude and character of future traffic conflicts at each study site are estimated.

1.2.3. Possible alternative solutions are generated which have the potential to lessen the intensity and/or the frequency

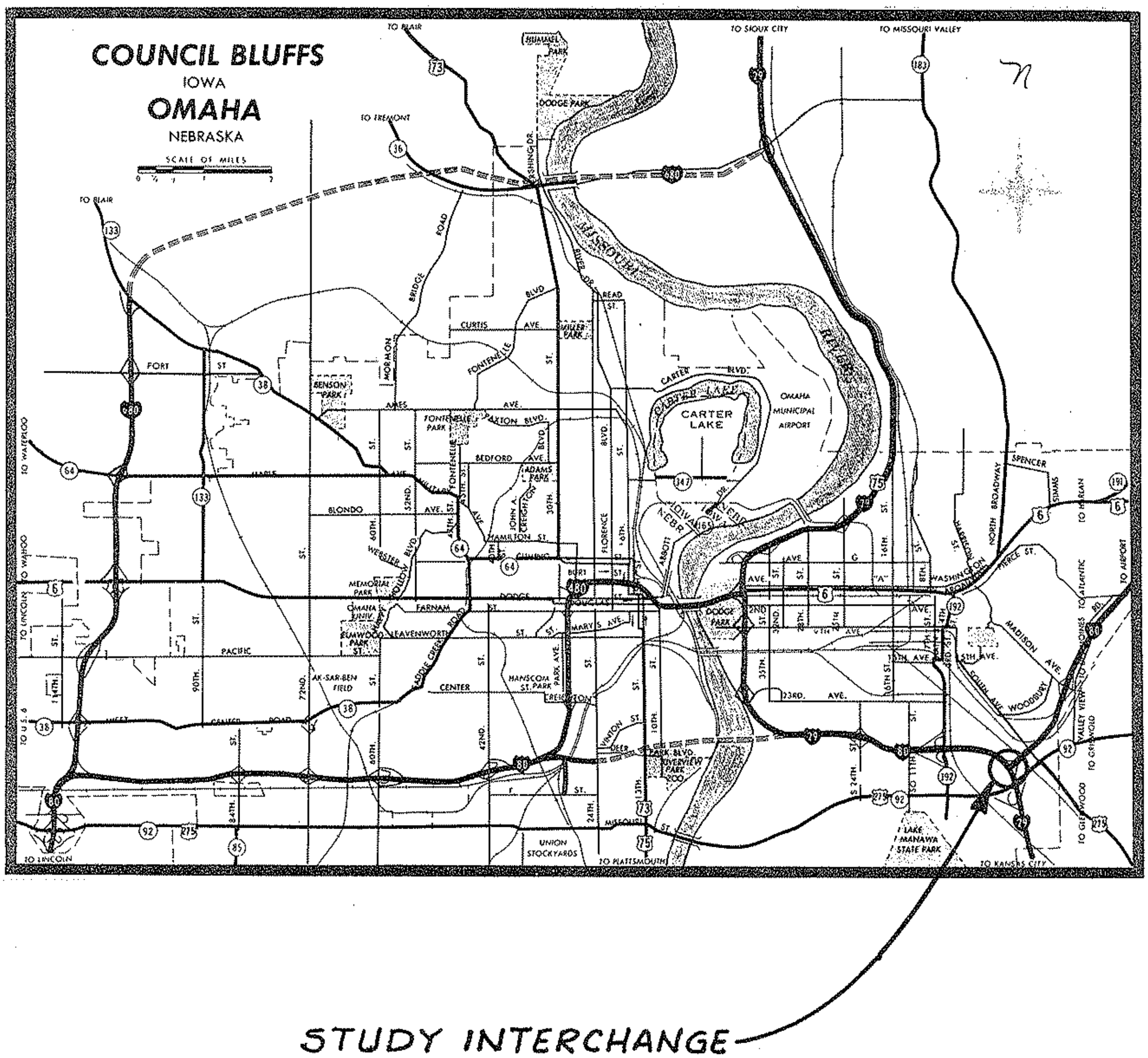


Figure 1. Site Location Map

of both present and future traffic conflicts in each study area.

1.2.4. Alternative solutions are compared and evaluated in a structured manner.

1.2.5. The applicability of video-tape techniques to traffic operations analysis is demonstrated.

1.3. Operations Study Procedure

1.3.1. Preliminary Traffic Volume Data

Prior to video-tape data collection the Transportation Data Base Department of the Iowa State Highway Commission Planning Division conducted one-week 24-hour a day recording counts at each study site. These data were examined to establish the daily variation in hourly volumes on each leg of both the diverge and the merge sites. For one 24-hour period at each study site the traffic was classified into eleven different vehicle types. Large trucks and out-of-state drivers were thought to have an adverse effect by increasing the traffic conflicts. These data were examined to select the days of the week and the hours of the day that would potentially maximize the data on traffic conflicts while simultaneously covering the maximum range of traffic volume conditions with the minimum number of taped data periods.

1.3.2. Data Sample Periods

The merging and the diverging volume counts indicated that at the I-29S and I-80E diverge area (Study Site #1) one tape should be recorded during the period

8:00 a.m. to 8:30 a.m., two tapes during the period 10:00 a.m. to 11:00 a.m., one tape from 3:30 p.m. to 4:00 p.m., one tape from 4:15 p.m. to 4:30 p.m., and one tape from 5:00 p.m. to 5:30 p.m. Each tape contained approximately 30 minutes of data. It was not possible to always start a tape at the planned time, thus, the actual data record has some variation from the planned schedule. The data sample was replicated on Thursday (July 26, 1973), Friday (July 27, 1973) and on Saturday (July 28, 1973) to cover potential variations in local and out-of-state drivers.

Analysis of the volume counts at the merging volume when I-29N joins I-80W (Study Site #2) indicated a slightly different data collection pattern was appropriate to sample variations in traffic volumes and vehicle classifications. The time periods selected were one tape from 7:30 a.m. to 8:00 a.m., two tapes from 8:00 a.m. to 9:00 a.m., one tape from 11:00 a.m. to 11:30 a.m., one tape 3:30 p.m. to 4:00 p.m. and one tape from 4:00 p.m. to 4:30 p.m. As in the data collection at Study Site #1, replications were conducted on Thursday (August 2, 1973), Friday (August 3, 1973) and Saturday (August 4, 1973) with similar variations in the actual real time of each data tape due to varying minor difficulties in maintaining the programmed schedule. The actual data collection time sequences are shown in Table 1 in addition to the vehicle classification of the data counts extracted from each tape. Note that for the

Table 1. Classification of Data Collected.

Date	Time (STUDY SITE #1)	P[1]		PT[2]		SU[3]		ST[4]		M[5]		Hourly Flow Rate
		No.	%	No.	%	No.	%	No.	%	No.	%	
7/26/73	8:05-8:36 AM	268	82.2	11	3.4	16	4.9	30	9.2	1	0.3	650
	10:00-10:34 AM	322	76.1	21	5.0	37	8.7	39	9.2	4	1.0	840
	10:38-11:11 AM	320	73.2	38	8.7	22	5.0	53	12.1	4	1.0	870
	3:30-4:04 PM	466	80.9	19	3.3	36	6.3	49	8.5	6	1.0	1150
	4:15-4:47 PM	573	83.9	12	1.8	24	3.5	61	8.9	13	1.9	1360
	4:55-5:25 PM	762	90.3	11	1.3	25	3.0	41	4.9	5	0.5	1690
7/27/73	8:05-8:38 AM	312	80.0	15	3.8	26	6.7	35	9.0	2	0.5	780
	10:00-10:34 AM	314	77.7	20	5.0	22	5.4	45	11.1	3	0.8	800
	10:38-11:08 AM	350	78.7	33	7.4	19	4.3	42	9.4	1	0.2	890
	3:30-4:04 AM	521	84.0	25	4.0	29	4.7	38	6.1	7	1.2	1240
	4:13-4:45 PM	670	89.3	21	2.8	20	2.7	33	4.4	6	0.8	1500
	4:52-5:26 PM	867	89.1	24	2.5	25	2.6	48	4.9	9	0.9	1940
7/28/73	8:05-8:37 AM	252	79.0	25	7.8	15	4.7	27	8.5	0	0	630
	10:00-10:32 AM	350	85.8	27	6.6	13	3.2	18	4.4	0	0	810
	10:38-11:11 AM	386	83.4	32	6.9	10	2.2	32	6.9	3	0.6	920
	3:30-4:02 PM	417	87.4	24	5.0	3	0.6	19	4.0	14	3.0	950
	4:12-4:46 PM	462	88.0	22	4.2	5	1.0	31	5.8	5	1.0	1050
	4:52-5:25 PM	389	87.2	20	4.5	5	1.1	24	5.4	8	1.8	890

1 P = passenger cars, pickup trucks and small vans

2 PT = a class P vehicle towing a trailer

3 SU = a single unit truck or a bus

4 ST = any tractor-trailer truck, semi-trailer, or SU truck with trailer

5 M = motorcycle

Table 1 (Continued). Classification of Data Collected.

Date	Time	P		PT		SU		ST		M		Hourly Flow Rate
(STUDY SITE #2)		No.	%	No.	&	No.	%	No.	%	No.	%	
8/2/73	7:36-8:06 AM	231	73.3	55	17.5	8	2.5	19	6.0	2	0.6	630
	8:11-8:41 AM	141	67.8	21	10.1	21	10.1	25	12.0	0	0	410
	8:46-9:16 AM	160	69.0	21	9.1	11	4.7	38	16.4	2	0.9	460
	11:00-11:30 AM	157	61.6	38	14.9	19	7.5	39	15.3	2	0.8	510
	3:30-4:00 PM	217	73.1	37	12.5	17	5.7	17	5.7	9	3.0	590
	4:05-4:35 PM	231	74.8	34	11.0	14	4.5	27	8.7	3	1.0	620
8/3/73	7:53-8:23 AM	178	67.2	41	15.5	9	3.4	35	13.2	2	0.8	530
	8:30-9:00 AM	149	70.3	29	13.7	5	2.4	29	13.7	0	0	420
	9:05-9:35 AM	141	65.3	34	15.7	13	6.0	27	12.5	1	0.5	430
	11:00-11:30 AM	210	70.0	40	13.3	19	6.3	31	10.3	0	0	600
	3:30-4:00 PM	248	72.5	47	13.7	19	5.6	27	7.9	1	0.3	680
	4:05-4:35 PM	269	74.7	47	13.1	10	2.8	31	8.6	3	0.8	720
8/4/73	8:02-8:32 AM	138	69.0	33	16.5	6	3.0	23	11.5	0	0	400
	8:37-9:07 AM	183	75.0	25	10.2	14	5.7	21	8.6	1	0.4	490
	10:25-10:55 AM	289	76.9	38	10.1	10	2.7	33	8.8	6	1.6	750
	11:03-11:33 AM	295	76.6	42	10.9	8	2.1	40	10.4	0	0	770
	3:25-3:55 PM	223	72.6	55	17.9	7	2.3	18	5.9	4	1.3	610
	4:00-4:30 PM	316	76.3	64	15.5	5	1.2	20	4.8	9	2.2	830

I-29S and I-80E diverge (Study Site #1) the classified volume count is the combined freeway volume approaching the diverge area while the classified volume at Study Site #2 is only the I-80W traffic.

1.3.3. Field Procedure

Figures 2, 3 and 4 illustrate the view of traffic approaching Study Site #1. Figure 5 illustrates the invisibility of the data collection process to traffic passing near the recording station. The data recording equipment is located under the edge of the bridge at the abutement as shown in Figure 6. The arrangement of the equipment in Figure 6 is as used at Study Site #1: camera mounted on a tripod and connected to a recorder; the recorder under the tripod; small television screen monitor connected to the recorder to check the quality of the signal being recorded; various miscellaneous items of equipment.

Figures 7 and 8 illustrate the view of traffic approaching Study Site #2. Figures 8, 9 and 10 illustrate the use of a pole to remotely mount the video camera above the roadway for observation of traffic in an inconspicuous manner. Figure 11 shows the completed installation as viewed from an adjacent local road with the video camera mounted on a bracket sixteen feet above the ground on a luminaire standard, with the remote cable from the camera leading to the recorder and television monitor on the ground off the shoulder, and a technician controlling the data collection. Traffic being observed is totally oblivious of the installation.

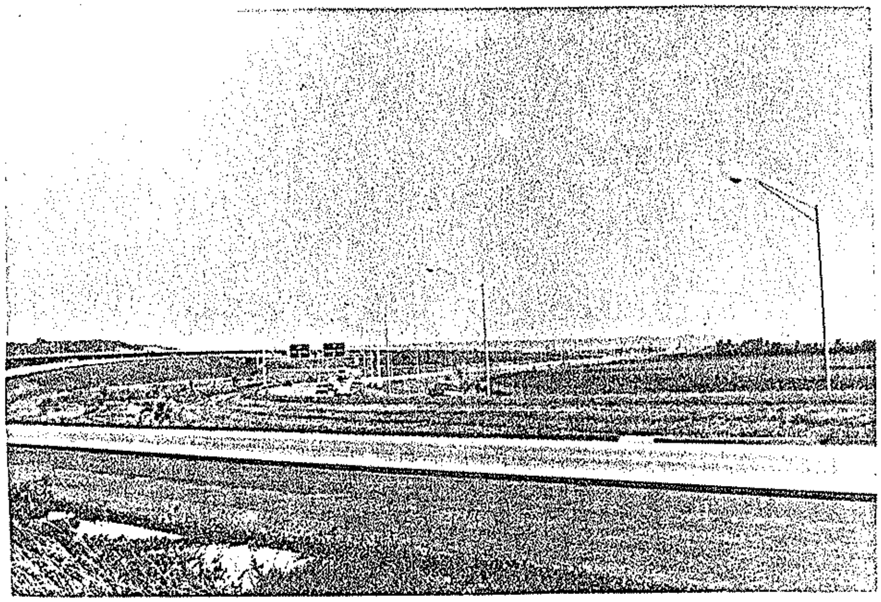


Figure 2. I-29S and I-80E Approach to Study Site #1. (Looking south with traffic moving away from the camera.)

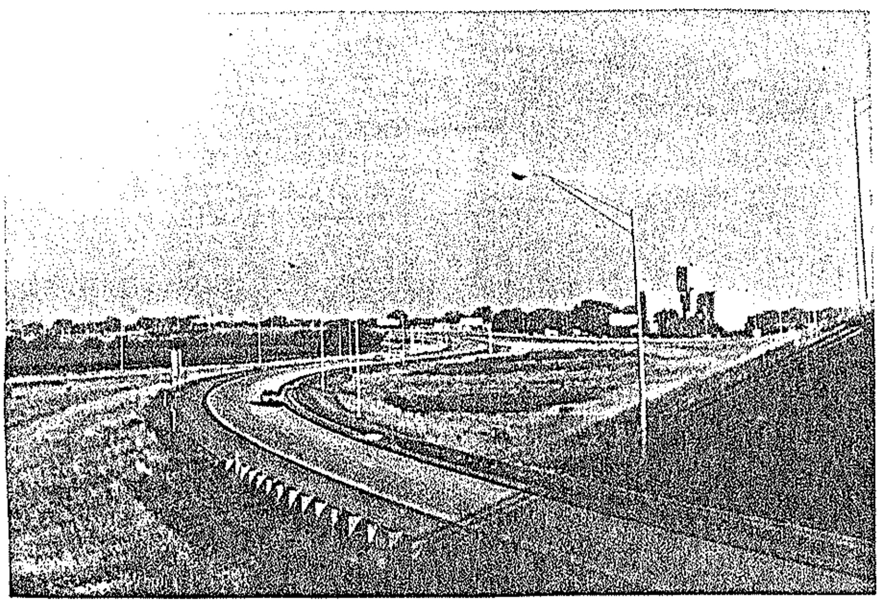


Figure 3. I-29 and I-80E Study Site #1. (Looking north with the traffic moving toward the camera.)

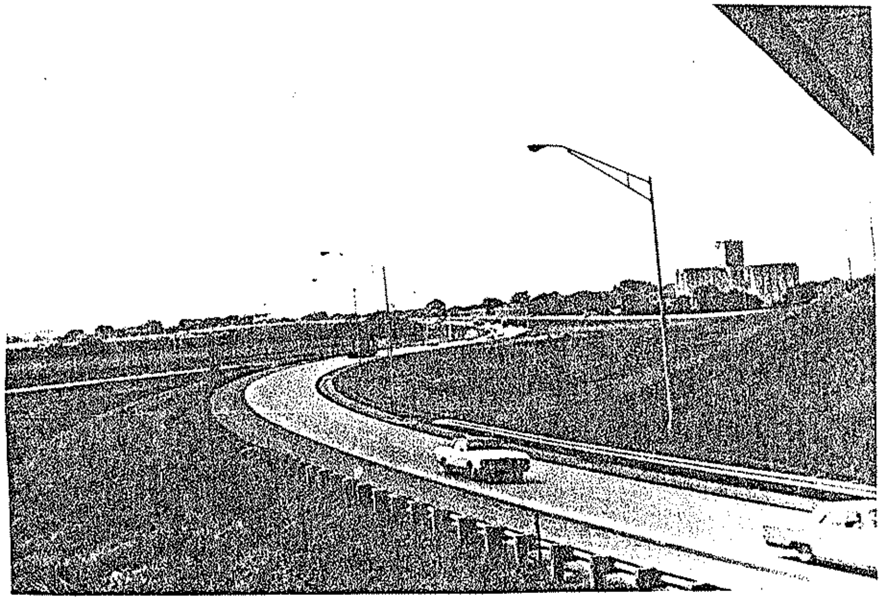


Figure 4. Study Site #1. (As viewed from the video-tape camera and recorder location.)

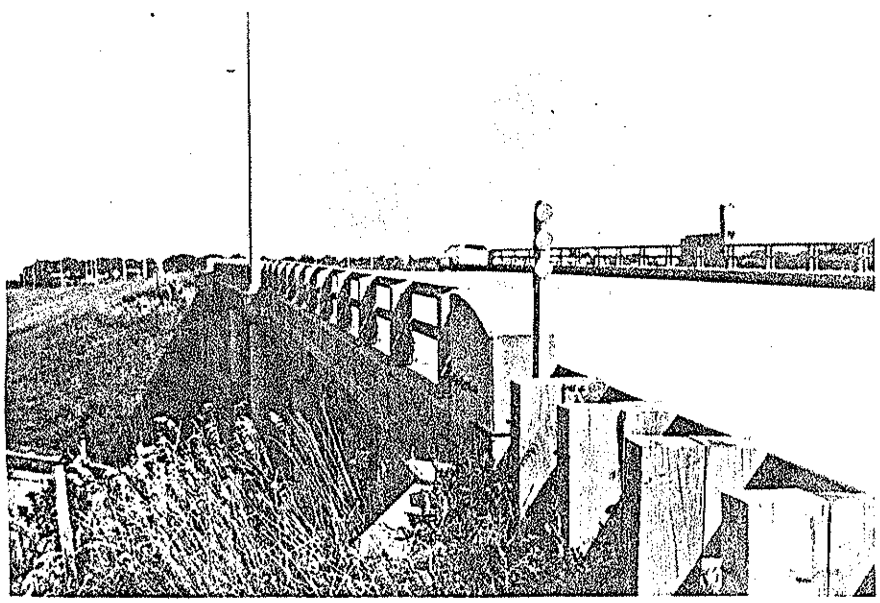


Figure 5. Video-tape Camera and Recorder in Place at Study Site #1.

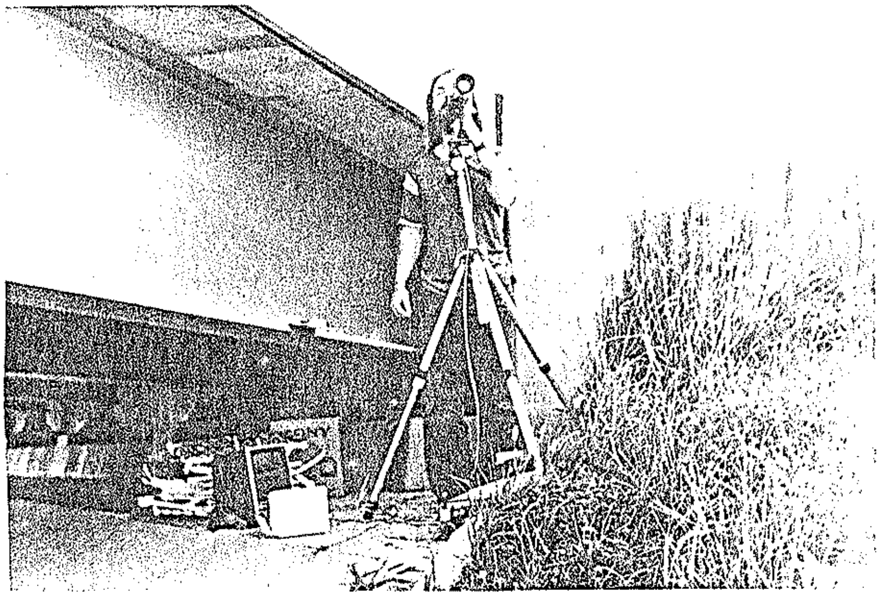


Figure 6. Video-tape Camera and Recorder in Operation at Study Site #1.

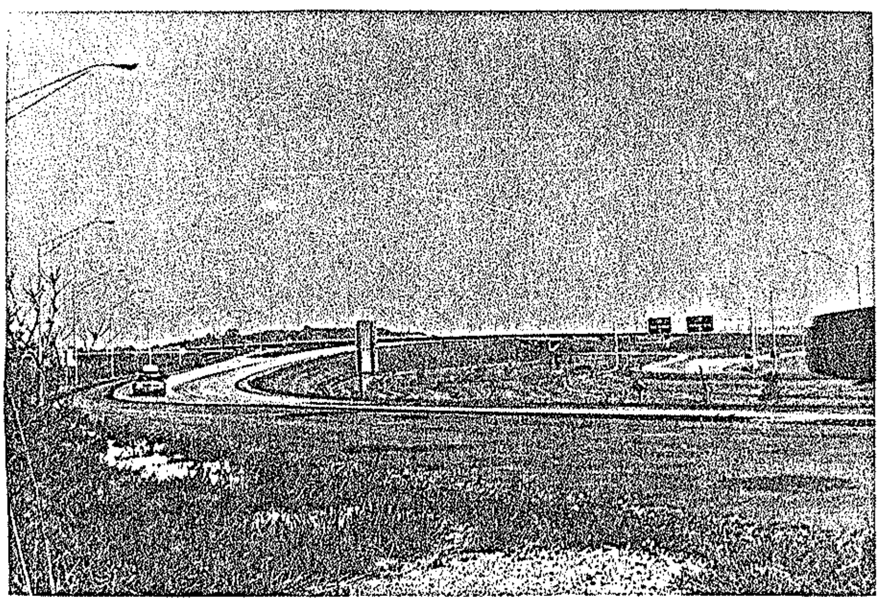


Figure 7. I-29N and I-80W Merge Area at Study Site #2. (Looking south with traffic moving toward the camera.)

CAMERA

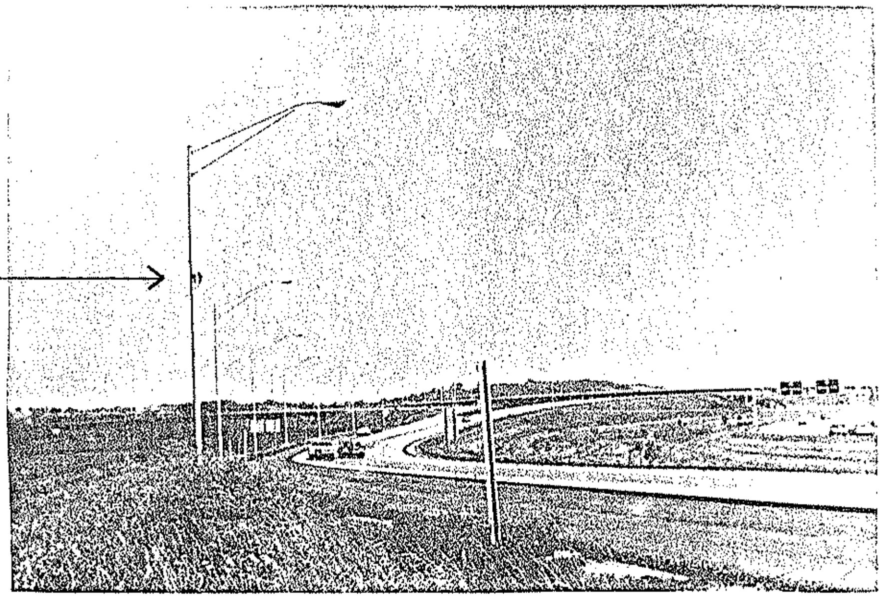


Figure 8. I-29N and I-80W Merge Area at Study Site #2 with Video Camera Remote Mounted on Luminaire Pole.

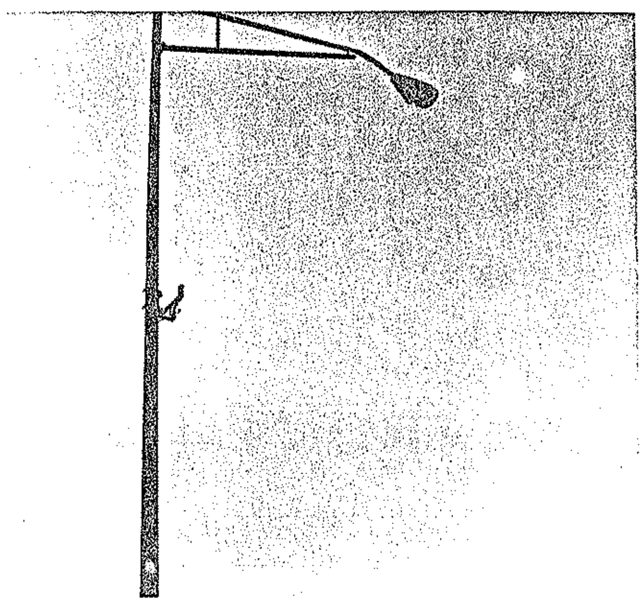


Figure 9. Video Camera Bracket Mounted on Pole.

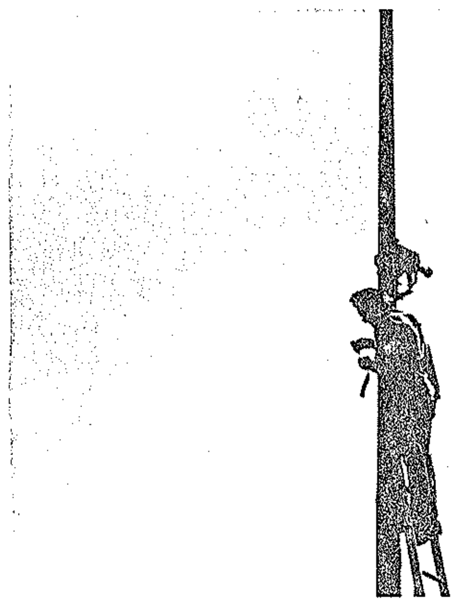


Figure 10. Technical Assistant Installing Video Camera on Mounting Bracket to Prepare Remote Surveillance.

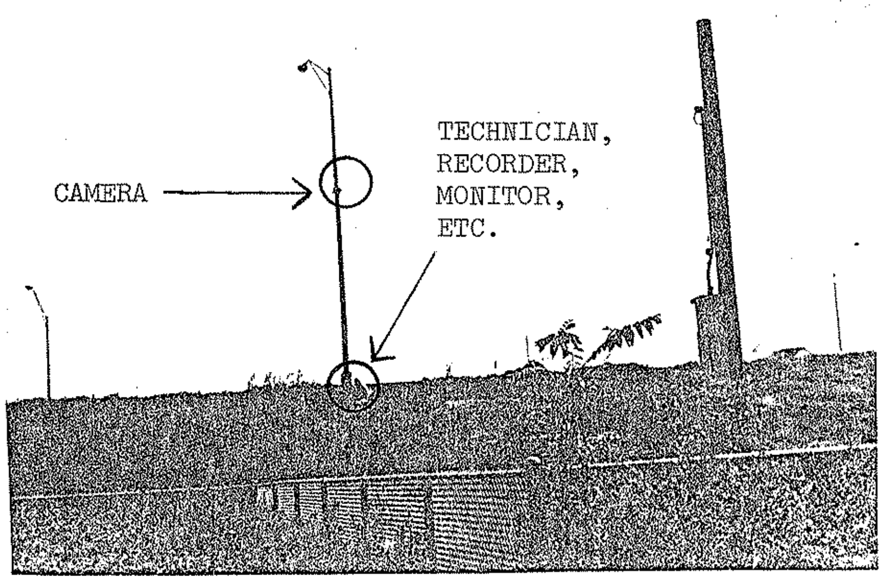


Figure 11. Video Camera and Recorder System in Place at Study Site #2.

1.3.4. Data Reduction

The data tapes were continuously observed in the field on the television monitor to ensure that each tape was a valid data sample with no equipment system malfunction nor environmental disturbance that destroyed the utility of a sample. Therefore, when the data was returned to the office for reduction the technicians were certain the data were available for reduction. Note that this is a significant advantage of video-tape techniques over standard photography techniques.

The equipment was organized in the data analysis laboratory as shown in Figure 13. Figure 12 is an example of the television monitor view of a tape obtained at Study Site #2 while Figure 14 is illustrative of Study Site #1 data. In Figure 15, a technician is reducing data from a Study Site #1 data tape. Each vehicle was identified by vehicle classification and by lane placement at predetermined critical points along the length of the roadway section under analysis. Subsequent analysis of the data yielded data on traffic volumes, traffic stream composition, traffic weaving and simple lane changing. The reduced data formed the basis of the operations analysis discussed in detail in following report sections.

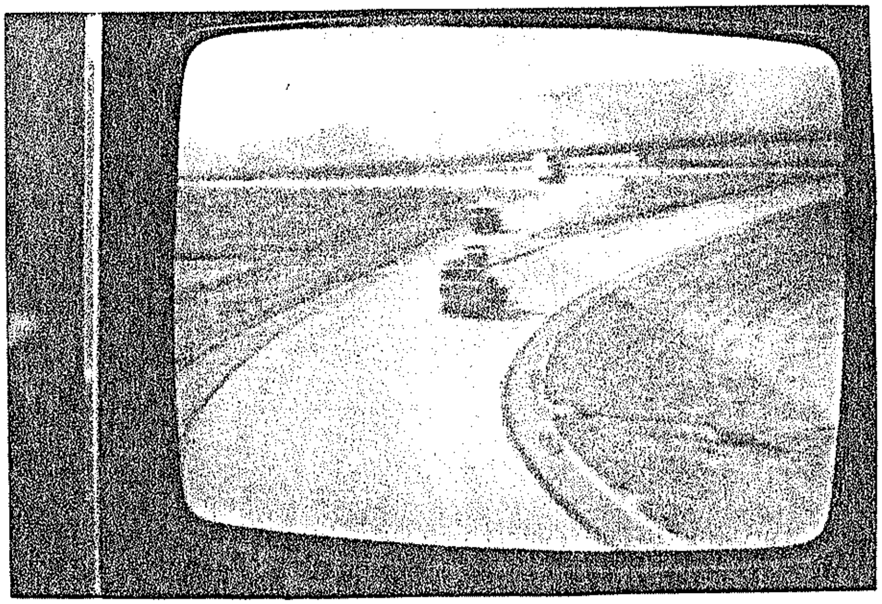


Figure 12. Monitor View of Study Site #2 Data in the Reduction Process.

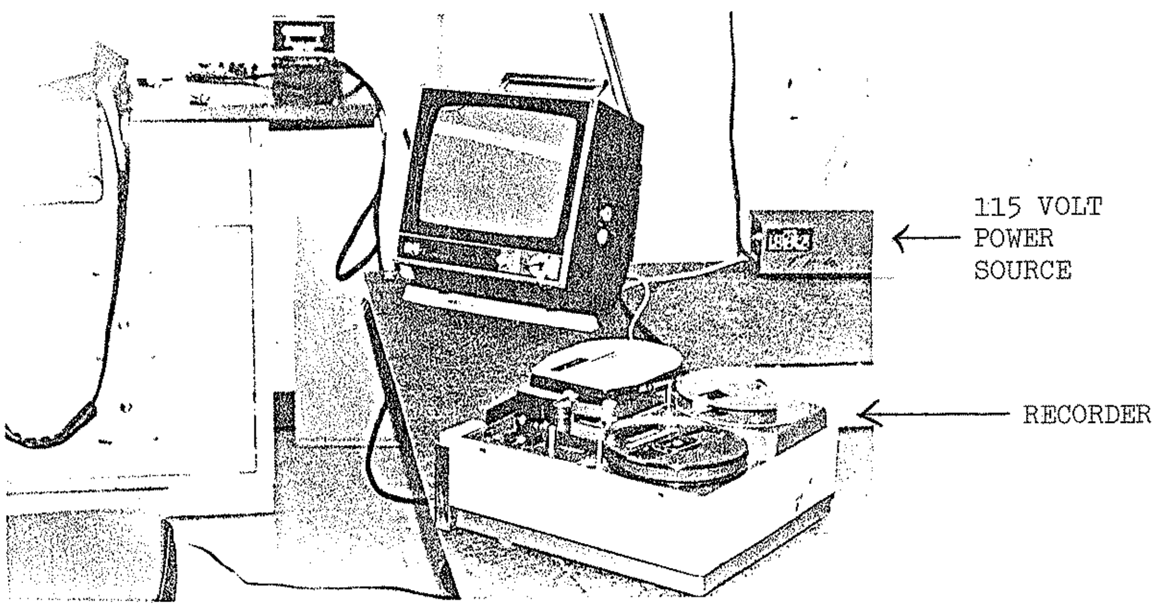


Figure 13. Video-tape System Ready to Begin Data Reduction.

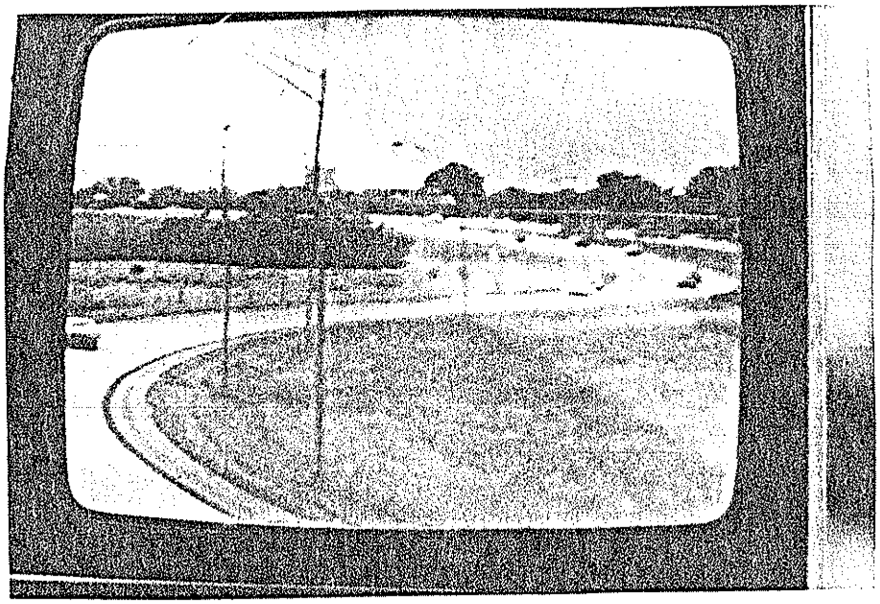


Figure 14. Monitor View of Study Site #1 Data in the Reduction Process.

Figure 15. Technician Reducing Data.

2. Present Traffic Conflicts

2.1. I-29 Southbound and I-80 Eastbound Diverge.

This location is also denoted as Study Site #1 and has been previously referred to in Figures 1 through 6.

2.1.1. Definition of Conflicts and Hazard.

Conflict and hazard were defined on the basis of erratic maneuvers by vehicles negotiating the I-29S and I-80E diverge area. As the combined routes approach the point where the taper begins adding a third lane (Station 292 + 75.00 I-29), the right-hand lane is designated lane 1 and the left-hand lane is denoted lane 2. (Refer to Figure 16.) This is the first critical lane placement section and is identified as section A-A in Figure 16. Ideally, all traffic destined for I-29 would be in lane 1 and all I-80E traffic would be in lane 2.

The second critical lane placement section is denoted B-B in Figure 16 and corresponds to the location of the overhead sign bridge visible in Figures 2, 3 and 4. As vehicles pass under this sign bridge all opportunity for sign message communication with the driver is gone. Changes in lane placement required in order for the driver to maintain route continuity at this point must be accomplished in about 450 feet or the driver is committed to the wrong route. At section B-B lane 3 is a full lane width available for use by traffic.

The third and final critical section was about 200 feet beyond the physical nose of the exit gore (designated section C-C in Figure 16). At this point each

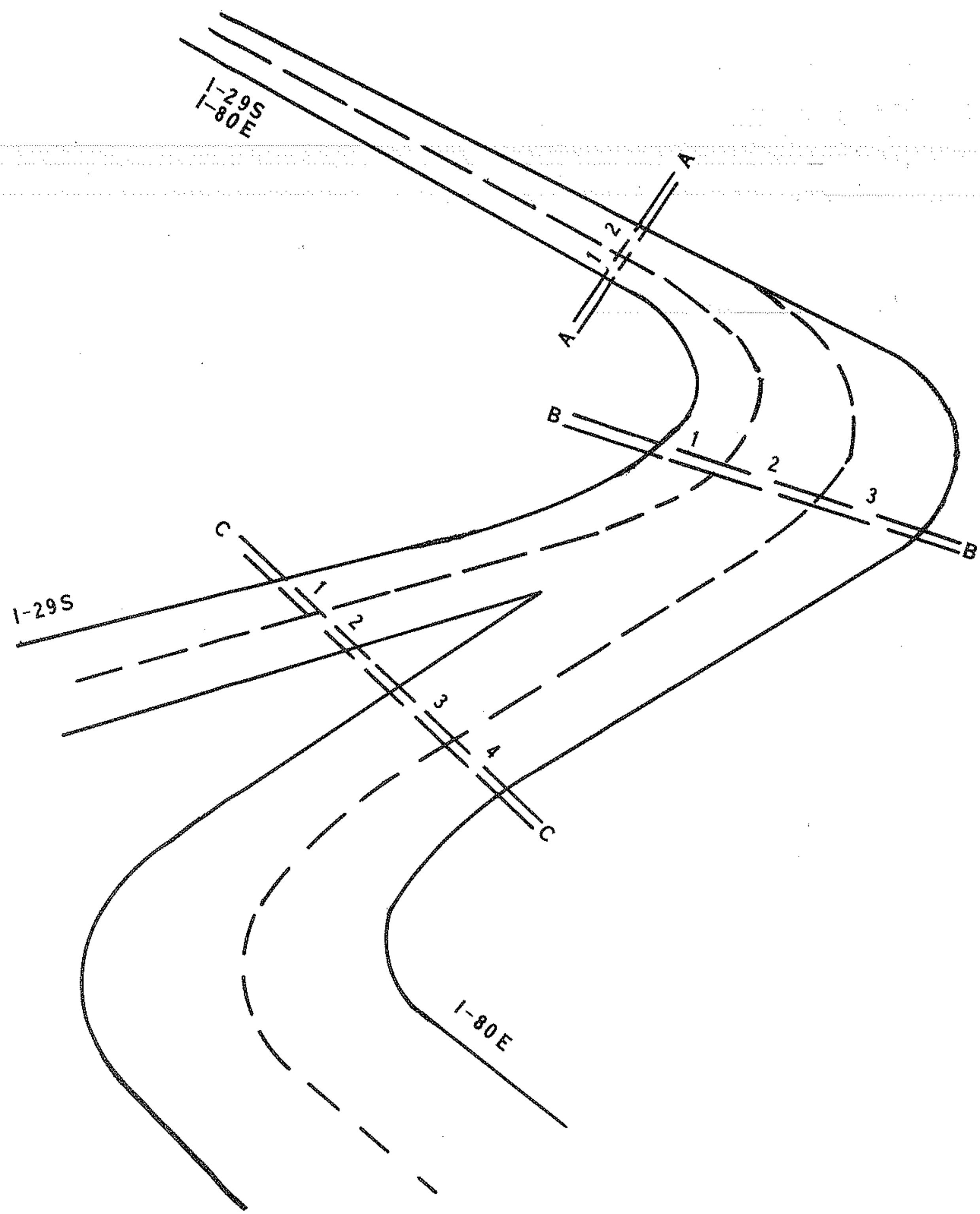


Figure 16. Study Site #1 Lane Designation and Identification Sections.

driver had positively completed negotiating the diverge. This section location was selected to coincide with a luminaire standard at the shoulder edge of lane 4. The lane 3 shoulder at section C-C at right angles to this luminaire was marked with temporary pavement striping tape. When a data tape was being viewed on the television monitor a line was drawn on a thin-film clear plastic overlay to positively mark the section. (A similar reference mark was placed on the lane 1 shoulder edge of section A-A opposite the end of the taper but was not utilized in the data reduction process.) Refer to report section 6 for video-tape demonstration narrative of examples.

Each vehicle was coded as its path was traced through the three sections. Thus, a vehicle coded as 112 was in lane 1 at section A-A, in lane 1 at section B-B, exited onto I-29S and was in lane 2 after passing the physical gore at section C-C.

All possible vehicular movements were identified as normal or erratic. Normal movements included vehicles which were in lane 1 at section A-A and exited to I-29S in a natural transition path in addition to vehicles which were in lane 2 at section A-A and exited to I-80E by a natural path.

Hazardous maneuvers were attributed to vehicles which entered section A-A in lane 1 and remained there through section B-B to subsequently exit to I-80E.

Vehicles which performed lane changing to complete a passing maneuver within the region bounded by sections A-A and C-C was designated as hazardous. Such maneuvers were considered hazardous even if no other vehicles were present in the area since the degree of "erraticness" indicates extreme driver uncertainty.

All other maneuvers were classified as undesirable. These maneuvers involved at least one change of lane considered to be erratic and having the potential under certain traffic flow conditions to produce accidents (incidents may be a better term). Table 2 contains the complete maneuver categorization developed with this logic.

2.1.2. Data Collected

The data collected were reduced by following each vehicle through the study site, identifying each vehicle classification as defined in Table 1, and classifying each maneuver as defined in Table 2. Study Site #1 data reduction results are contained in Table 3.

Table 2. Maneuver Designations at Study Site #1.

Movement Classification[1]		
NORMAL	ERRATIC	
	UNDESIRABLE	HAZARDOUS
111	121	113[2]
112	122	114
223	123	131
224	124	132
234	134	133
	211	213
	212	214
	221	231
	222	232
	233	

[1] Refer to Figure 16 for sketch of the I-29S and I-80E diverge.

[2] A vehicle which is in lane 1 at section A-A, in lane 2 at section B-B, and in lane 3 at section C-C (as denoted in Figure 16).

Table 3. Study Site #1 Traffic Maneuvers (I-29S and I-80E).

Date and Time	Tape	Movement Class	P		PT		SU		ST		M		Total	
			No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
7/26/73	1	Normal	215	85.0	7	2.8	11	4.3	19	7.5	0	0	253	77.6
8:05-		Undesirable	45	71.4	4	6.3	5	7.9	9	14.4	0	0	63	19.3
8:36 AM		Hazardous	8	80.0	0	0	0	0	2	20.0	0	0	10	3.1
7/26/73	2	Normal	261	78.9	11	3.3	28	8.4	30	9.1	1	0.3	331	78.3
10:00-		Undesirable	55	66.3	9	10.8	9	10.8	7	8.4	3	3.7	83	19.6
10:34 AM		Hazardous	6	66.7	1	11.1	0	0	2	22.2	0	0	9	2.1
7/26/73	3	Normal	263	75.1	26	7.4	19	5.4	38	10.9	4	1.2	350	80.1
10:38-		Undesirable	56	66.7	10	11.9	3	3.6	15	17.8	0	0	84	19.2
11:11 AM		Hazardous	1	33.3	2	66.7	0	0	0	0	0	0	3	0.7
7/26/73	4	Normal	389	82.1	13	2.7	30	6.3	36	7.6	6	1.3	474	82.3
3:30-		Undesirable	73	76.0	5	5.2	5	5.2	13	13.6	0	0	96	16.7
4:04 PM		Hazardous	4	66.6	1	16.7	1	16.7	0	0	0	0	6	1.0
7/26/73	5	Normal	508	86.2	8	1.4	19	3.2	42	7.1	12	2.1	589	86.2
4:15-		Undesirable	60	71.4	3	3.6	5	6.0	16	19.0	0	0	84	12.3
4:47 PM		Hazardous	5	50.0	1	10.0	0	0	3	30.0	1	10.0	10	1.5
7/26/73	6	Normal	689	92.1	9	1.2	17	2.3	29	3.9	4	0.5	748	88.6
4:55-		Undesirable	69	78.4	1	1.1	6	6.8	11	12.6	1	1.1	88	10.4
5:25 PM		Hazardous	4	50.0	1	12.5	2	25.0	1	12.5	0	0	8	1.0
7/27/73	1	Normal	258	84.0	10	3.3	16	5.2	22	7.2	1	0.3	307	78.7
8:05-		Undesirable	45	63.4	4	5.6	9	12.7	12	16.9	1	1.4	71	18.2
8:38 AM		Hazardous	9	75.0	1	8.3	1	8.3	1	8.4	0	0	12	3.1
7/27/73	2	Normal	250	80.4	13	4.2	17	5.5	29	9.3	2	0.6	311	77.0
10:00-		Undesirable	57	67.9	5	6.0	5	6.0	16	19.0	1	1.1	84	20.8
10:33 AM		Hazardous	7	77.8	2	22.2	0	0	0	0	0	0	9	2.2
7/27/73	3	Normal	279	81.6	17	5.0	17	5.0	29	8.4	0	0	342	76.9
10:38-		Undesirable	66	68.8	14	14.6	2	2.1	13	13.5	1	1.0	96	21.6
11:08 AM		Hazardous	5	71.4	2	28.6	0	0	0	0	0	0	7	1.5
7/27/73	4	Normal	448	85.0	18	3.4	26	4.9	28	5.3	7	1.4	527	85.0
3:30-		Undesirable	72	79.1	6	6.6	3	3.3	10	11.0	0	0	91	14.7
4:04 PM		Hazardous	1	50.0	1	50.0	0	0	0	0	0	0	2	0.3

Table 3 (Continued). Study Site #1 Traffic Maneuvers (I-29S and I-80E).

Date and Time	Tape	Movement Class	P No.	P %	PT No.	PT %	SU No.	SU %	ST No.	ST %	M No.	M %	Total No.	Total %
7/27/73	5	Normal	588	90.5	15	2.3	15	2.3	26	4.0	6	0.9	650	86.7
4:13-		Undesirable	81	82.7	5	5.1	5	5.1	7	7.1	0	0	98	13.1
4:45 PM		Hazardous	1	50.0	1	50.0	0	0	0	0	0	0	2	0.3
7/27/73	6	Normal	758	90.6	15	1.8	22	2.6	36	4.3	6	0.7	837	86.0
4:52-		Undesirable	98	79.7	9	7.3	3	2.4	10	8.1	3	2.5	123	12.6
5:26 PM		Hazardous	11	84.6	0	0	0	0	2	15.4	0	0	13	1.4
7/28/73	1	Normal	205	82.7	16	6.5	10	4.0	17	6.8	0	0	248	77.7
8:05-		Undesirable	46	69.7	9	13.6	3	4.5	8	12.2	0	0	66	20.7
8:37 AM		Hazardous	1	20.0	0	0	2	40.0	2	40.0	0	0	5	1.6
7/28/73	2	Normal	291	89.0	16	4.9	9	2.8	11	3.3	0	0	327	80.1
10:00-		Undesirable	54	74.0	8	11.0	4	5.5	7	9.5	0	0	73	17.9
10:32 AM		Hazardous	5	62.5	3	37.5	0	0	0	0	0	0	8	2.0
7/28/73	3	Normal	301	88.0	19	5.6	6	1.8	13	3.8	3	0.8	342	73.9
10:38-		Undesirable	81	71.7	10	8.8	3	2.7	19	16.8	0	0	113	24.4
11:11 AM		Hazardous	4	50.0	3	37.5	1	12.5	0	0	0	0	8	1.7
7/28/73	4	Normal	328	87.9	20	5.4	3	0.8	14	3.8	8	2.1	373	78.2
3:30-		Undesirable	85	86.7	3	3.1	0	0	5	5.1	5	5.1	98	20.5
4:02 PM		Hazardous	4	66.6	1	16.7	0	0	0	0	1	16.7	6	1.3
7/28/73	5	Normal	399	88.5	21	4.7	3	0.6	23	5.1	5	1.1	451	85.9
4:12-		Undesirable	61	85.9	1	1.4	1	1.4	8	11.3	0	0	71	13.5
4:46 PM		Hazardous	2	66.7	0	0	1	33.3	0	0	0	0	3	0.6
7/28/73	6	Normal	317	91.1	13	3.7	2	0.6	12	3.4	4	1.2	348	78.0
4:52-		Undesirable	70	73.7	7	7.4	3	3.2	11	11.6	4	4.1	95	21.3
5:25 PM		Hazardous	2	66.7	0	0	0	0	1	33.3	0	0	3	0.7

2.1.3. Data Analysis Results

2.1.3.1. Sample Consistency

A modified chi-square test was conducted to analyze the variation among data tapes and among sample days. A separate analysis was run for "undesirable" maneuvers and for "hazardous" maneuvers. The calculated chi-square for "undesirable" maneuvers was 12.91 and for "hazardous" maneuvers was 16.28. Both chi-squares were not significant at the 5% level when compared to the theoretical value of 18.3. On this basis it was concluded that each day sample could be assumed to be a sample from a larger common population. Prior to collecting the data and conducting this analysis, it was presumed that Saturday traffic would be significantly different from week-day traffic.

2.1.3.2. Erratic Maneuvers

Figure 17 illustrates the variation in erratic maneuvers through time of day. The raw number of maneuvers have been converted to maneuvers per 1000 total volume vehicles to be consistent with previous Federal Highway Administration research. The higher level of erratic maneuvers in the early morning with the drop off later in the day and with the rise toward 5:00 p.m. (1700 hours) is typical. The p.m. peak erratic maneuvers not reaching as

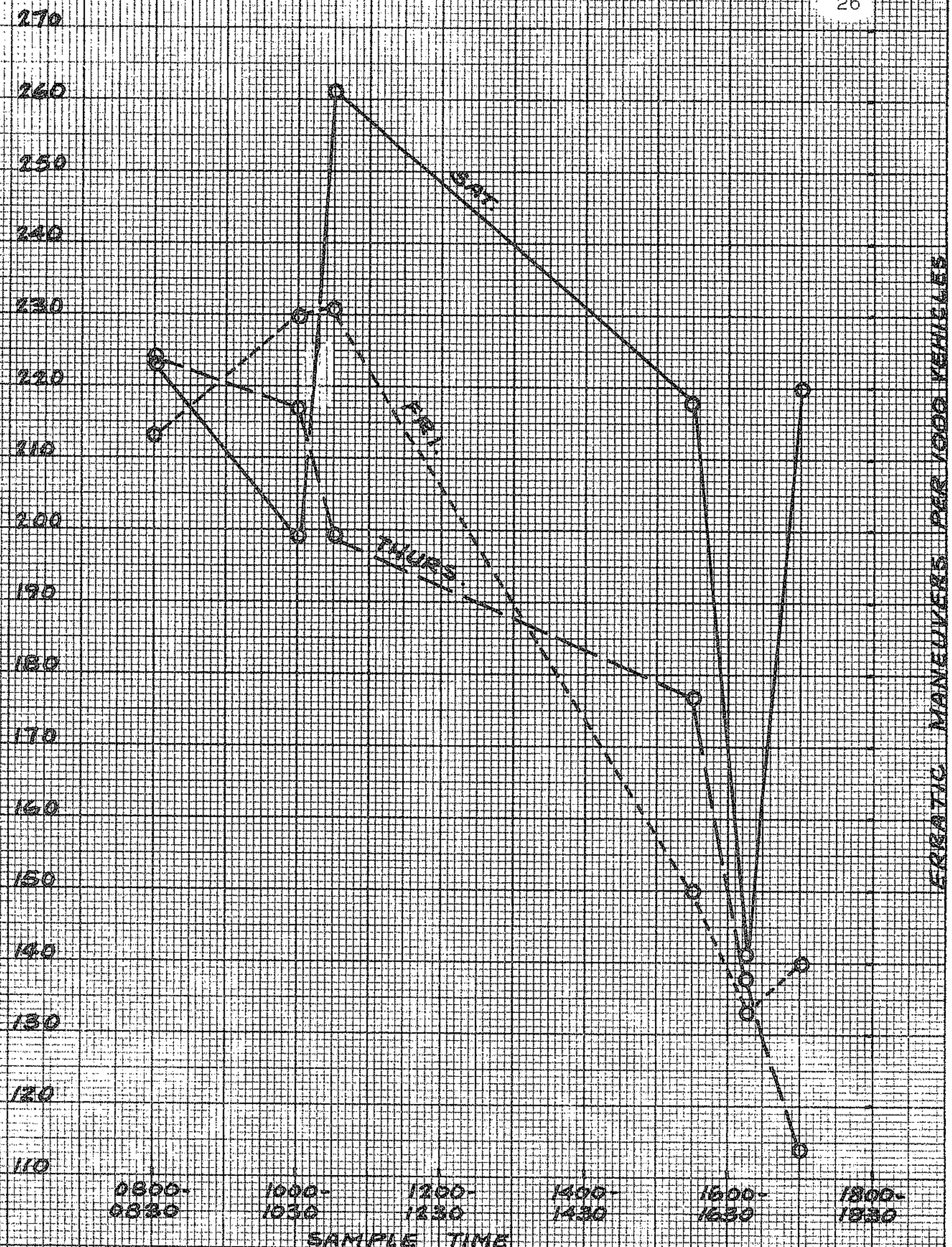


FIGURE 17A. ERRATIC MANEUVERS PER 1000 VEHICLES.

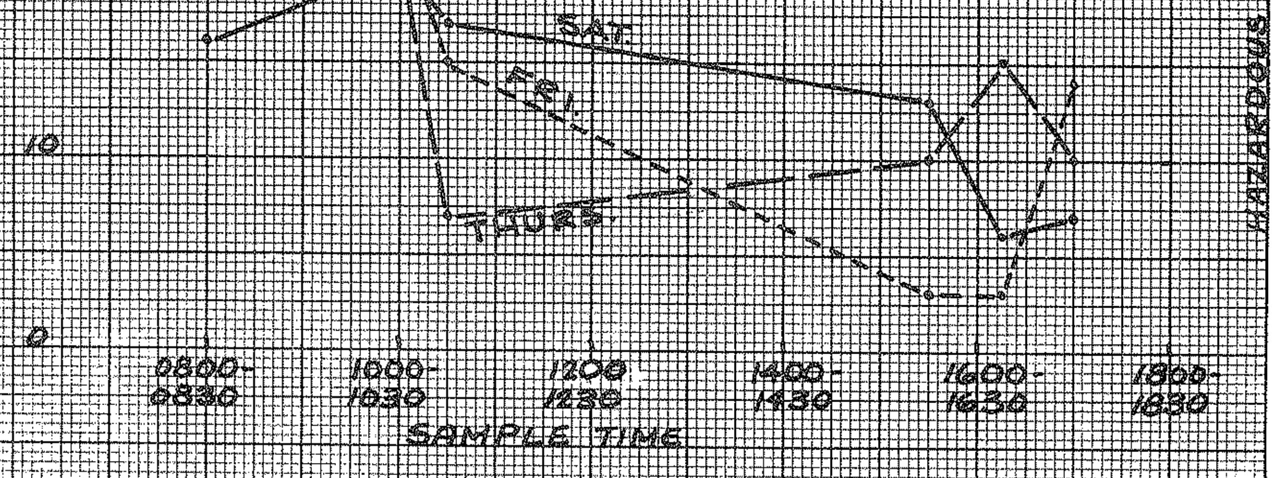


FIGURE 17B. HAZARDOUS MANEUVERS PER 1000 VEHICLES.

pronounced peak as in the a.m. is also typical. The presently accepted critical level of erratic maneuvers designated in this report as "hazardous" is generally taken to be 3% (30 per 1000 vehicles). The merge area is approaching a critical or problem state.

2.1.4. Summarization of Diverge Conflicts

2.2.4.1. Contributing Factors

Before discussing the present hazard several of the factors contributing to the hazard in general need to be mentioned. One factor in driver confusion for through travelers is that a driver on an interstate (through) route typically expects an exit to the right. Thus, I-80E drivers who interpret their route as exiting from the combined I-80E/I-29S route tend to be in the right most lane (lane 1) as they enter the merge area.

In the same manner, I-29S traffic which interprets I-29 as the through route tends to be in the left lane (lane 2) approaching the merge area. Fortunately, this traffic movement is primarily local at the highest conflict periods since I-29 is not yet open all the way to Kansas City, Missouri. When this connection is completed, the potential for misinterpretation of through and exiting can be expected to result in even more hazardous maneuvers.

The combined effect of the two above discussed driver expectancies is a criss-cross in the diverge area which is quite undesirable.

The parclo interchange at Iowa 192 just north of the diverge area is a contributing factor in two ways. First, it provides a freeway-over crossing of the crossroad and a rail yard adjacent to the crossroad. The vertical curvature of the freeway lanes over the crossroad and the rail yard combined with a curve to the right prevents unfamiliar drivers from viewing the sign bridge which precedes the diverge. The driver's attention is diverted from advance signing as he negotiates the interchange ramps at Iowa 192. Secondly, a concentration of truck stops and terminals on Iowa 192 in the vicinity of the interchange produces high-volume low-speed truck traffic entering I-29S/I-80E at this interchange. A significant proportion of the trucks entering the freeway are destined for I-80E and have difficulty weaving into the outside lane to exit until they are in the merge area. This creates special traffic operations problems for both the trucker and auto drivers who are intimidated by large trucks.

2.2.4.2. Present Hazard

As mentioned reference to Figure 17B, during the morning peak period the rate of hazardous maneuvers approaches the currently accepted critical level of 3%. Accident record report forms available at the Iowa State Highway Commission for accidents recorded through July 1, 1973 were examined. Those reports which documented the accident in sufficient detail to determine that the accident definitely occurred within the study interchange are noted on Figure 18. Only one accident could be identified positively near Study Site #1 (on Ramp B near station 2570 + 00). This supports the traffic movements analysis in that most of the time the rate of hazardous movement occurrence is low enough that the probability of collision incident is low.

The preceding discussion of the present hazard is somewhat misleading. Even though the "hazardous" maneuvers are a relatively small percentage of the flow at the present, the percent of the traffic entering the merge area in lane 1 (the outside lane) and exiting to the left on to I-80E is considerably

Figure 18.

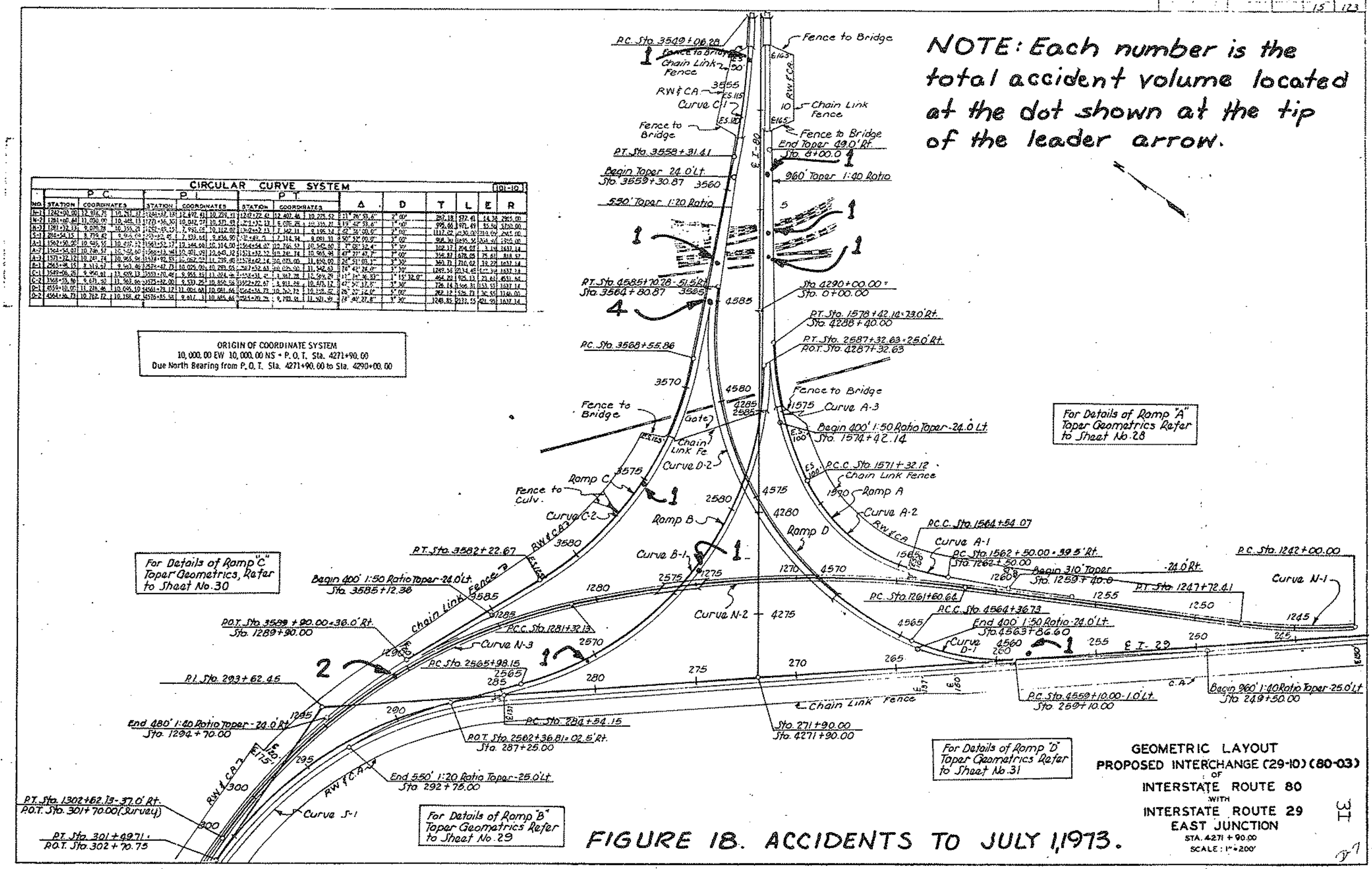


FIGURE 18. ACCIDENTS TO JULY 1,1973.

CIRCULAR CURVE SYSTEM (101-10)

NO.	P.C. STATION	P.C. COORDINATES		P.I. STATION	P.I. COORDINATES		P.T. STATION	P.T. COORDINATES		Δ	D	T	L	E	R
N-1	1242+00.00	12,974.79	10,261.37	1244+92.13	12,692.41	10,239.31	1247+72.41	12,407.46	10,275.52	21°26'53.6"	2°00'	287.18	572.41	14.38	2865.00
N-2	1261+60.64	11,030.99	10,443.13	1271+56.30	10,042.07	10,537.49	1281+32.13	9,076.25	10,355.22	19°42'53.6"	1°00'	995.66	971.49	85.96	5730.00
N-3	1281+32.13	9,076.25	10,355.21	1292+49.15	7,956.05	10,112.07	1302+62.13	7,342.31	9,195.34	42°24'00.0"	2°00'	1117.02	[illegible]	[illegible]	2865.00
S-1	284+54.15	8,739.42	9,946.09	293+62.45	7,933.08	9,836.90	301+49.71	7,316.74	9,091.31	50°52'00.0"	3°00'	908.36	1695.56	[illegible]	1910.08
A-1	1562+50.00	10,945.55	10,497.52	1563+52.37	10,844.66	10,514.00	1564+54.07	10,746.52	10,542.60	7°08'32.4"	3°30'	102.17	204.07	3.19	1637.14
A-2	1564+54.07	10,746.57	10,542.60	1568+13.94	10,401.39	10,643.32	1571+32.12	10,249.74	10,965.94	47°27'47.7"	7°00'	356.87	678.05	75.63	818.57
A-3	1571+32.12	10,249.74	10,965.94	1574+92.55	[illegible]	11,339.48	1578+42.14	10,073.68	11,690.02	25°51'03.1"	3°30'	360.71	710.02	39.22	1637.14
B-1	2565+98.15	9,319.67	9,563.46	2578+47.73	10,026.08	10,293.55	2587+32.63	[illegible]	11,542.63	74°42'24.0"	3°30'	1249.58	2134.48	[illegible]	1637.14
C-1	3549+06.28	9,960.61	13,439.13	3553+70.48	9,955.35	13,024.46	3558+31.41	9,347.28	12,569.29	11°38'36.5"	1°15'32.0"	464.20	925.13	23.61	4551.66
C-2	3568+55.86	9,671.52	11,563.66	3575+82.00	9,530.25	10,856.56	3582+22.67	8,911.24	10,475.12	47°57'12.8"	3°30'	726.14	1366.81	153.51	1637.14
D-1	4559+10.00	11,276.46	10,025.10	4561+78.12	11,004.68	10,081.66	4564+36.73	10,762.72	10,158.52	26°37'12.0"	5°00'	262.12	525.73	30.55	1146.00
D-2	4564+36.73	10,762.72	10,158.42	4576+85.58	9,617.31	10,585.66	4585+70.78	9,793.91	11,921.39	74°40'27.8"	3°30'	1248.85	2133.55	421.98	1637.14

higher as shown in Table 6. Not all these movements are hazardous at the present time due to the relatively low total volumes. These data provide a key to estimating the future level of hazardous maneuvers which, as the traffic increases to design volumes, may utimately approach 5 to 8 percent of the total traffic.

Table 4. Percent Total Traffic Entering in Lane 1 and Exiting I-80E.

	TAPE NO.						
SURVEY DATE	1	2	3	4	5	6	TOTAL
July 26, 1973	19.6	19.6	16.5	13.2	7.9	7.7	12.6
July 27, 1973	18.7	19.5	20.3	12.6	9.3	9.2	13.5
July 28, 1973	20.0	17.6	23.3	16.4	11.8	19.1	17.8

2.2. I-29 Northbound and I-80 Westbound Merge

This location is also denoted as Study Site #2 and has been previously referred to in Figures 7 and 8.

2.2.1. Definition of Conflicts and Hazard.

Conflict and hazard were defined on the basis of erratic maneuvers by vehicles negotiating the I-80W connection to I-29N. As the I-80W traffic entered the area where the painted channelization begins the lane placement of each vehicle was noted with the right-hand shoulder designated lane 1, the right-hand lane designated lane 2 and the left-hand lane containing the painted channelization designated lane 3 (refer to section A-A in Figure 19). Any vehicle located in lane 3 at this section is undesirable.

At section B-B the physical taper reduction of lane 3 begins. Any vehicle still located in lane 3 at section B-B was considered to be executing a hazardous maneuver.

Section C-C was located at the end of the physical nose of the merging area. Here at I-80W traffic had to be in lane 1 (shoulder) or in lane 2 since lane 3 was dropped. The I-29N lanes were designated 4 and 5 to account for the presence of I-29 traffic which conflicted (or potentially could) with the merging I-80W traffic. Some drivers execute hazardous and undesirable maneuvers by driving across the painted taper channelization at the merge and entering I-29 at a sharp angle. Such maneuvers are classified as either "undesirable" or "hazardous" depending upon the presence and location of vehicles in lanes 4 and 5.

Section D-D defines the final position of I-80W merging vehicles as they leave the merging area. Certain lane changing maneuvers between sections C-C and D-D are highly erratic. Table 5 lists the individual movements possible for I-80W traffic and classifies each movement. The *movement code for each* I-80W vehicle was similar to that utilized on the reduction of the diverge area data and is explained in Table 5.

2.2.2. Data Collected.

The data collected were reduced by following each

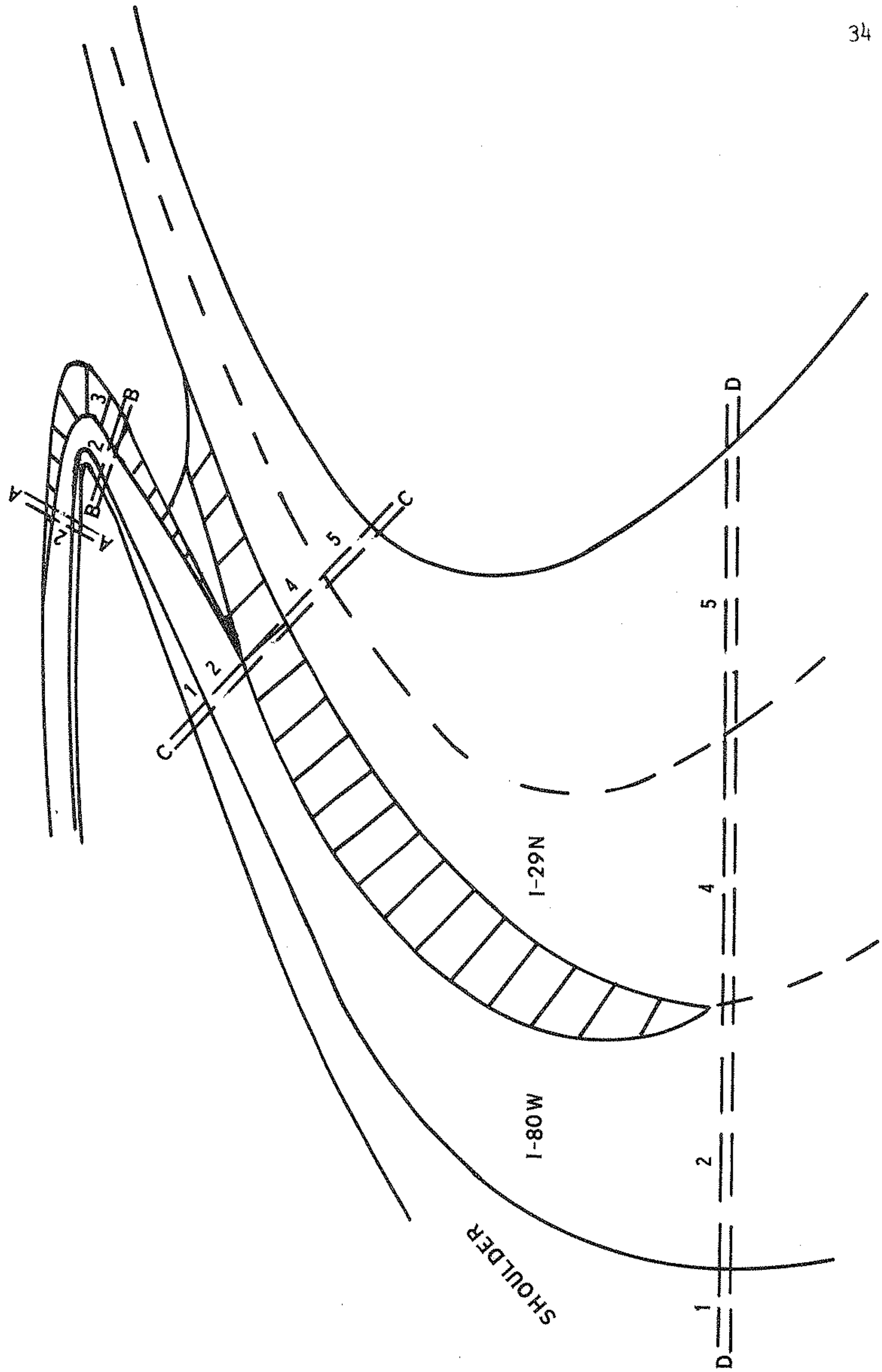


Figure 19. Study Site #2 Lane Designation and Identification Sections.

Table 5. Maneuver Designations at Study Site #2.

Movement Classification[1]		
NORMAL	ERRATIC	
	UNDESIRABLE	HAZARDOUS
2222-ANY	2224-00[2]	2225-ANY[3]
	3224-00	2322-ANY
	3222-ANY	3322-ANY
		2324-ANY
		2325-ANY
		3225-ANY
		3324-ANY
		3325-ANY
		3224-ANY[4]
		2224-ANY[5]

[1]Refer to Figure 19 for sketch of the I-80W and I-29N merge.

[2]A vehicle which is in lane 2 at section A-A and continues in lane 2 through sections B-B and C-C, but changes to lane 4 in exiting the area at section D-D, with no I-29N traffic in lanes 4 or 5 as the vehicle reached the merge area.

[3]ANY = an I-29N vehicle in either lane 4 or lane 5 as the I-80W vehicle negotiates the merge area.

[4]Exclude the maneuver 3224-00.

[5]Exclude the maneuver 2224-00.

I-80W vehicle through the study site and identifying lane placement at each section. Table 6 contains a listing of the summarized classified maneuvers for each data sample both by total traffic and subdivided by classification of vehicle performing the maneuver.

2.2.3. Data Analysis Results.

2.2.3.1. Sample Consistency.

Applying the modified chi-square test to analyze the variation among data tapes and among sample days yielded a different result at Study Site #2 than previously discussed with respect to Study Site #1. Analysis of "undesirable" maneuvers produced a calculated chi-square of 66.17 and analysis of "hazardous" maneuvers yielded a value of 51.57. Both of these values are highly significant when compared to the theoretical chi-square distribution (5% level of error chi-square is 18.3). Thursday appears to be a highly deviant data sample day with respect to Friday and Saturday. However, when Thursday data was deleted the calculated chi-squares still indicated significant differences between Friday and Saturday data for both undesirable and hazardous maneuvers. Even when hazardous and undesirable maneuvers are grouped together as "erratic" maneuvers the variation among sample days is highly significant.

Table 6. Study Site #2. Traffic Maneuvers (I-80W and I-29N).

Date and Time	Tape No.	Movement Class	Percent of Movement Class					TOTAL	
			P	PT	SU	ST	M	No.	%
8/2/73 7:36- 8:06 AM	1	Normal	70.8	20.1	2.7	5.9	0.5	219	69.3
		Undesirable	75.8	14.5	3.2	4.8	1.6	62	19.6
		Hazardous	85.7	5.7	0	8.6	0	35	11.1
8/2/73 8:11- 8:41 AM	2	Normal	64.0	10.3	11.0	14.7	0	136	65.7
		Undesirable	70.0	10.0	12.5	7.5	0	40	19.3
		Hazardous	83.9	6.5	3.2	6.5	0	31	15.0
8/2/73 8:46- 9:16 AM	3	Normal	69.1	9.6	5.3	15.4	0.5	188	81.0
		Undesirable	60.7	10.7	0	25.0	3.6	28	12.1
		Hazardous	81.3	0	6.3	12.5	0	16	6.9
8/2/73 11:00- 11:30 AM	4	Normal	60.0	15.1	8.4	15.6	0.9	225	88.2
		Undesirable	70.6	17.6	0	11.8	0	17	6.7
		Hazardous	76.9	7.7	0	15.4	0	13	5.1
8/2/73 3:30- 4:00 PM	5	Normal	74.0	13.2	5.8	4.5	2.5	242	81.5
		Undesirable	60.9	4.3	8.7	17.4	8.7	23	7.7
		Hazardous	75.0	12.5	3.1	6.3	3.1	32	10.8
8/2/73 4:05- 4:35 PM	6	Normal	73.4	11.4	4.6	9.5	1.1	263	85.1
		Undesirable	75.0	6.3	6.3	12.5	0	16	5.2
		Hazardous	90.0	10.0	0	0	0	30	9.7
8/3/73 7:53- 8:23 AM	1	Normal	66.2	16.0	3.7	13.7	0.5	219	82.6
		Undesirable	75.0	5.0	5.0	15.0	0	20	7.5
		Hazardous	69.2	19.2	0	7.7	3.8	26	9.8
8/3/73 8:30- 9:00 AM	2	Normal	68.5	14.9	2.8	13.8	0	181	85.4
		Undesirable	90.9	0	0	9.1	0	11	5.2
		Hazardous	75.0	10.0	0	15.0	0	20	9.4
8/3/73 9:05- 9:35 AM	3	Normal	65.4	15.7	6.5	11.9	0.4	185	84.9
		Undesirable	54.5	9.1	9.1	27.3	0	11	5.0
		Hazardous	72.7	18.2	0	9.1	0	22	10.1
8/3/73 11:00- 11:30 AM	4	Normal	68.3	13.9	6.3	11.5	0	252	84.3
		Undesirable	81.5	3.7	7.4	7.4	0	27	9.0
		Hazardous	75.0	20.0	5.0	0	0	20	6.7
8/3/73 3:30- 4:00 PM	5	Normal	70.7	14.1	5.7	9.2	0.4	283	83.0
		Undesirable	71.4	14.3	14.3	0	0	14	4.1
		Hazardous	84.1	11.4	2.3	2.3	0	44	12.9
8/3/73 4:05- 4:35 PM	6	Normal	74.4	13.7	2.8	8.1	1.1	285	78.9
		Undesirable	83.9	12.9	0	3.2	0	31	8.6
		Hazardous	68.9	8.9	4.4	15.6	2.2	45	12.5
8/4/73 8:02- 8:32 AM	1	Normal	67.8	17.5	3.5	11.1	0	171	85.5
		Undesirable	56.3	18.8	0	25.0	0	16	8.0
		Hazardous	100.0	0	0	0	0	13	6.5
8/4/73 8:37- 9:07 AM	2	Normal	72.6	10.4	6.6	9.9	0.5	212	86.9
		Undesirable	76.9	23.1	0	0	0	13	5.3
		Hazardous	100.0	0	0	0	0	19	7.8

Table 6 (Continued). Study Site #2. Traffic Maneuvers.

Date and Time	Tape No.	Movement Class	Percent of Movement Class					TOTAL	
			P	PT	SU	ST	M	No.	%
8/4/73 10:25- 10:55 AM	3	Normal	75.2	11.6	3.0	8.3	2.0	303	80.6
		Undesirable	76.7	3.3	0	20.0	0	30	8.0
		Hazardous	88.4	4.7	2.3	4.7	0	43	11.4
8/4/73 11:03- 11:33 AM	4	Normal	75.2	11.4	2.2	11.1	0	315	81.8
		Undesirable	76.2	9.5	0	14.3	0	21	5.5
		Hazardous	85.7	8.2	2.0	4.1	0	49	12.7
8/4/73 3:25- 3:55 PM	5	Normal	70.5	18.3	2.4	7.2	1.6	251	81.8
		Undesirable	88.9	11.1	0	0	0	18	5.9
		Hazardous	78.9	18.4	2.6	0	0	38	12.4
8/4/73 4:00- 4:30 PM	6	Normal	75.4	15.8	1.5	5.0	2.3	341	82.2
		Undesirable	75.0	12.5	0	12.5	0	16	3.9
		Hazardous	81.0	13.8	0	3.4	1.7	58	14.0

On the basis of the foregoing discussion, it was concluded that in the merge area where I-80W joins I-29N the conflicts within the I-80 ramp are highly dependent upon the time of day and day of the week. Thus, the relative and absolute success of any counter measure intended to reduce or lessen the severity of conflicts will depend in part on the frequency of occurrence of the erratic maneuvers associated with the specific conflicts the counter-measures are supposed to correct.

2.2.3.2. Erratic Maneuvers

Variation in erratic maneuvers throughout the day as a rate (maneuvers per 1000 total volume vehicles) is shown in Figure 20A. The Thursday pattern is the type of pattern expected for Monday through Thursday with a very high rate in the morning peak-period traffic flow followed by a low level during the middle of the day with a moderate increase during the evening peak period. Friday mornings are expected to be only <u>slightly</u> different from Thursday mornings. However, the data sample was significantly different. No explanation is available. The higher rate of erratic maneuvers during the Friday evening peak-period traffic flow is

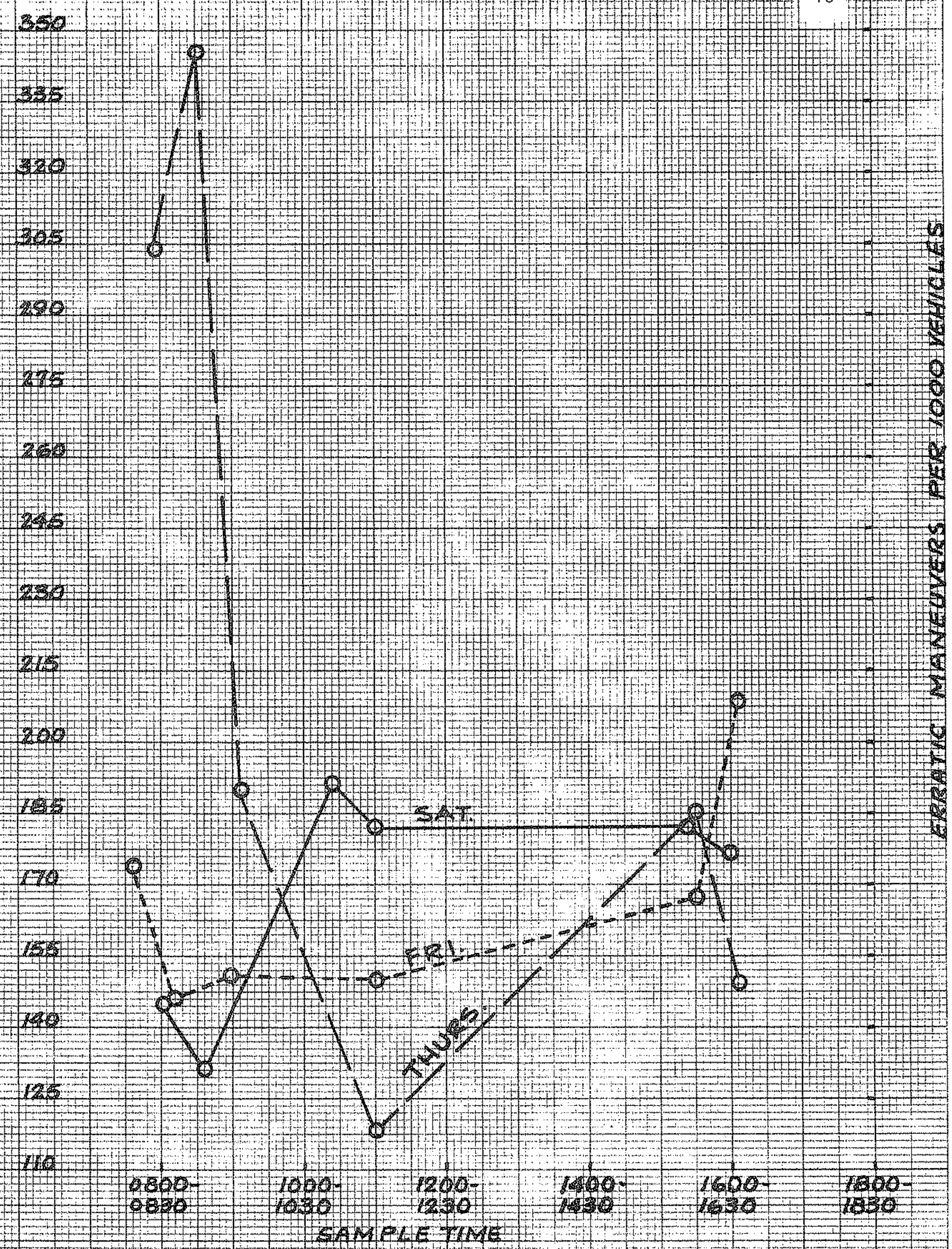


FIGURE 20A. ERRATIC MANEUVERS PER 1000 VEHICLES.

consistent with the commencement of weekend travel which adds hurried unfamiliar drivers to the traffic stream.

Variations in Saturday traffic erratic maneuver rates are consistent with expectations. Low rates during the morning peak with a quick rise to levels during the majority of the day which exceed weekday rates are expected due to shopping and recreation travelers not normally associated with the urban area on a weekday basis.

Hazardous maneuver rates are shown in Figure 20B. Patterns shown are more typical of expectations than the erratic maneuvers. Both Thursday and Friday follow a morning peak, mid-day lull and afternoon peak pattern. Saturday the hazardous maneuvers rise to a mid-day and afternoon peak level. While this trend is an acceptable pattern, the magnitude of the hazardous maneuvers is disturbing. The rate varies from five percent to fifteen percent of the total volume. Such a rate of hazardous maneuvering far exceeds the three percent rule-of-thumb problem level, and in fact, indicates a high risk traffic flow condition exists at various times during the day. Fortunately, the overall traffic volume is quite low.

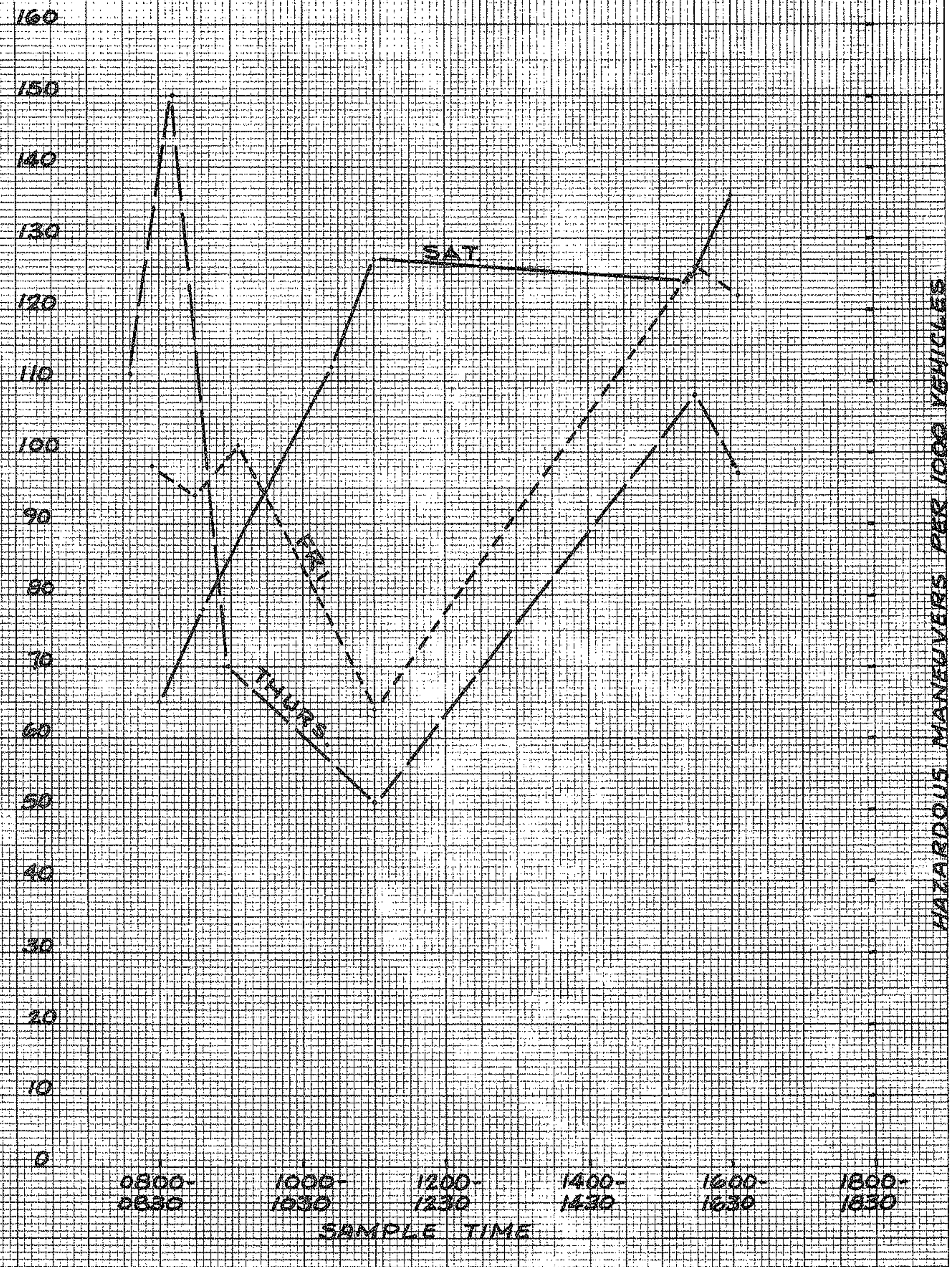


FIGURE 20B. HAZARDOUS MANEUVERS PER 1000 VEHICLES.

Figure 18 does indicate that three accidents have occurred within areas of conflict associated with the hazardous maneuvers (one at about Ramp C Station 3575 and two at about I-29N Station 1291).

2.2.4. Summarization of Merging Conflicts

2.2.4.1. Contributing Factors

The essence of the hazard/conflict associated with the merge area is that a full freeway marked route is dropped from two lanes to one lane in an interchange directional ramp on a curve to the right. Each of the previous descriptors represents a contributing factor. Driver expectancy in following a marked interstate route equals a minimum of two lanes for a uni-directional flow. Thus, when a transient Interstate 80 driver encounters his route narrowing to one lane he is faced with an unexpected driving environment. Secondly, dropping lanes within the interchange significantly increases the complexity of the driving task. Lane drop decisions and the driver tensions associated with such geometric changes are best made in open road "straight-pipe" freeway sections. Thirdly, the left lane is tapered out and dropped on a curve to the right. Centrifugal force of traversing the curve makes drivers tend to wander into the left lane and the left lane is normally associated with higher speed through movements. The combined physical laws and learned responses encourage unfamiliar drivers to be in the lane which is being dropped. Furthermore, since most of the approach to the lane drop area is on a bridge structure curving to the right, the visibility of the decision point is limited for advance warning.

2.2.4.2. Present Hazard

Previous discussion of Figure 20B pointed out the rate of hazardous maneuvers significantly exceeded the currently accepted critical level of three percent of the total volume. As previously noted three accidents have been recorded and reported in the vicinity of the lane drop and merge area that appear to be related to the traffic conflicts associated with erratic maneuvers.

Table 7 indicates that percent of the traffic using the I-80W ramp of the interchange which traveled on the painted channelization in the lane drop area and crossing the painted channelization in the merge area in conflict with I-29N vehicles. Some of these percentages, especially on the weekend travel, are quite high. As traffic volumes increase

Table 7. Percent Total Traffic on the Interstate 80 West Ramp Traveling on the Painted Channelization in the Left-Hand Lane and in the Merge Area in Conflict.

	TAPE NO.						
SURVEY DATE	1	2	3	4	5	6	TOTAL
August 2, 1973	4.1	8.6	6.0	3.5	8.7	8.7	6.6
August 3, 1973	6.4	6.1	9.2	5.7	9.1	11.4	8.2
August 4, 1973	5.0	7.7	11.7	10.9	6.2	12.3	9.6

these percentages can be expected to increase. Furthermore, since many I-80W vehicles crossed the merge painted channelization but did not do so when any I-29N traffic was in the merge area increases in I-29N traffic are anticipated to increase the conflicts and hazard. Consequently, while the present hazard is serious but not hypercritical, the present hazard can be expected to worsen rather than be alleviated by time (as discussed more fully later in this report).

2.3. Commonality of Merge and Diverge Conflicts.

Merge and diverge traffic movements are opposites in nature. However, the behavior of traffic flow at the I-29S/I-80E diverge and the I-80W/I-29N merge studied in this research have distinct common characteristics. In both cases, the horizontal and vertical curvature of the alignment obscure visual tracking clues which enable the driver to anticipate required movements. A driver then becomes "sign and pavement marking" dependent in roadway communication. In the absence of specific instructions to the contrary or in the case of signs "seen but not read nor understood," the driver follows the normal expectancy for the general highway environment (urban interstate route). Thus, at the diverge some drivers wanting to exit left are in the right lane and vice-versa. In a similar manner, drivers negotiating the entrance ramp curving to the right drive in the left lane to pass slower vehicles and/or to drive a curve of larger radius finding themselves in a lane drop. The common element is a complex geometric configuration violating general system expectations of the driver.

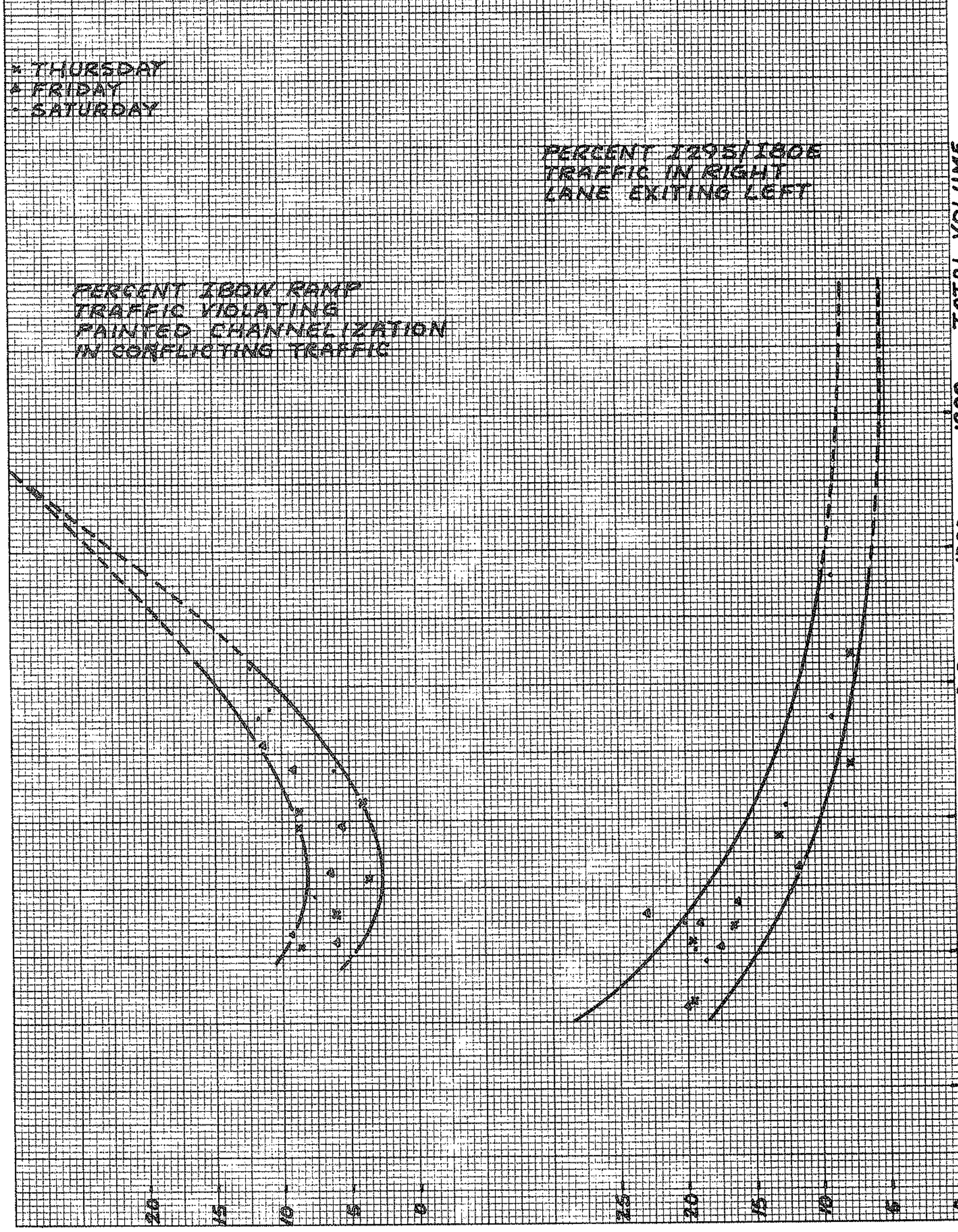
3. Estimate of Future Traffic Conflicts

3.1. Expected Magnitude of Conflict

The total number of conflicts per day, per week, per month or per year can not be predicted from the output of this research effort. However, for a particular hourly traffic flow an estimating relation does appear to exist for each site as shown in Figure 21. The data collected and processed in this research is sufficient to permit hypothesizing a trend relationship between the traffic volume approaching the conflict area and the percent of that traffic which will result in hazardous traffic conflicts.

At the I29S/I80E diverge area the data show a definite reduction in the percentage of traffic executing hazardous weaves to exit as the total hourly volume approaching the area increases. Extrapolating the trend band encompassing the central tendency of the data (dash lines on the plot) indicates the percent of traffic making a hazardous exit would stabilize at about five percent (5%) to eight percent(8%) as the approach

FIGURE 21. TRAFFIC VOLUME: CONFLICT RELATION



volume continues to increase. Increasing traffic density would make this magnitude of conflict quite a high accident potential area. This curve can be applied to forecast annual average daily traffic and factored according to hourly variations to yield a particular estimate of hazardous maneuvers for any desired time period.

At the I-80W/I-29N merge area the data indicate that at very low I-80W ramp hourly volumes a high percent of the ramp traffic violates the painted channelization in a hazardous manner, and then as the hourly ramp volume increases the traffic lane discipline increases followed by a sharp increase in hazardous behavior as the volume increases further. Extrapolating the upper and lower bound of the existing data indicates that, as the hourly ramp volume begins to approach the capacity of the single lane ramp terminal, the hazardous maneuvers might reach 30 percent of the ramp volume (dash lines). Increasing I-29N traffic will also contribute increased conflict by which the estimated relationship shown in Figure 21 may be a conservative estimate of the magnitude of the conflict within the I-80W traffic stream and between that stream and the I-29N traffic.

3.2. Expected Character of Conflict

As traffic volumes increase approaching the I-29S/I-80E diverge, the level of service can be expected to drop rapidly. Vehicles in the right-hand lane desiring to exit left can be considered functionally to be weaving. Since the length of section over which such a maneuver may take place is relatively short (500-800 feet) each vehicle executing such a maneuver can be expected to have an effect on level of service equal to about three straight through vehicles. (Refer to "Highway Capacity Manual - 1965," Highway Research Board Special Report 87, Chapter Seven.) When the traffic demand becomes sufficient to produce congestion in the bifurcation area, it is anticipated that the slow speed conflicts may generate shock waves back upstream. Such phenomena have been observed and studied on freeways in Detroit and Houston. The slow speed trucks entering upstream of the diverge area increase the potential for shock waves whenever any significant traffic densitites exist in the vicinity of the bifurcation area. Traffic demands sufficient to develop traffic densities associated with severe congestion are generated by urban development and suburban commuting. The combined Omaha-Council Bluffs area is large enough in both population and area to create such peak-period congestion. Whether such congestion may in fact develop at this location is dependent upon residential land use and employment concentration patterns which are outside the scope of this research. Superficial observation during the conduct of this research indicates the potential for the land use changes necessary to intensify commuter patterns exits in the Council Bluffs area. If no significant congestion increase develops, the traffic conflicts at the I-29S/I-80E diverge will retain essentially the same conflict character presently manifested.

Increasing traffic volumes will not alter the character of the traffic conflicts associated with the I-80W/I-29N merge area. As traffic increases on the I-80W ramp and to a lesser known degree as I-29N traffic increases, the absolute and relative number of conflicts can be expected to increase, however, these will be "more-of-the-same." Consequently, what ever will improve traffic operations in this location now will lessen future hazards simultaneously.

3.3. Contingencies

Contingency considerations that may alter anticipated hazards in future traffic streams include the long term impact of petroleum limitations. Continued automotive fuel shortages, whether real or contrived, have encouraged the sale of motorcycles and small cars. Mixing higher percentages of small automobiles and motorcycles with very large trucks in the traffic stream could have both positive and negative benefits. Small cars and motorcycles are more maneuverable than full sized cars but the fatalities per collision would rise sharply.

Higher fuel prices and motor fuel shortages may reduce the competitiveness of land use patterns which encourage commuting. Thus, long term fuel shortages might curtail anticipated traffic increases.

Populations are rapidly stabilizing in the United States and many areas of the Great Plains (especially Iowa) are reaching zero absolute population growth. When population stabilizes person travel will increase only as individual mobility increases. Goods travel will increase only as the economy expands. Environmental quality standards and declines in the consumption base (population) expansion may slow the demand for goods movement further reducing the expected increase in traffic.

Contingency considerations discussed above are outlined to emphasize that the generation of travel on an interstate highway route is influenced by a number of factors. Some of the factors are totally beyond the planning control of either the state or the local community.

4. Alternative Solutions to Traffic Conflicts

The following are possible alternative approaches to improving the present traffic operation and/or relieving future potential conflict and hazard. The alternatives are not discussed in any order of rank or relative worth. Subsequent sections will explore the relative merit of the alternatives.

4.1. Study Site #1 (Interstate 29 South and Interstate 80 East Diverge).

1. Add an exclusive truck lane roadway from Iowa 192 (bridging over the railroad tracks parallel to Iowa 192) and then passing over Interstate 29 on bridge between Stations 280 and 285, then joining Interstate 80 as a righthand entrance ramp on grade between Ramp B Stations 2570 and 2575. (Refer to Figure 18.) The 1973 Federal Highway Act permits the construction of special roadways and lanes for exclusive truck use where the traffic operations would be improved and the general traffic flow expedited by such roadways. Such a roadway would remove all the slow speed trucks entering I-29S/I-80E at the interchange of Iowa 192 from the right hand lane. A significant volume of weaving traffic would thereby be removed from the bifurcation area. It would not significantly contribute to the removal of other erratic maneuvers associated with driver error and

driver expectancy which conflicts with the roadway geometry. The need for truck lanes is associated with industrial/commerical land use concentration and/or truck terminals. Thus, any investigation of the desirability of development of truck lanes should include land use analysis of the traffic generators in the vicinity of the Iowa 192 interchange.

2. The Iowa 192 entrance ramp to I-29S/I-80E could be closed on either a temporary or a permanent basis. If, in the future, traffic conflicts in the diverge area are regularly and repeatedly associated with the disruption of through traffic by slow speed traffic entering a higher speed flow, the entrance ramp could be legally closed during these time periods every day. Such practices are now common freeway control measures and have been used in Houston, Detroit, Chicago, Kansas City and Los Angeles. Removing the side friction of an entrance ramp allows the through driver to concentrate more fully on his primary task of negotiating the main freeway.

   If the entrance were to be closed on a permanent basis, the interaction of adjacent interchanges would have to be considered. The outer connector exit from I-29S/I-80E to Iowa 192 might lead to wrong way entrances if no entrance was available at a partial interchange. Thus, if the entrance ramp is considered for permanent closure the possibility of removing the <u>entire</u> interchange should be evaluated. In order to provide the opportunity for drivers to make any movements that might be eliminated by permanent ramp closure, parallel frontage roads should be developed connecting Iowa 192 with the full diamond interchange north of the Iowa 192 interchange. Since the plan/design process has not been able to accurately predict how a constructed facility will operate, several major communities have removed ramps which contributed significantly to undesirable traffic operations (for example Houston, Kansas City and Chicago).

3. Designate the left lane of the approach for I-80E traffic only and the right lane of the approach for I-29S traffic only. At the present time the sign legends convey only an advisory meaning of lane placement that is desired to facilitate diverging maneuvers. The majority of the erratic maneuvers at the diverge area could be eliminated by communicating to the drivers the urgency of such lane placement prior to reaching the diverge area. Unless such communication took place well in advance of the interchange the erratic behavior would only be moved from one concentrated point to another.

4. Carry the third lane added at I-29S Station 292+75 back to the vicinity of the bridge over Iowa 192 and the railroad tracks. Since the bridge over Iowa 192 is three lane to accomodate two through lanes and the entrance ramp acceleration lane the freeway would become a 2 to 3 to 2-2 split lane configuration. By resurfacing to remove the delineation effect of pavement joint patterns the roadway could be so marked with lane lines. The economic costs of such an alternative are obvious but the benefits in improved

traffic operations are tenuous. It is not at all obvious that such modification would significantly alter the lane distribution of vehicles in a manner that would reduce the hazardous maneuvers. If some I-29S traffic continued to drive in the left most lane of the approach presuming their route to be the through route and anticipating right hand exit for I-80E, then such vehicles would be even more of a hazard in future traffic than they are now.

5. Use a diagrammatic sign as advance warning indicating a major route fork with I-80 diverging to the left and I-29 diverging to the right. This diverging major route fork is one geometric configuration that is effectively communicated based on current research (1, 2, 3). A critical factor in considering such diagrammatic signing is the location of the sign. For maximum visual tracking effectiveness by the driver it should be located overhead. In order to eliminate confusion in identifying the interchange associated with the diagram it must be placed between the diverage area and the Iowa 192 interchange. Consequently, a limited travel distance is available in which the sign can be read, interpreted and action taken which is to result in a better traffic operation condition than exists today.

6. Advance signing of through lane designation. Between the diamond interchange at 24th Street and the Iowa 192 interchange advance signing could be installed designating the left lane for I-80 through traffic and the right lane for I-29 through traffic. Presuming most drivers would receive and understand the message the traffic maneuvering necessary

to redistribute the traffic into the proper lanes would take place in a straight, open, relatively flat freeway section with a minimum number of distractions. As traffic entered the freeway at Iowa 192 the vehicles would be joining the I-29 traffic stream. Any vehicles that entered I-29S/I-80E at Iowa 192 destined for I-80E (primarily heavy trucks) could then use the roadway between the entrance and the diverge area to merge left into the I-80 traffic stream. Very few vehicles should be conflicting with such traffic by trying to weave right for an I-29S exit from the left lane.

4.2. Study Site #2 (Interstate 80 West Ramp Connection to Interstate 29 North).

1. Modify advance signing information on the I-80W ramp lane drop. To compensate for sight restrictions associated with horizontal curvature, vertical alignment and bridge structure components, the signing instructing drivers to merge right and informing them of the left lane ending can be modified to attempt to achieve better driver communication. Modification might take the form of larger signs, signs warning of a lane drop further in advance than now exist, and/or the addition of flasher units to signs. The effectiveness of any of these measures is expected to be quite limited with the exception of adding flashers. Static signing is frequently read and ignored as trivial information if the meaning is inconsistent with driver expectation. Sign flasher units might add enough dynamic character to yield a significant improvement in lane placement on the ramp lane drop.

2. Rumble strip the existing painted channelization associated with both the lane drop and the merge area delineation. Rumble areas, either sawed or scabbler cut, are significant driver control devices on freeways.

   Developing a rumble on the painted channelization in the ramp lane drop will not prevent drivers from being in the left lane so long that they begin to encroach on the channelization. However, once a driver enters the rumble area the disturbance will encourage him/her to merge right quickly. As such, this treatment does not correct the problem but solves the symptom.

   Rumble treatment in the merge area painted channelization should be highly effective in reducing a major source of hazard. Drivers forced into a single ramp lane who subsequently make an abrupt, sharp angle entry to I-29N by driving obliquely across the painted channelization would be discouraged from doing so as soon as their left tire encountered a rumble. Queueing discipline in merging should be significantly improved.

3. Make the ramp a full two lane connection and dropping one ramp lane in the ramp merge area taper carrying the other ramp lane over the Iowa 192 interchange bridge to either be dropped at the exit ramp or continued through the interchange to be dropped in the straight-pipe freeway section. Since a minimum of two lanes is the expectation of drivers while negotiating a marked interstate route, the two lane ramp would be consistent with driver expectancy. Dropping one of the two ramp lanes in the merge taper may not be

completely desirable but is more consistent with driver expectancy since at that time the driver has recognized the lesser status of his route when compared to the route being joined. Dropping another lane at an exit ramp is not necessarily condusive of smooth safe traffic flow upstream of the exit but it is normally more desirable than dropping the lane within an entrance ramp.

4. Change the ramp lane drop from a left lane drop to a right lane drop. As previously discussed, the laws of physics encourage the driver to use the left lane as well as unfamiliar drivers expecting the through traffic to be associated with the left lane. Furthermore, the visibility from within the vehicle is greater to merge left than to merge right. If paint or rumble strip channelization was used to merge the right lane into the left lane, the right hand shoulder of the roadway would remain as an escape route for any vehicle trapped during the merge process. Observing shoulder use by trapped vehicles would also provide a key to the desirability of proceeding to alternative three above. Changing from a left lane drop to a right lane drop requires examination of the pavement joint pattern. Resurfacing may be necessary to eliminate joint patterns which may delineate the original left lane drop.

5. Evaluation of Alternative Solutions

5.1. Study Site #1 (I-29S/I-80E Diverge)

The problem is fundamentally associated with through drivers being in the wrong lane, drivers failing to accumulate the proper information about route continuation (last second weave to exit), and slow trucks which entered at Iowa 192. It appears that most of the hazardous maneuvering can be eliminated by proper lane placement of the through drivers well in advance of the diverge area. Because driver communication is quite difficult to predict, alternative solutions that are relatively inexpensive, can be removed relatively easily if they are found to be ineffective after installation, and that hopefully have some salvage value if removed, should be pursued. Using these general guidelines the most promising alternative solution is to develop advance signing designating the left lane for I-80 through traffic and the right lane as I-29 through traffic (alternative six previously discussed). The second most desirable alternative is develop and install a diagrammatic sign identifying a major route fork.

The potential payoff from either of these alternative solutions is probably nearly equal. However, if the through traffic can be redistributed into the proper lanes prior to reaching the Iowa 192 interchange, then the only turbulence in the traffic stream between Iowa 192 and the major route fork will be due to slow trucks entering at Iowa 192 and destined to exit on I-80E. Since such trucks will be merging left, the transition should be as smooth as can possibly be attained without the installation of special truck lanes. Thus, alternative six previously discussed is preferred with alternative five being the second most desirable. Alternative five (diagrammatic sign) can be considered as a supplement to alternative six if so desired.

While it might appear that alternative three is equally acceptable, simply using the existing sign systems to designate lanes will not probably provide enough advance warning nor will it probably elicit a sufficiently positive response to alter the lane distribution in sufficient time to be effective. The present signing should be as effective as this alternate.

Alternative one (add a truck lane) and alternative four (extend the added third lane back further) both appear to be dealing with too small a proportion of the hazardous and erratic maneuvers. A substantial part of the hazard is not at all associated with heavy truck traffic. Adding lane width to the roadway immediately upstream will have the same effect as widening a weaving section. Examination of Chapter Seven of the 1965 Highway Capacity Manual indicates that to completely eliminate a weaving problem the section needs to be made very long, not wider. Alternative six would come closer to achieving this and should be much cheaper.

Alternative two (close the entrance ramp) might be helpful in estimating the effect of installing a truck lane. Temporarily closing the ramp could provide data on the potential to improve the traffic operations at the major fork at minimum capital costs before investing design time. Permanent closure of the ramp should only be considered a temporary step toward complete removal of the present Iowa 192 interchange as previously discussed. Such action involves a long term capital improvement program.

5.2. Study Site #2 (I-80W/I-29N Merge)

Traffic operations problems associated with Study Site #2 are related to basic design concepts. Thus, it is appropriate to here list the major findings of a recent research effort on interchange design (4):

(1) When the downstream traffic volume justifies a reduction in the number of through traffic lanes at a major interchange, the preferred location for the lane drop is beyond the influence of the interchange.

(2) There should be no reduction in the number of lanes through the interchange, except where economic considerations dictate.

(3) When a lane is to be dropped immediately beyond the exit terminal, the right through lane should always be dropped.

(4) When a lane is to be dropped beyond the influence of the interchange, the right lane is the preferred lane to be dropped; but the left lane may be dropped, particularly where a future continuation of the left lane is contemplated. An interior lane should never be dropped.

(5) The most important considerations in designing lane drops are to provide adequate visibility of the lane drop configuration and inform the driver of the impending situation. Therefore, lane drops should be on tangent alignment, preferably on sag vertical curves, and ample advanced signing should be provided.

(6) The taper at lane drops should be designed as acceleration lanes, with a minimum taper ratio of 50:1.

In light of the above concepts, alternative two should be considered for implementation to the extent that the merge area painted nose should be rumble treated to discourage the sharp angle entry of I-80W vehicles with I-29N flow. No other area should be rumble treated until a more fundamental decision is made regarding other alternative modification of the ramp lane drop.

If the ramp lane drop is to be retained, then alternative four should be implemented to change to a right lane drop. As previously discussed, this would provide a more natural vehicle path throughout the entire area and allow an escape route in case of driver error.

If the ramp lane drop is retained as a left lane drop as exists, then the rumble treatment on the ramp discussed in alternative two should be implemented. Additionally, it may be desirable to enhance the advance warning signing with flashers. Such modification could be done, if needed, after the effect of ramp rumble treatment was evaluated as it might not be necessary to add flashers.

As I-80W demand volumes increase, the level of service may drop during peak periods to a quality of flow in the vicinity of the ramp terminal that a single lane ramp may be unsatisfactory. Should continued decentralization and urban development in the fringe of Council Bluffs cause sharp peak period flows, producing ramp congestion on a regular basis alternative three would have to be implemented. Freeway control measures have been utilized on directional interchanges to improve the level of service before but the horizontal and vertical alignment of this ramp might make storage of vehicles on it condusive to rear-end collisions. Therefore, an analysis at the time such congestion began to develop would have to be conducted to see if freeway control techniques might be applicable. Freeway control techniques also have to be regarded as temporary measures which do not replace capital improvements but in many cases do improve traffic operations sufficiently to allow the basic facility to function for many years without major expansion.

6. Video Tape Techniques Documentation

6.1. Introduction

The portable video camera/recorder system is a versatile tool for the highway engineer. Its application may vary from the routine field inventory activity to the very sophisticated research project. The utilization of this system not only optimizes the performance of routine production operations, but in addition offers an opportunity for advancing the state-of-the-art in a rapidly changing technological environment.

There are certain basic applications of the system that can be directly applied to highway engineering:

6.1.1. The field environment can be rapidly and inexpensively transformed into the office/laboratory environment for the retrieval of operational data.

6.1.2. An isolated vantage point for the monitoring of operations (usually from an elevated or aerial position), can be obtained without detection from the motorist.

6.1.3. The data obtained for a primary activity (such as an inventory of operations) provides a secondary source of data for supplementary uses (such as research).

6.1.4. The system is especially adaptable to training or documentaries, being inexpensive, reusable, and requiring no previous operating experience.

Note that photography is not a viable alternative in most cases. The cost is prohibitive, the delay in film processing reduces the utility and the lack of flexibility in editing, dubbing in a sound track, and the one time use seriously limits the photographic media applications.

6.2. System Operation

The basic video system is composed of a camera, recorder, and monitor. The camera may be hand held, mounted on a tripod, mounted on a small platform placed across the dash and seat backs in a vehicle, or attached to a roadside telephone pole. The lens is interchangeable and may be wide angle, telephoto, or zoom and may have auxiliary lenses such as split (½ of the field) attachments. An aperature setting requires an initial adjustment with operational adjustments made electronically. A built-in microphone records sound on the tape automatically. An auxiliary microphone may be used at the recorder (with an extension cord) if the sound source is distant from the camera. An added feature allows new sound to be dubbed into a completed tape during the playback sequence.

The recorder is portable with a replaceable built-in 12 volt rechargeable battery. Each battery will operate 30-45 minutes. The tape is ½ inch wide and plays for 30 minutes in the black and white reel to reel model under discussion. Other types are available including cassettes and color. Note that extra battery energy time (over the 30 minute tape time) is generally necessary as energy is required when in the viewing mode when not actually recording. The controls are similar to the common audio tape recorders in use: play, rewind, fast forward and record. An auxiliary 110 volt power convertor source is available for non-portable use and for monitoring. This power source also functions as a battery charger.

When the recorder has the record-play levers depressed the system is activated and the small video tube (viewing screen) in the camera records the view. When the trigger is depressed on the camera the tape is transported and the scene is recorded. When it is desired to stop recording, the camera trigger is again depressed stopping the tape transport. To deactivate the system, the play lever is moved to stop and no energy is being used.

After rewinding, playback may be monitored through the eyepiece of the camera. Or, the recorder may be connected to the monitor for playback. (Note that the monitor may be attached to the recorder during the recording phase to view the scene being recorded on the tape.) While viewing a scene on the monitor, depressing the still lever stops the tape transport at any desired location. Micro movement of the tape may be effected by rotating the reels by hand.

An accessory is available to superimpose the date and time, as digital printing, on the tape during the recording. Also, the standard off-the-shelf recorder may be modified for time lapse mode.

The acquisition of traffic operations field data is a simple procedure. An individual with no engineering experience may be used with minimal instruction. The hand held camera with the portable recorder can be used from a parked vehicle carried in the hand, placed on a tripod, directed from an upper story of a building, or attached to a remote location telephone pole. The vantage point should desirably be an elevated position above the scene to be recorded, but an adequate vehicle volume record may be obtained from a ground level tripod. If data on the location and movement of of vehicles is desired an aerial vantage point becomes more important. The lateral placement, and the longitudinal travel time across pavement markers for example can only be observed from an elevated position.

6.3. Traffic Engineering Applications

The following examples are presented as illustrations of the video system's application to highway engineering.

6.3.1. Inventory or basic survey data acquisition (by one person).

- 6.3.1.1. Vehicle turning volumes at major intersections.
- 6.3.1.2. Video log/road inventory made from a moving vehicle.
- 6.3.1.3. Travel time data from a "floating car."
- 6.3.1.4. Long-term vehicle volume counts using time lapse mode (may be non-manned).
- 6.3.1.5. Observations for a bridge condition report.
- 6.3.1.6. Special inventory of traffic signs, driveways, billboards, junkyards, etc.

6.3.2. Monitoring traffic operations from an elevated position.

- 6.3.2.1. A video log from an aircraft of a construction project for a report on progress or for problem review.
- 6.3.2.2. A video record of major flood damage for emergency action decisions.
- 6.3.2.3. A video record of traffic operations during a congested period to identify problems and analyze solutions.

6.3.2.4. Surveillance of an accident prone location with time lapse mode from a remote camera attached to a telephone pole or a structure.

6.3.2.5. Pedestrian volumes and rates of movement which are difficult to obtain with mechanical devices.

6.3.2.6. Observations of parking lot operations from an adjacent building.

6.3.2.7. Recording license plate numbers for later retrieval and identification of vehicle origin.

6.3.3. Research applications.

6.3.3.1. Determine vehicle headways and starting delays for intersection signal/capacity analysis.

6.3.3.2. Obtain data for vehicle movement for short measured distances to establish acceleration and deceleration rates for different conditions.

6.3.3.3. Evaluate weaving lane operations on freeways.

6.3.3.4. Evaluate vehicle operation at freeway entrance and exit terminals.

6.3.3.5. Observe the effects of operational restrictions such as a ramp closure.

6.3.3.6. Compare spot speed studies obtained by radar as opposed to an unobserved video camera observation.

6.3.4. Video documentaries and training.

6.3.4.1. Relatively inexperienced personnel may prepare video training tapes to reduce the demand on their time for repeat type activities. An individual being trained may in fact gain from the ability to repeat the lecture or a portion thereof at his discretion.

6.3.4.2. A video record of a particular route, obtained through the windshield of a moving vehicle, can be used for communication with a city council, at a public hearing, and for review in the central (distant) office by planners and designers.

6.3.4.3. A documentary of a field problem (construction, operations, maintenance, or location for example) could be prepared for presentation to administrators, policy makers, or state government agencies.

6.3.4.4. Employee orientation programs.

7. Acknowledgements and References

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Reference was made to the following material during the conduct of this reported research:

1. Kolsrud, Gretchen S., "Diagrammatic Guide Signs for Use on Controlled Access Highways, Volume III," Final Report Contract DOT-FH-11-7815, December 1972.
2. Mast, Truman M., and Kolsrud, Gretchen S., "Diagrammatic Guide Signs for Use on Controlled Access Highways, Volume I," Final Report Contract DOT-FH-11-7815, December 1972.
3. Shepard, Frank, Informal communication and presentation, Human Factors Workshop, 53rd Annual Meeting, Highway Research Board Meeting, January 1974.

4. Taylor, James I., and Stockfish, Charles R., "Major Interchange Design, Operation and Traffic Control," presented at the Tulsa National Transportation Engineering Meeting of ASCE, July 9-13, 1973.

5. Highway Research Board, Special Report 87: Highway Capacity Manual, 1965, Washington, D.C. (1965).

6. Taylor, James I., Olsen, Richard A., Hayward, John C., Raymond, William L., and Hostetter, Robert S., "Major Interchange Design, Operation, and Traffic Control," Final Report, Contract DOT-FH-11-7795. (1973).

7. American Association of State Highway Officials, A Policy on Design of Urban Highway and Arterial Streets, 1973, Washington, D.C. (1973).

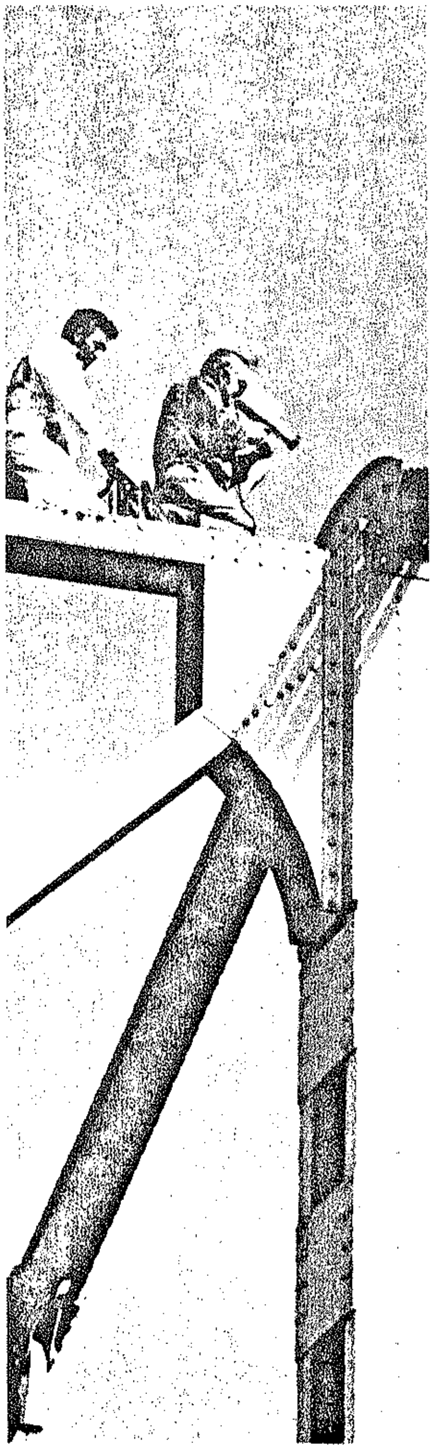
8. Leisch, Jack E., "Determination of Interchange Types on Freeway Facilities," Traffic Engineering, May 1972, pg. 16+.

APPENDIX

VIDEO TAPE

REFERENCE MATERIAL

Florida DOT Uses Candid Camera Technique



Tom Jones (left) and Chuck Owen climb 90 feet above the ground, photographing towers and cables on the Hal W. Adams Bridge, Florida's only suspension bridge.

Florida's Department of Transportation, which pioneered the use of underwater television cameras for bridge inspection, is now expanding the use of video-tape cameras in other problem areas.

Although the camera used for underwater photography is mounted in a waterproof casing and equipped with a special distortion-free lens, a standard Sony battery-powered television camera is used by the department for other inspections.

Simultaneously recording both audio and visual images on magnetic tape, the camera and battery pack weigh about 30 pounds.

To demonstrate its application to inspection methods, Chuck Owen, department engineer of structures maintenance, used the camera 90 feet atop Florida's only suspension bridge, the Hal W. Adams Bridge spanning the Suwannee River on Route 51 north of Mayo, Fla.

Climbing the 90-foot tower with District Bridge Inspector Tom Jowers, Owen photographed the cables. A fixed lens on the video camera is set to focus at three feet; however, an f16 64mm zoom lens brings more distant areas into sharp focus.

Following his descent, Owen was immediately able to view the film which was then taken to the district office for maintenance officials to inspect and returned to department's central office in Tallahassee where road operations officials could view the film.

The taped films can be stored indefinitely for later use in comparison studies, data analyses, training films, or for demonstration purposes.

Praising the system's versatility and reasonable cost, Owen said, "It's just a far superior method of communication. We can record our spoken impressions while the camera records actual facts, depths, reference points, and other pertinent data." •

Chuck Owen replays the video-tape bridge inspection report to State Highway Engineer P. W. Ekey, Deputy State Highway Engineer of Operations Bill Gartner, and Director of Road Operations Jay W. Brown.

Videotapes and Privacy

About 50 police departments in Iowa have videotape equipment which is used for various functions — auto accident investigations, police training programs, first-aid classes. Videotape films showing drunk drivers have been used to get convictions in many Iowa courts.

The Clinton Police Department has taken videotapes to schools to teach children about the dangers of jaywalking and the proper way to ride bicycles. Accident films taken by Dubuque police have led to corrective work on traffic hazards.

Nearly two-thirds of the police departments acquired their videotape equipment with funds provided through the federal Highway Safety Act. The law specifies that the equipment is to be used only for "traffic-dedicated purposes." Whether all the departments abide by the rule is uncertain. Departments in the bigger cities usually have videotape cameras for other activities as well as traffic enforcement.

Cameras are fixed in several places in Waterloo's police headquarters to film every stage of the booking process after a person's arrest. The videotapes show how the prisoner was treated, whether he was properly informed of his constitutional rights, whether an officer did anything to arouse an accusation of "police brutality."

Videotapes are gaining popularity with police officials because they are cheaper, easier to use and quicker to process than conventional motion picture film. But like other technological innovations in law enforcement, videotapes can be misused.

Last fall, for example, a detective testified in a trial that the Cedar Rapids Police Department kept files of videotape film from antiwar demonstrations and a picket line of strikers outside an industrial plant. Police in other cities have filmed rallies, riots and incidents considered potentially disruptive to public order.

Films of public disorders may be used to show how police reacted to a crowd of protestors. That was the explanation given by Cedar Rapids police officials. Did persons in the crowd taunt police? Did police antagonize the crowd, causing the disturbance they were sent to check? Did police use lawful means to control the crowd?

Once such questions have been answered and the possibility of legal action has passed, police departments hardly need to save the videotapes. The presence of a film file can have as much of an inhibiting effect on the First Amendment rights of free speech and free assembly as unverified information preserved in a police computer.

Citizens who attend public rallies or demonstrations in support of unpopular causes should not have to fear they are under police surveillance and that they may be under suspicion for years because of a film kept at police headquarters. Police should stick to enforcing the laws and leave past events to historians.

As Iowa legislators weigh the threat to privacy in unregulated police data banks, they might turn some of their attention to writing guidelines on the use of videotape and film. A person's privacy extends as much to an image on a film as it does to data in a computer.

PLANNING

Land-use reforms urged

"'No growth' is simply not a viable option" in the current debate over urban land use in America, reports a 12-member citizens' task force headed by Laurence S. Rockefeller.

"The case for more development does not come down merely to demography—to the fact that we must house the people who are already around or whose birth is foreseeable—nor even to any inevitability of economic growth," says the task force report. "There is also an ideal involved. Mobility has been a traditional road to opportunity in American life. Wholesale growth restrictions, imposed by many communities, could block the road for many who still most want to travel it."

Instead, the group urges major changes in land use decisionmaking because "we still have neither adequate institutional processes nor the necessary legal doctrine to attack the problems of urban growth."

As the best hope for getting states to initiate needed institutional reforms, the task force looks to the carrot-and-stick provisions of pending federal land-use legislation. (The Senate passed June 21 the Land Use Policy and Planning Assistance Act of 1973 by a 64-21 vote. The bill now goes to the House which failed to act on a similar Senate-passed measure last year.)

However, the task force concludes that specific decisions about the use of land should be left to the states and individual communities. The bulk of its report consists of recommended strategies—addressed selectively to citizen groups and all levels of government—for shaping policies that will insure rational development.

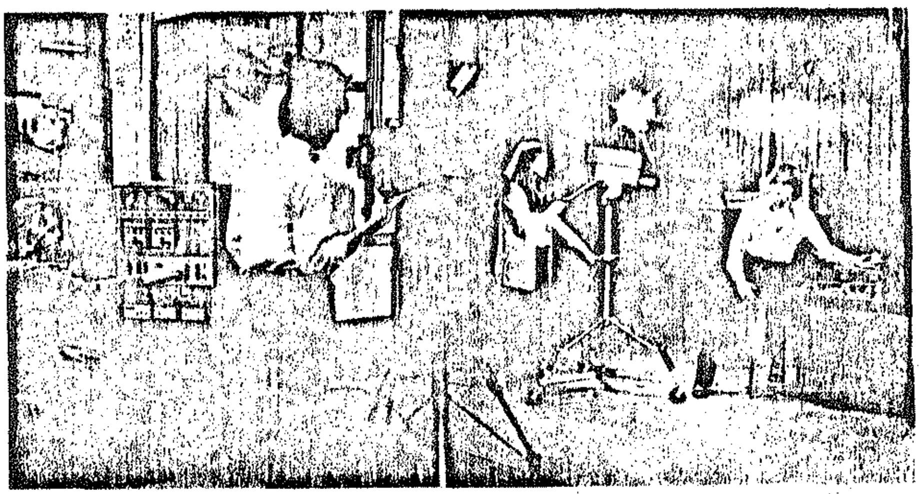
The task force says it detects "a new mood" among Americans which could provide the leverage for vast reforms in the way state and local land-use decisions are made.

Other recommendations call for a National Lands Trust to assist public bodies preserve green spaces in and around major urbanizing areas plus new laws to reduce conflicts of interest among officials.

Among the members of the task force were Mayor Pete Wilson of San Diego and John F. Collins, former Boston mayor and now consulting professor of urban affairs at the Massachusetts Institute of Technology.

Copies of the group's report, *The Use of Land: A Citizens' Policy Guide to Urban Growth*, sell for $10 hardcover and $3.95 paperback from Thomas Y. Crowell Co. of New York.

municipal news



Studio technicians ready equipment for Madison program.

Madison uses videotape for employee orientations

Madison, Wis., has videotaped its new employee orientation program to save instructor time, assure clarity and completeness, and provide the best mix of audio and visual information.

The 1½-hour program covers work rules, policies, and benefits found in municipal employment. It was conceived by Charles F. Reott, director of personnel. The idea for using videotape came from Rogers Littlejohn, the city's training officer.

The orientation programs are conducted weekly and usually only for a small group. It became apparent, the city says, that in-person presentations by city staff would be costly and instruction quality could decline because of the boredom of repetition.

The orientation program was taped in the Madison Area Technical College studio.

HOUSING

Urban homesteaders

Wilmington, Del., has enacted what is said to be the first urban "homestead plan" in the nation.

Under the plan, proposed by Mayor Thomas C. Maloney, vacant houses owned by the city will be given free to persons who are willing and able to rehabilitate them. A homesteader will be given 18 months to bring a house up to city code standards and must agree to live in it for three years.

The only preconditions of the agreement with the city are that the potential homesteader be 18 years of age, the head of a family, and a citizen or resident alien.

Under the ordinance, a Homestead Board will be appointed to oversee the program. Once selected, the homesteader will have technical assistance in the form of a specific listing of the work to be done, and advice on selecting a reputable contractor, cost estimates, purchase of materials, and actual performance of the work. The city owns about 50 houses.

Philadelphia also is considering a similar homestead plan.

BICENTENNIAL

1976 Program for cities

The American Revolution Bicentennial Commission unveiled a national program of "Bicentennial Communities" at last month's annual Conference of Mayors in San Francisco.

Invitations will be sent to the chief executive officer or governing body of 40,000 communities and Indian tribes throughout the nation advising them of the Bicentennial program. The program makes it possible for any community to be officially recognized as a Bicentennial Community and use the national Bicentennial symbol in conjunction with its commemoration of America's 200th birthday in 1976.

More information may be obtained from the ARBC, 736 Jackson Place, N.W., Washington, D.C. 20276.

Time-Lapse Television: A Highway Engineering Tool

OFFICE OF TRAFFIC OPERATIONS

Reported by WILLIAM T. BAKER, JAMES C. WILLIAMS,[1] and CHARLES W. DALE, *Highway Engineers, Traffic Performance and Analysis Division*

Introduction

THE continuing research of highway problems is highly dependent on traffic operations data. Unfortunately, many of the techniques used for data collection and evaluation do not fully satisfy the information requirements of today's highway control systems.

One of the most promising new tools for improving data collection, reduction and evaluation is closed-circuit television (CCTV).

Closed-circuit television may be distinguished from commercial broadcast television in that video is transmitted through coaxial cables rather than being broadcast from a transmitting tower. CCTV has been used by highway engineers in the following ways:

- *Real-time observation,* as in the surveillance of tunnels, freeways, and other places where it is desirable to respond immediately to emergency situations. For such uses, the minimum equipment necessary is the camera, coaxial cable, monitor, and power source.

- *Recording for playback,* as in the monitoring of impact attenuation devices for later detailed study. An additional component, the *video tape recorder,* is required for this use.

This article concerns the use of CCTV in recording for playback. For the highway engineer, video tape recording has much potential because of its relatively low cost and simplicity of operation. There has been, however, some disadvantage to this method for monitoring traffic operations because it takes as long to view a video tape as it does to record the data. Therefore, to make this kind of surveillance even more useful to highway engineers, viewing time should be reduced.

Time-lapse video for data collection and evaluation appears to be one solution to this problem. In time-lapse video recording, the tape speed is reduced, resulting in fewer recorded pictures. When the tape is viewed at the normal playback speed, the action is faster. The slower tape recording speed also permits longer periods of coverage with each reel of tape. For example, at a speed of 1:1, a 2,400-foot reel of video tape will last 1 hour; at 2:1, the reel will last 2 hours; etc.

To evaluate the use of time-lapse television for highway engineering, a study was conducted by the Office of Traffic Operations of the Federal Highway Administration. The objectives of this study were (1) to find off-the-shelf time-lapse video recording equipment which could be used for data collection, (2) to determine what information could be obtained from the time-lapse video tape, and (3) to test the use of the equipment at various highway locations. It was not the intention of this study to provide comprehensive analyses of operational traffic characteristics.

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[1] Mr. James C. Williams now is with the California Division Office, Federal Highway Administration.

Procedure

Traffic operations at gores, acceleration and deceleration lanes, weaving sections, mainline splits and other conflict areas were recorded in time-lapse to see if operational difficulties could be detected. When viewed at the normal playback speed it was readily apparent that the resultant fast action on the television monitor made it easier to spot sudden stops, lane changing, and other erratic maneuvers.

A recently completed ramp modification at the junction of two Interstate routes was taped for 5 hours at a recording speed of 5:1 both before and after improvements were made (a 5:1 ratio permits 5 hours of time-lapse recording to be viewed in 1 hour at normal speed) to see how the modification affected traffic operations. A total of 22 separate items of data were extracted from the tape, including traffic volumes per lane, number of weaving maneuvers, encroachments within the gore areas, vehicle classification, and pedestrian–vehicle conflicts. It was estimated that a crew of 10 men would have been required to obtain this data by conventional means in the field. Only one field man was necessary when the video equipment was used. Data reduction was accomplished by two men in the office in one 8-hour day, replaying the tape as many times as necessary to extract the desired information.

The ability to condense many hours of real-time operation into a relatively short viewing time suggested the use of time-lapse video for the surveillance of hazardous locations on low-volume roads. At these sites it is often difficult to determine accident causation because funds are not available to pay for skilled observers at these locations over long periods of time. The cost of observation could be reduced by using unattended television equipment. To test the equipment for this application, a hazardous rural intersection was monitored at a recording speed of 29:1 for an 8-hour period. At normal playback speed, maneuvers such as U-turns, backing up, and stop sign violations within the intersection were very apparent; however, a slower playback speed was necessary to count traffic volumes.

Urban intersection studies lend themselves particularly well to analysis by video tape if a satisfactory vantage point can be found. To determine usable information that could be obtained for this application, traffic operations at several urban intersections were recorded on video tape at recording speeds of 2:1, 3:1, and 5:1. When viewed on a television monitor, it was possible to determine lane volumes, turning movements, vehicle classification, and load factor. A measurement of delay proved to be more difficult to obtain with a single camera since queue lengths often extended so far in the distance that determining the number of individual cars stopped was difficult. Another camera mounted upstream in conjunction with readily available equipment that provides camera switching or split-screen capabilities might be a solution to this problem.

A tri-level interchange that was experiencing traffic operational problems was studied by four engineer-trainees using the video equipment. Examples of the problems were shown to a group of highway administrators. The presentation demonstrated that the operators of the equipment do not need extensive training and that recorded television is useful in presenting information to highway officials.

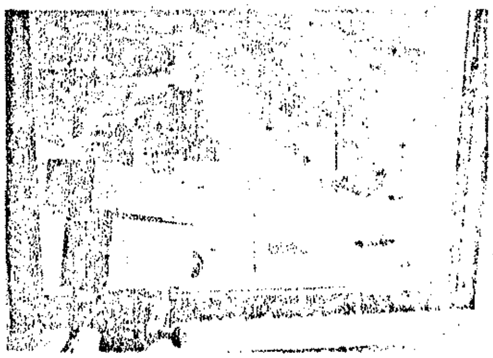
As the study progressed, the following potential uses for time-lapse video, in addition to those tested in this study, were suggested:

- Condensing construction activities (that is, at a recording ratio of 61:1, 40 hours of construction activity can be viewed in about 40 minutes).
- Evaluating the effectiveness of speed limit changes.
- Recording traffic movements through construction areas to evaluate the adequacy of construction signing.
- Continuous monitoring of impact attenuation devices.
- Recording pedestrian movements at intersections.
- Evaluating curbside parking.
- Evaluating the effectiveness of diagrammatic signs.
- Collecting traffic operational data—time headways, lateral placement—for research studies.

Equipment

In the early stages of this project it was found that only one available time-lapse video tape recorder featured more than two recording speeds. The video tape recorder used in this study was a 10-speed model which also has the provision for recording one field at a time. (In video recording, the word "field" denotes a very short length of recorded video tape and is synonomous with the word "frame" when discussing photographic film.) To complete the package, a video camera equipped with an f/1.5 zoom lens (22.5 mm.–90 mm.), was used in conjunction with a monitor.

The recording unit was designed to operate on standard 120-volt alternating current, but for most locations in this study standard power sources were not available. For these situations two 12-volt batteries were wired in parallel and used with a static inverter. Powered by batteries, the system can be operated continuously for 8 to 24 hours, depending upon the power requirements of the inverter and the ampere-hour rating of the batteries.



Results

With the limited amount of work done to date with time-lapse video, it is difficult to determine all of the possible applications for this equipment. Major advantages of using this tool are compressed viewing time and increased reliability of data. Other advantages include the provision of a permanent tape record and an opportunity for engineers in the office to view actual traffic operations.

Time-lapse video is particularly adaptable to the surveillance of intersections, interchanges, and other special highway locations. For example, at a recording speed of 5:1, events covering a 10-hour period can be viewed in the office in 2 hours at the normal playback speed. If nothing of interest is found, the recording tape can be erased and used again.

At sites with higher traffic volumes it was necessary to use the faster recording speeds (i.e., 5:1 and 3:1) so that when the tape was viewed at the normal play-back speed, vehicle motion was slow enough for a viewer to make vehicle counts and extract other data. For very light traffic volumes, operational difficulties could be detected at a recording speed of 29:1.

The selection of the proper vantage point from which traffic is to be viewed is important. It was learned early that it is desirable to mount the camera somewhat above and directly in line with the approaching traffic in order to pick up lane changing and erratic maneuvers. Volume counts were also easier to obtain when the approach was viewed at other than right angles.

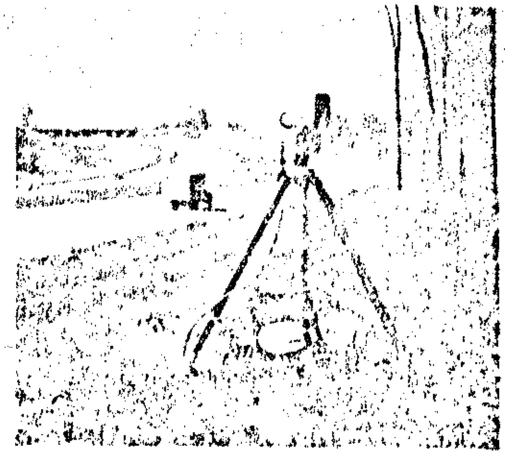
It was found that lane volumes, weaving maneuvers, classification counts, turning movements, load factors for signalized intersections, and erratic maneuvers could be counted in the time-lapse mode and that for the locations in this study this data could be extracted for analysis in approximately one-half the time required by conventional methods. In most cases, one man can set up the equipment. Data reduction can be accomplished by one or two men in the office reviewing the tape as many times as is necessary to obtain the desired information.

A recording speed of 5:1 is probably the most useful for traffic operational studies. When the tape is then played back at normal speed it is possible to record most of the information that is usually obtained from field studies using manual methods.

For several days of continuous surveillance, an unmanned installation would be advantageous. This would require a weather-tight and vandal-proof housing for the equipment.

In addition to the basic equipment used in this study, there is more sophisticated components available for special situations such as video recording at night, split-screening, multi-camera switching, and remote sensing.

For a tool such as time-lapse television to be used in the field, it must be highly portable and simple to operate. The equipment used in this study was, at times, somewhat cumbersome; especially when the camera and tripod, recorder, TV monitor, inverter, and two truck batteries had to be unloaded under heavy traffic condtions. A number of manufacturers now market lightweight two-speed recorders; however, all but one are designed for alternating current only, necessitating the use of inverters for conversion to direct current.



Conclusions

The use of time-lapse video recording equipment appears to be suitable for data collection and analysis in the highway engineering field. The time savings in data collection and reduction along with the increased reliability of the data would seem to justify the initial investment in equipment.

The Kansas City Police Department, which has been among the leaders in the utilization of such devices as the computer and the helicopter for actual law enforcement work, has added another dimension to its mechanized capabilities with the recent acquisition of two video tape (VTR) units for the Traffic Unit.

The VTR equipment, which consists of two cameras and two tape units, and obtained through funding offered by the Highway Safety Act, found a ready home in Kansas City. Capt. Robert J. Rennau, a member of the Traffic Unit, wasted little time in implementing the VTR and integrating it into the daily routine of the unit.

When first considering its use, command staff personnel had to consider whether to use the VTR for training purposes or as an enforcement tool. The final conclusion was to make the best of both applications.

The VTR thus far has been transported to accident scenes to record the actual handling of the situation. This information is later replayed for the benefit of new accident investigation specialists. The information recorded consists of proper traffic control around a serious accident, accident reporting and proper photographic technique. Previously it was necessary to place an Accident Investigation Unit (AIU) candidate in the car with the working officer and then wait for something to happen. Now the accident can easily be brought to the classroom.

Prospective AIU members are also given expert instruction in the proper use of the breathalyzer and in setting up radar. Here, again, instruction can be given en masse, rather than a time consuming one-to-one basis.

As an aid in intersection traffic control training, the VTR is proving extremely valuable. It might be pointed out, too, that while serving as a training device in this instance, it is also being utilized in the day-to-day activity. In Kansas City the professional sports of baseball and football are played at a Municipal Stadium and the arterial streets were not designed for the traffic load which is generated by a game. By focusing on the problem areas (some are more acute than others) with the VTR, traffic unit personnel are able to review problems and make necessary changes. In addition, traffic men are able to note individual problems and make the appropriate changes.

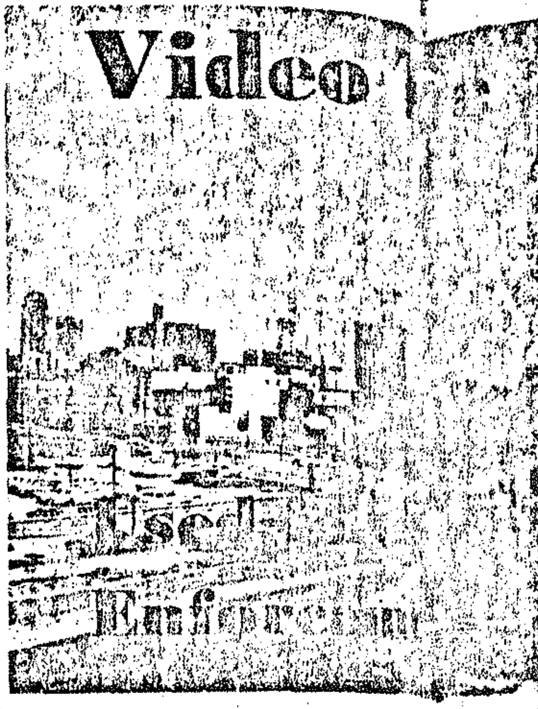
By filming several frenzied traffic days at the sports site, the traffic unit training personnel are able to take newcomers into the center of the action immediately so they are prepared when they must take up a corner on a given day.

As an enforcement aid, the VTR has yet to reach its full stature, but with every new application the vast potential is realized, or at least recognized, by the operators. It is currently being used to study hazardous intersections in an effort to pinpoint accident causation and to determine what type of enforcement is appropriate to control the situation.

The application mentioned is also beneficial in that the department has been able to graphically, not just statistically, illustrate a dangerous physical problem at an intersection. The proper traffic authorities, those responsible for design or redesign, are able to first-hand see the situation and make a determination on change.

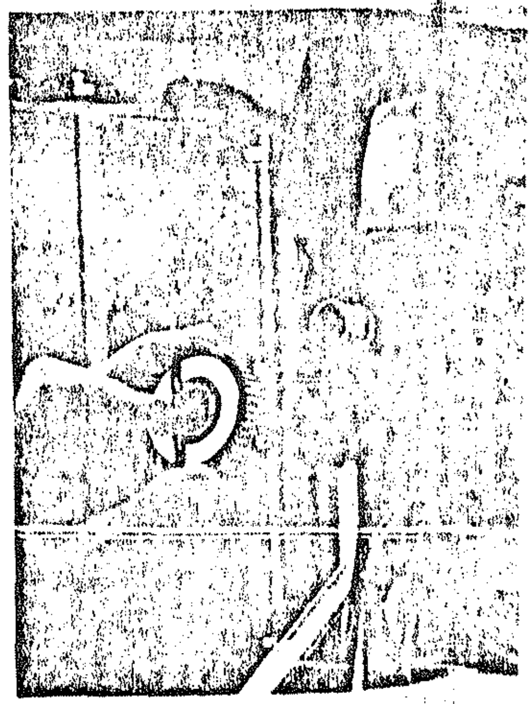
The VTR is also being utilized in high-accident areas in an effort to more nearly isolate the causes and provide enforcement personnel with an enforcement point.

An extremely practical use has been to tie the VTR into the department safety officer's lectures on driving safety. By the very nature of police work and the number of hours spent in a patrol car, officers are disproportionately prone to accidents. By reaching large numbers of officers through the VTR and by explicitly showing them the causes of accidents, it is the goal of the department to reduce the



by [illegible]wort[illegible]

A busy intersection in Kansas City is [illegible] the VT[illegible] J. Rennau. Traffic Unit personnel will [illegible] can be done to make the intersection [illegible] Here, a sergeant in the traffic unit [illegible] of the camera and, eventually a [illegible] coverage as well as extreme close[illegible]



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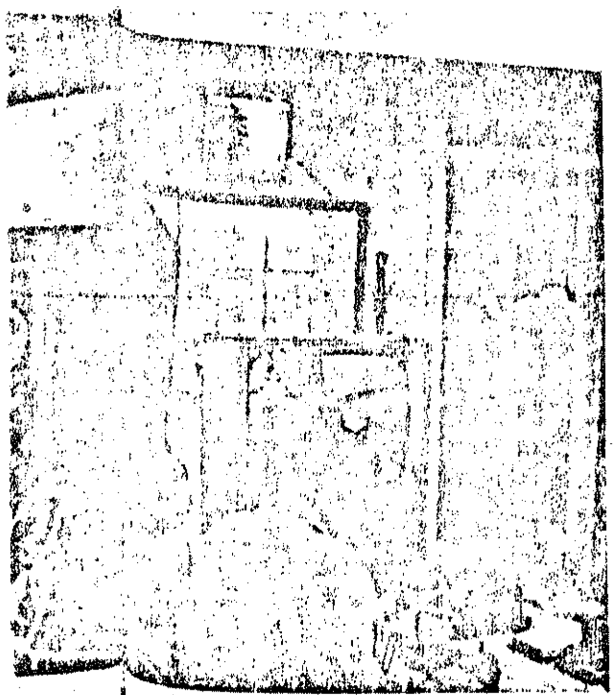

number of on-duty vehiculars.

It is also anticipated that the VTR will be brought into play when officers are handling an intoxicated arrest. Quite possibly the VTR will be used in court to show the actual accident scene, prevailing weather conditions and relationship of the involved vehicle to any pertinent fixed objects.

Another valuable use of the VTR has been the taping of the actions of school crossing guards (this department uses a number of civilians in this capacity, most of them retired persons) to show what errors they might be making in removing crossing signals from intersections or stopping cars themselves, an area of activity outside their designated duties.

In connection with this phase of the operation of the VTR system, the student crossing guards have also found themselves to be the subject of the traffic unit. Because of the ability of the unit to clearly record activity up to a block away, officers are able to surreptitiously document the actions of the youngsters and then later show them their shortcomings. As a result of not knowing when the unit is around, the youngsters are now nearly letter perfect in the crossing guard procedure.

A new and practically untouched area of use for the VTR is the coupling of the unit with the helicopter. By placing the camera and allied equipment on board the 'copter, the officers are able to record hazardous intersections, traffic jams and any other traffic problems, all from a vantage point well out of the way of ground traffic.

It should be obvious, by now, that traffic is not the only area where the VTR will be used to great advantage. In the daily fight with crime it will be extremely valuable as a surveillance tool.

The training aspects of the VTR have also been considered by Col. C. M. Kelley, Chief of Police, who realizes the difficulty in trying to reach the more than 900 men on the department through personal visits to the roll calls. By taping a message the chief can easily reach the majority of the men in the least amount of time.

Basically, the VTR is earmarked for the use of the Traffic Unit and its application is being expanded upon daily. "The capabilities are limited only by our own imagination," Capt. Rennau points out.

A van-type truck is now being used to haul the equipment and provide the power supply. A portable power source has been added and the unit is now fully portable. The viewing equipment is maintained at the Traffic Unit headquarters and as money becomes available, more and more viewing units will be added to the various stations and bureaus, making dissemination of the tape more widespread.

Chief Kelley, who is a confirmed supporter of technological assistance to the man in the field, believes that the VTR is a very sound and logical approach to the solution of traffic problems.

"There is no single answer to the traffic problem here or in any other city in this country. I do feel, however, that the video tape unit will seriously aid us in our fight with the mounting accident rate," Chief Kelley said.

"By proper and judicious application of the unit I envision a more rapid discovery of where our problems lie and a more firmly founded solution to these problems."

The thought of having an instant replay on an accident is exciting to the men who daily reason how to avoid accidents.

"We know, or at least think we do, what needs to be done to reduce accidents," Capt. Rennau said. "Maybe we are wrong in some of our thinking and maybe this approach will show us just what we are not doing right.

"The sentiment is as old as time, but if this unit can help us in preventing the loss of even one life the expenditure will be justified." □

new dimension to traffic studies

Analyses include everything from vehicle counts to snow removal operations

By LOUIS FORTE, Jr., management engineer, Sky Count Aerial Studies Group, Port of New York and New Jersey Authority ■ One experienced employee can produce the same traffic counts from slow-motion movie film as eight or more persons can on-site. The movie counts are more accurate because we can verify them by running and rerunning the film.

We first used the film traffic-counter technique on a project for the George Washington Bridge. The port authority had under consideration a redesigning of the span's eight traffic lanes. Before the study, the number of inbound and outbound lanes was changed daily for morning and afternoon traffic.

Only three days after receiving the request for the study, our Sky Count Aerial Studies Group had two battery-operated cameras in position 350 feet above the bridge deck. Shooting at 12 frames a second, we produced a 100% record of traffic from 7 a.m. to 9 a.m.

The filmed record covered traffic in both directions, verified by toll receipts. A stopwatch timed each film run at five minutes.

This allowed one minute for changing exposed film and restarting the second camera.

The two-hour session consumed 24 rolls of color film. Later we made a duplicate film to document traffic response to lane changes on the bridge.

Putting it all together

The appeal of this type of system for government use is its versatility. We used it for accident prevention studies, pedestrian analyses, traffic studies, industrial engineering, security progress reports and public relations applications.

An 8mm camera using super 8 film

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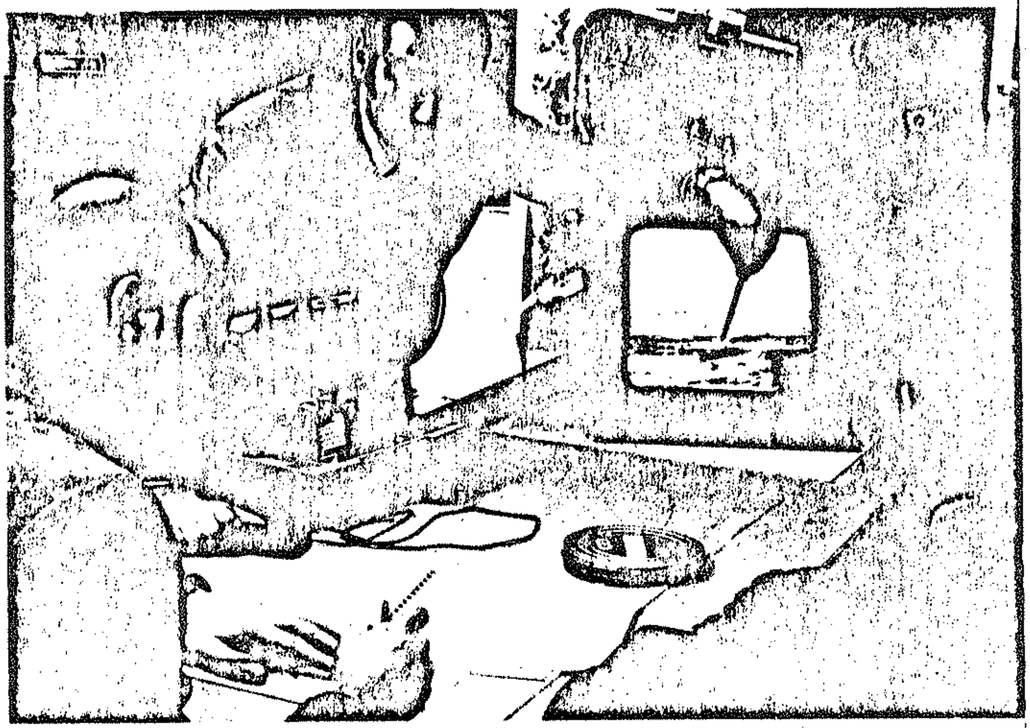


Data reduction and analysis start with a preview screening. This one involves gate utilization at JFK International Airport.

Louis Forte, Jr., Sky Count Group management engineer, prepares a "show-in" for port authority personnel.

Sky Count studies require 24,000 feet of film a year.

(Continued from preceding page)

and a Kodak *Ektagraphic* MFS-8 projector form the heart of the film analyses operation. The projector is a multimedia device. It will show movies or single images, in slide fashion, from a reel of film. In addition to remote control, automatic focus and film reverse, the unit operates at any of three speeds.

Pilot project

Our Sky Count Group organized a pilot project about five years ago to evaluate the use of the projector and super 8 film. During the years, we exposed some 2000 feet of *Kodachrome II movie* (type A), *Plus-X* reversal, *Tri-X* reversal and high speed *Ektachrome film*.

The camera selected for the project was an automatic exposure control model with an F/1.8 lens. It has pushbutton zoom capability with a ratio of six-to-one. The battery-powered unit is designed for films with ASA ratings of 25 to 400.

LaGuardia Airport provided the setting for our first movie system test. Airport officials were concerned about crowded conditions in the taxi-hold area and the hazards to vehicles on the adjacent roadway as the cabs pulled into traffic. Since all taxis in New York are yellow, the cabs showed up extremely well on color film.

Later, we shot footage from a moving car for a "driver's-eye view" of the roadway and signs around the airport. As a result, several difficult-to-read signs were redesigned.

Who uses

Our group performs film analysis based on the specific information needed by the "customers." In our case, the customers are the port authority's 30 operating facilities. These range in scope from airports, bus, truck and marine terminals, to bridge tunnels and a commuter railroad.

Most commonly, we hold a screening session where Sky Count personnel, customers and appropriate Port Authority Operations Standards Division people discuss the film. We will rerun interesting segments at various speeds. Then we generally "brain bust" for useful secondary data from the footage.

Formal data reduction and analyses by Sky Count Group or Operations Standards Division personnel usually take place in the photo analysis center. This is a small projection area partitioned off for light control and privacy. However, a collapsible rear-screen viewing unit allows us to turn a desk into a reviewing area when needed.

The 20-pound projector is portable. When closed for storage or carrying, the projector and carrying case measure only six inches wide.

The projector's true value lies in its analytical capability. Without this unit's special features, films would remain only a real-time tool. The projector allows us to change time sequences while viewing. It will operate either forward or in reverse, will still frame or slow motion at six frames a second and will run extra fast at 54 frames a second.

A Bell *Jet Ranger* helicopter with an oval opening in the back seat usually is selected by our group for aerial missions. The opening, designed by the port authority personnel, has since become an optional fitting offered by Bell.

Aerial photography played an important part in planning expansion and redevlopment of the city's three airports — especially JFK International. This included ground traffic studies around the airports, aircraft traffic analyses, internal passenger movement and parking lot studies.

Van Wyck Expressway, which serves JFK airport, was filmed continuously for two hours from an altitude of 500 feet during three consecutive peak traffic periods. Viewed at varying speeds, the film provided the New York City Department of Traffic and the Port Authority Traffic Engineering Division with facts on service-road problems and local traffic congestion. The films, when projected one frame at a time, documented the "accordian effect" of entrance flows on the entire length of the expressway. The film revealed that grade changes produced similar problems.

Training next

Training is one area for which we feel the movie system has great potential. For example, we have sent out Operations Standards Division and Sky Count Group personnel with cameras to film snow removal procedures at the airports. Films of the melting equipment and clearance operations were shown to department personnel who eventually will be responsible for inspecting these sites. Automatic code sensing (setting the projector on automatic where it will stop on any desired frame as coded with metallic tape) proved very beneficial for this type of analyses.

Code-sensing should provide even more dramatic results in the training of security officers for airport patrol. We have under consideration a plan to film each "beat" at the airports. The film would take the officer step-by-step over his terrain and point out, by stopping on a single frame, points of concern.

We have not yet reached the peak of our capabilities with photography. In fact, we have only scratched the surface. Drop us a line if you would like more information on this concept. ■■

Traffic Quarterly, January 1974.

A Closed Circuit Television System for Traffic Surveys

RICHARD E. DANIELSON, ROBERT S. BROWN,
RICHARD M. HANCHETT, AND WAYNE C. ALLINSON

Mr. Danielson graduated from Rhode Island College in 1962. He joined Allinson, Inc. in 1967 and was appointed Vice President in 1970. He served as Study Director for the 1971–1972 Rhode Island Origin-Destination Update Study.

Mr. Brown received his B.S. degree in Civil Engineering from Tufts University in 1969 and Master's degree from the Massachusetts Institute of Technology. He is Transportation Planning Engineer for Allinson, Inc.

Mr. Hanchett received his B.S. degree in Civil Engineering from the University of Rhode Island. He is Project Engineer and Data Processing Manager with Allinson, Inc. He is an associate member of the American Society of Civil Engineers.

Mr. Allinson received his B.S. degree in Civil Engineering from the University of Rhode Island. He is a registered professional engineer in three states. He has been President of Allinson, Inc. since its inception in 1967.

METHODOLOGIES used in the analysis of transportation systems have progressed steadily over the past 10 years, while the state of the art in data collection has remained relatively stagnant. No modeling technique has yet been developed which corrects for erroneous or redundant data. Often data used as input for transportation planning models have been assumed as accurate. Moreover, those responsible for data acquisition have shown little imagination in performing their tasks and appear to be content with "established" data collection procedures.

External cordon surveys have traditionally been performed by the roadside interview method. A predetermined count of vehicles crossing the cordon line would be sampled by rerouting the vehicles into an interview area along the roadside. This survey, besides being relatively expensive, is an inconvenience to the motorist and on today's freeways poses a safety problem.

In an attempt to reduce the inconvenience and improve safety, some states have experimented with 35 millimeter movie cameras as an alternative to the interview station. License plates can be photographed during normal conditions by positioning the cameras on an overpass and focusing one camera on each lane of travel. The films are then developed, license plate data keypunched from the films, registry files searched for the owner of the vehicle, and a questionnaire concerning travel information for the day the vehicle was observed is sent to the person by mail. Obviously, the time required to photograph a license plate, develop the film, search registry files, and mail the questionnaire is a critical defect in this method.

In an effort to minimize this data reduction time, a closed circuit television (CCTV) system was developed and successfully used when the Rhode Island Department of Transportation updated its statewide origin and destination data. This article is an account of the development and survey procedures used for this first CCTV external survey.

PROJECT SCOPE

The external survey represented the fifth and final phase of the Rhode Island Origin and Destination Update Study. The four other phases included a home interview survey completed by telephone contact, airport and mass transit surveys conducted by on-board questionnaire, and a truck survey completed with mail-out, mail-back questionnaires.

The information obtained through the external survey serves two purposes. The first purpose is to gather data on passenger and vehicle trips excluded from the home interview (or internal) survey. This information is obtained by recording the trip information of those persons who either live or have their vehicle garaged outside the study area defined in the internal survey. Since trip information in an external survey is obtained for both residents and nonresidents of the study area, it is necessary to sort this information according to home location. The second purpose is to compare and expand similar, but less concentrated, data obtained in the internal survey using the trip information gathered for residents of the study area.

The cordon line for the external survey was the Rhode Island state boundary line. Along this line 35 stations were selected to represent the various Rhode Island functional classes of roadways with traffic volumes varying from under 400 to over 40,000 vehicles per day. These 35 stations provided data representative of the different land-use patterns, socioeconomic distribution, and population densities that exist at the state's boundaries.

The information sought from the drivers of sampled vehicles was as follows:

Passenger Vehicles	*Trucks*
Origin and destination	Origin and destination
Travel times	Travel times
Trip purpose	Type and weight of commodities carried
Number of passengers	Type of structure at origin and destination
Garage address	Garage address

The stations were operated for either 8 or 12 hours during daylight so as to include at least one peak-travel period. The criteria for operating either 8 or 12 hours at a station were its average daily traffic (ADT) and class under the Rhode Island Highway Functional Classification Scheme. Vehicle classifications and 24-hour traffic volume counts were completed for each station.

In essence, the basic requirements and goals for conducting the survey were to:

1. use CCTV equipment to video tape all license plates; [1]
2. identify the lane, time, and direction of travel of each vehicle (and the external station location);
3. search registry files from Rhode Island, Massachusetts, Connecticut, and New York for the name and address of the driver (or owner) of the vehicle recorded on video tape; and

1. Only the front license plates were recorded to avoid conflicts with tractor-trailer combinations where the tractor and trailer had different registrations. However, the rear plate or any portion of the vehicle can be video taped.

4. mail questionnaires to these addresses to obtain information on the trip being made at the time of the recording.

Video equipment was used at stations where the ADT exceeded 8,000. At stations with ADT's under 8,000, cassette tape recorders were used for a less costly means of recording license plate numbers.

SYSTEM DEVELOPMENT

Work on the external survey was started approximately 4 months prior to the first scheduled survey day. This lead time was required to develop a workable CCTV system, train a survey crew, develop computer programming techniques for rapid accessing of registry files, and design and print questionnaires.

Initially, about 2 days were spent visiting the 35 proposed external station locations. A sketch of each station showing lane widths, shoulder widths, speed limit, median width, etc., was prepared. In addition, a photograph of the area was taken and later included in a reference album. Moreover, when possible, the station was investigated from an overpass and the appropriate dimensions were recorded. At this time, it had not been determined whether it would be better to set up cameras on an overpass or at road level.

The equipment used at the start of the developmental stages was: a tape recorder which uses one-half inch video tape with a maximum running time for one tape of 1 hour (2,400 feet), a CCTV camera, a TV monitor, a 75 millimeter telephoto lens, a 2X extender, and a 2.5 kilowatt portable generator.

The first attempt at recording license plates was made from an overpass on a freeway, and it was immediately apparent that certain factors needed to be considered more carefully. These were: (1) vehicle speed, (2) distance from vehicle to camera, (3) angle of approach (horizontal and vertical), (4) light, and (5) lens size. The 75 millimeter lens was too small for use from an overpass. When used at the roadside, it could only record a legible plate if the vehicle were traveling at less than 10 miles per hour and was about 50 feet from the camera.

Different lens combinations [2] and camera positions were tried during the test period. Also, it was more difficult to record a

2. 75, 150, 230, 300, 460, 500, and 1,000 millimeter (fixed focus).

legible license plate from an overpass than from the street level. The results of the tests indicated that (1) the point at which the camera was focused had to be far enough away from the camera (somewhere in the range of 250 to 300 feet) so that the plate remained in focus for a sufficient length of time to be legible—at these distances the depth of field[3] was usually sufficient to accomplish this, and (2) the horizontal angle formed between the line of sight of the camera and the line of travel of the vehicle had to be minimized—this meant locating the camera close to the lane of travel. If the horizontal angle was too large (greater than 3 degrees), the license plate moved too quickly across the monitor and only a blurred image of the plate was recorded. Once the angular problems were solved, it was then a matter of selecting a lens with a long enough focal length to be able to focus at a distance of 250 to 300 feet and still obtain a license plate of sufficient size and legibility. To accomplish this, a 500 millimeter lens was found to be suitable.

Further testing of the camera and lens on a four-lane, non-divided, high-density road on an interstate highway, with the posted speed limit of 60 miles per hour and average daily traffic volumes of 20,000 to 30,000, showed that the best possible roadside setup was on a tangent following a curve. Under these conditions, vehicles coming around the curve would, for a few seconds, actually be heading directly toward the camera. This, in fact, represents a situation where the horizontal angle is zero degrees. Again, the 500 millimeter lens proved to be the best suited for this situation.

The above test results indicated that the roadside setup should be refined and utilized, and that no further studies from an overpass should be made. This decision was made because the most easily identifiable license plates were recorded where the horizontal and vertical angles were near zero degrees (on a tangent following a curve) and because sunlight and shadows were more critical from an overpass location (also, there were only four overpasses at the 35 station locations).

Three criteria for setting up the cameras were established. First, distances from the camera to the license plates should be

3. Depth of field represents the distance range a vehicle can travel and remain in focus.

such that 80 percent of the lane can be seen on camera and a depth of field of at least 40 feet is obtained. Second, the size of the license plate seen on the television monitor should represent 20 to 30 percent of the total viewing area. Finally, a minimum vehicle separation of 20 feet is needed to be able to view license plates between consecutive vehicles.

In addition to studying the closed circuit television system itself, the problem of illuminating the front license plates of vehicles during the night hours was also investigated. Three approaches were tried: high-level (14 foot) spotlight and floodlight illumination, low-level (2 foot) spotlight and floodlight illumination, and a so-called "moonlight," television camera which required no additional artificial illumination. It was found that the "moonlight" camera was not adaptable for this use and that, even with low-level illumination, the light could not be shielded sufficiently to prevent it from being a safety hazard to motorists. It was recommended, therefore, that the video stations be operated only during daylight hours.

ACCESS TO REGISTRY FILES

During the early stages of the system's developmental phase, it was realized that the desirable possibility of a one-day turnaround time could not be achieved if there were delays in matching the recorded plate number to the name and address of the driver. Previous pilot studies using the photographic technique had experienced this delay when the registry files of motor vehicles had to be searched for these data.

The Rhode Island Department of Transportation decided that plates from four states—Rhode Island, Massachusetts, Connecticut, and New York—would be recorded. This could mean that four states would be relied on to search their files to provide the required data. Instead, these states were asked to furnish copies of their registry files for use by the study's computer facility. Three states—Rhode Island, Massachusetts, and New York—agreed to supply copies of their files. Connecticut did not; however, it offered to access its files and to supply the study with the names and addresses needed.

The size of the New York and Massachusetts registry files, 9.5 and 3.7 million records, respectively, would have created computer storage space problems. It was decided, therefore, to use a 20-percent sample of these files and try to match 100 percent of the recorded license numbers. For Rhode Island and Connecticut the 20-percent sample was obtained by matching 20 percent of the license plate numbers recorded to the 100 percent of the registry files.

A normal daily computer run averaged 1 hour and included the searching of some 3.2 million records and addressing 2,000 questionnaires.

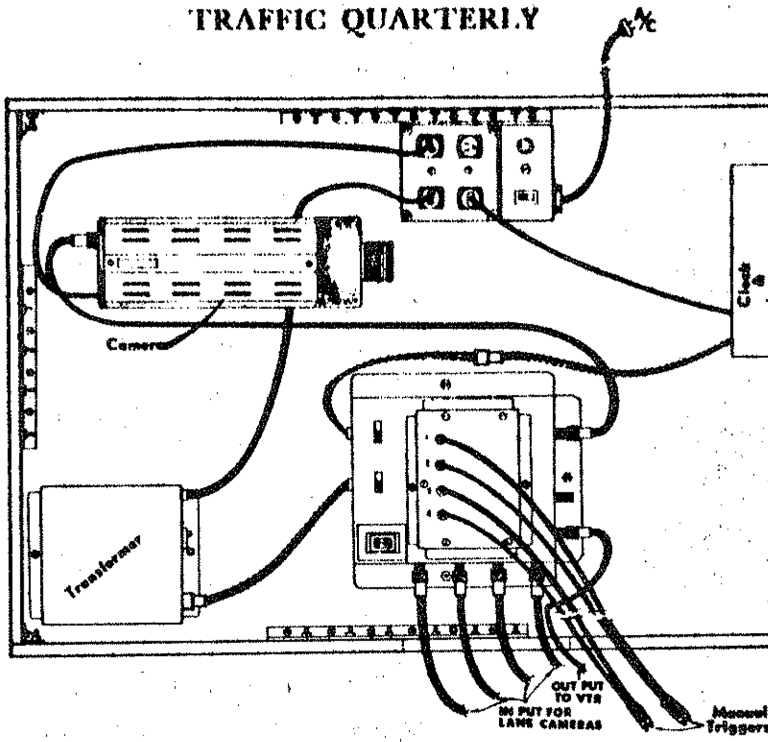
SWITCHING AND TRIGGERING BOX

To enable the monitoring of more than one travel lane and the use of several cameras on one system, a switching and triggering box was specifically designed and constructed for this project. The "box" was so designed as to enable recording of license plate numbers of vehicles on as many as six lanes of travel on a single 1-hour, half-inch video tape. The ability to capture more than one lane of travel on a given tape reduced the time needed for data reduction. In addition, a clock internal to the box made it possible to include a time reference on the tape, showing the time of recording as well as the lane of travel.

The "box," when triggered by an external signal input, first switches to and records from the camera monitoring the lane in which the vehicle is traveling. It then switches to an internal camera which records the time and lane of travel. Triggering could be done either manually or automatically. Manual triggering is accomplished by pressing a button which is wired to the triggering mechanism in the "box." Automatic triggering is described in the next section. Figure 1 shows a diagram of the "box."

INDUCTION LOOP MATS

During development of the video system, different types of camera triggering devices were considered. These ranged from a simple manual trigger to a very sophisticated one activated by a change in the electrical current generated by the television camera. Of all the concepts tested, the most reliable was an induction loop attached to a vinyl mat and used in conjunction with a vehicle detector loop (Figure 2). The wire of the induc-



SWITCHING & TRIGGERING BOX

Figure 1. Diagram of switching and triggering box

tion loop was attached to the mat with vinyl adhesive. The mat was, in turn, glued to the center of the travel lane with its long edge facing traffic. Mats were placed in all lanes with the contact leads from each detector connected to a loop detector amplifier and thence to the "box."

While experience has proven this system to be workable, the adhesive used (the best of all the products tested) had some shortcomings. When used on damp or wet pavement, it would hold until the pavement dried and then it seemed to lose its adhesive qualities. Recent investigation, however, has revealed a more usable adhesive. There was also an inherent weakness at the solder joints in the loop and at the point where the internal lead crossed other wires.

TESTING OF POWER AND COAXIAL CABLES

Two alternatives for crossing the road with coaxial and power cables were investigated. One included building a sup-

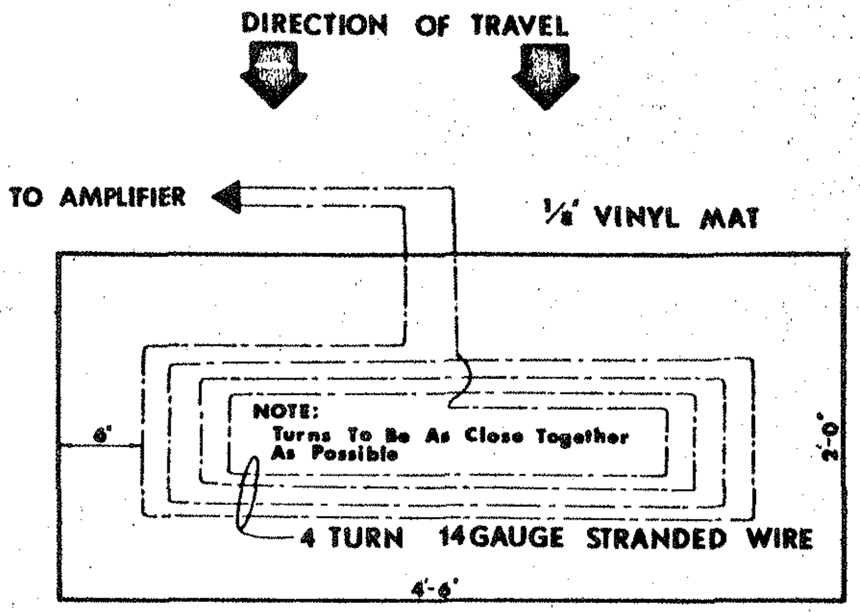


Figure 2. Diagram of induction loop mat

port tower for carrying the wires overhead. The other consisted of laying the wires across the surface of the road. If the wires were to be strung overhead, the minimum necessary clearance would be 16 feet. Moreover, precautionary measures would have to be taken in case something came in contact with the wire (i.e., a break-away system for separating the wires from the support tower and for cutting off power). In addition, the tower method is rather costly and its installation would add to the time necessary to establish a station. The time element is critical when a station has to be set up in a maximum of half an hour.

The other alternative, laying wire across the roadway, had not been tried before, and it was not known what type of wire could withstand the impact of cars and trucks passing over it for up to 12 hours. A test of these wires was made which consisted of simply laying them across a road for various periods of time and examining the results.

The test showed that the power and coaxial cables tested could withstand the impact from both automobiles and trucks. The signal from the camera to the recorder was not affected as

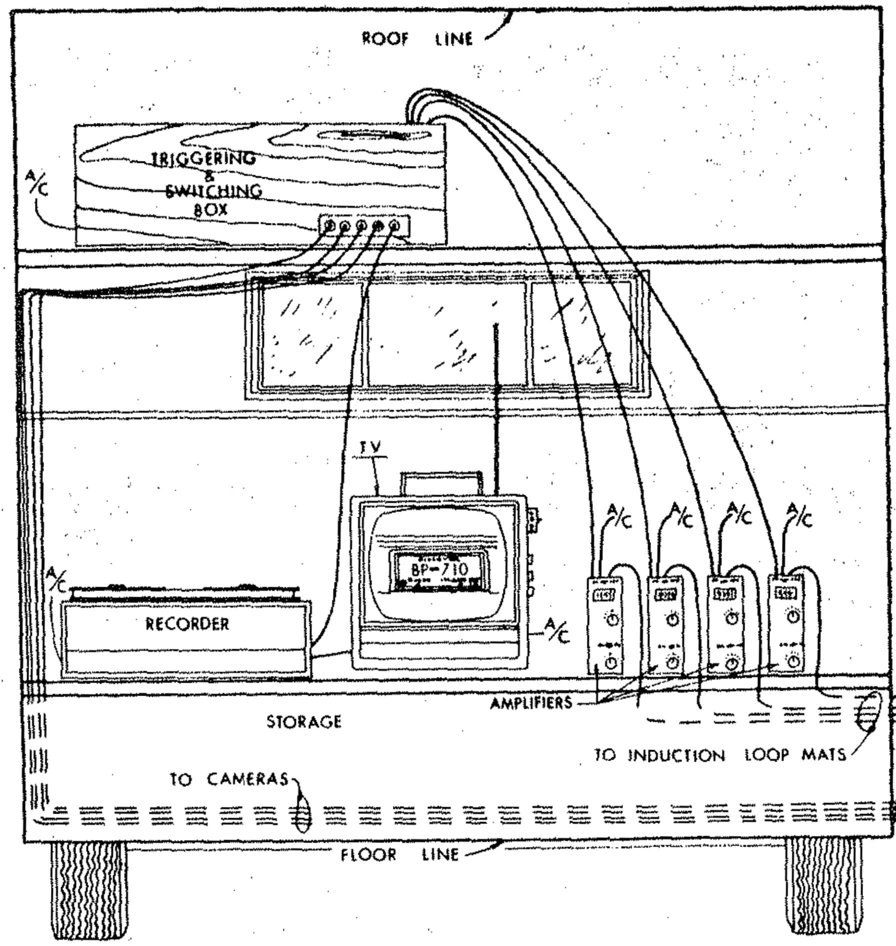


Figure 3. Illustration of mobile station showing four-lane setup and automatic mode

long as the cable remained intact. However, the lifetime of a cable ultimately depends upon traffic volumes and, therefore, the cables were checked for damages when picked up at the end of each survey day. Wires were anchored to the pavement edge with pneumatic tube clamps.

MOBILE STATION

Since the closed circuit television equipment had to be moved around the state on a day-to-day basis, it was necessary to establish a convenient way of moving it. A small, 15-foot mobile home trailer was converted for this purpose. In transit all video equipment was stored within this mobile station (Figure 3).

SIGNING

Adequate signing at each station was required by the Rhode Island Department of Transportation and the Federal Highway Administration. A series of four signs was set up. They read "Traffic Photo Survey," "Please Maintain Speed," "Please Stay in Lane," and "Thank You." They were diamond shaped (48 by 48 inches) with black letters and an orange reflectorized background (as suggested by the 1972 Manual on Uniform Traffic Control Devices for Streets and Highways). The signs informed the motorist that a traffic survey was ahead and gave instructions for proceeding through the station. In addition, the initial sign, "Traffic Photo Survey" was reprinted in black and white on the cover of the questionnaire to help "key" the driver back to the location of the station.

DATA REDUCTION

At the beginning of the survey, it was estimated that data reduction time for a single 1-hour tape would take about three manhours. Thus, if a single video tape recorder (VTR) were used for each lane of travel on a four-lane highway, it would require 120 manhours to reduce a day's taping (i.e., four tapes at 3 manhours per tape and ten tapes per station).[4] The "box" provided a means of placing the data from all four cameras on a single tape which resulted in a total daily savings of some 90 manhours in data reduction.

The sample chosen, by direction, consisted of every fifth Rhode Island vehicle (truck or passenger car), every fifth Conneticut vehicle, and every New York and Massachusetts vehicle. The equipment needed for data reduction included the VTR, television monitor, vehicle coding sheets, and a data bearing video tape. When a vehicle was selected during the video tape replay, the date, time, license plate number, direction, and

4. For a 12-hour station where both directions were recorded on the same tape, an average of ten tapes was used during the day.

station number were recorded on the vehicle identification sheet.

It took an average of 4 to 5 manhours to reduce a 1-hour video tape, compared with the assumed 3 manhours. This time varied according to the number of vehicles which actually passed the station in that hour and the number of variables being considered (direction, time, lanes, state of license plate, etc.). It was found that four lanes of traffic on a single tape afforded the best efficiency in data reduction.

Vehicle identification sheets collected throughout the day were later keypunched and verified. Afterwards, keypunched cards were sorted by state code and license plate identification (since separate disk packs were used for each state's registry files) and then were sent to the computer center for processing.

SUMMARY OF EQUIPMENT AND SYSTEM OPERATION

The following is a list of the minimum equipment necessary to operate a six-lane station for 12 consecutive hours.[5] The total estimated cost is $19,000. This, of course, does not include equipment necessary for data reduction.

Type	*Quantity*
Video tape recorder	2
Television monitor	2
Television camera	6
500 millimeter lens	6
Portable generator (2.5 kilowatt)	2
Triggering and switching "box"	2
Video tape	24
Vehicle detectors and amplifiers	6
Camera support	6
Walkie-talkies	2
Accessories (cable, wire, batteries, fittings, etc.)	
Mobile station	1

The CCTV system was designed to operate as follows (see flow chart in Figure 4):

1. A CCTV camera positioned off the roadway records license plate numbers of passing vehicles on video tape.

5. Six-lane stations require two video recording tapes—one for each direction.

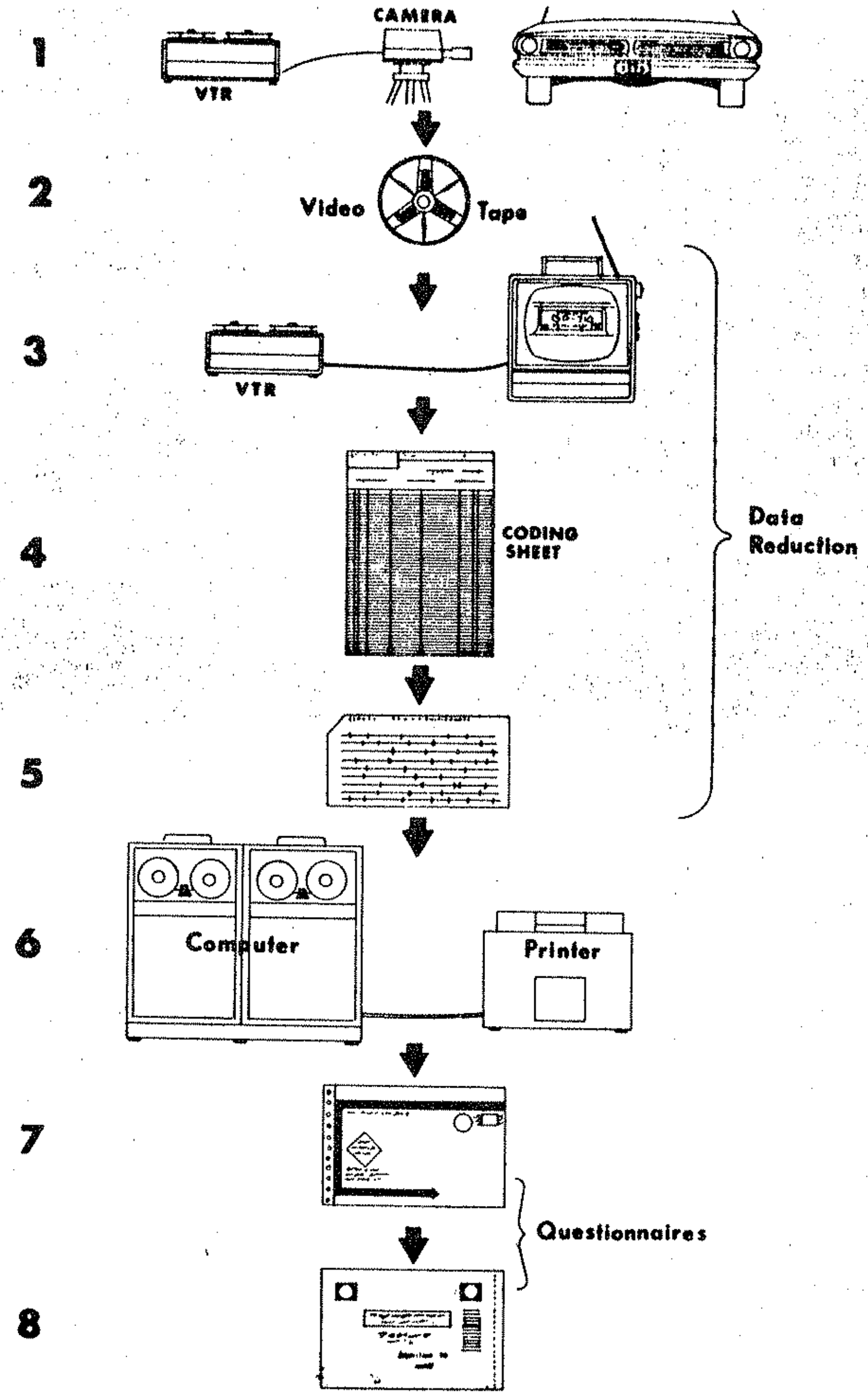


Figure 4. Flow chart of operation

2. The video tapes are returned to the office.

3. The video tapes are reviewed on a television monitor and a sample is selected.

4. The sampled license plate numbers are then recorded on coding sheets along with the state of registration, time observed, station, date, and direction.

5. This information is then keypunched onto computer cards.

6. Using state registry files, the license plate numbers are matched with names and addresses.

7. A questionnaire, addressed by the computer, is sent to the owner of the observed vehicle.

8. The driver of the observed vehicle completes the questionnaire at his convenience and returns it by mail.

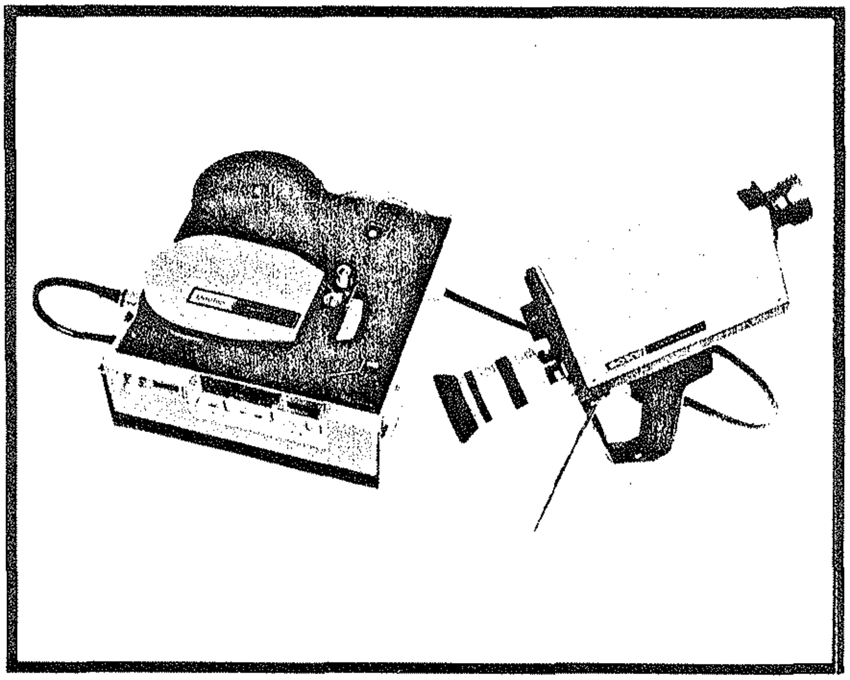
CONCLUDING REMARKS

There are a number of advantages in using the CCTV method to replace roadside interviews for surveys of this type. It is safer for the surveyed driver as well as for the survey crew, and since vehicles are not stopped, motorists are not delayed in long queues waiting to be questioned. In addition, the quality of collected data is better because a more consistent sample rate is obtained and more details concerning vehicles and trips are possible in a mail-back survey.

The CCTV system method may also be cheaper. The estimated cost to accomplish data gathering, reduction, and trip table development for the 35 stations was $5.34 per sample using the conventional method of stopping the vehicle. The actual cost using closed circuit television, as described in this article and including all research and development, was $4.72 per sample.

PORTABLE TIME LAPSE VIDEO RECORDER MODEL TP 400

ODETICS, INC., Video Time Lapse Division has answered the need for a **portable time lapse** video tape recorder with the new TP 400 portable, battery operated, ½ inch video tape recorder system. The TP 400 can be carried and operated by one person, as a normal portable video tape recorder, or used as a time lapse video tape recorder with the ability to record up to 15 hours on a single 1,200 ft. reel of tape.



The TP 400 video tape recorder system includes a video camera (with zoom lens and built-in electret condenser microphone), and the time lapse video tape recorder. The recorder is used to record and playback in normal speed or a time lapse speed. Time lapse speed pre-selected to fit application.

The camera has an electronic viewfinder that shows the operator the picture exactly as it will appear when played back on a T.V. screen. The viewfinder can also be used for playback to check the tape as soon as it has been recorded.

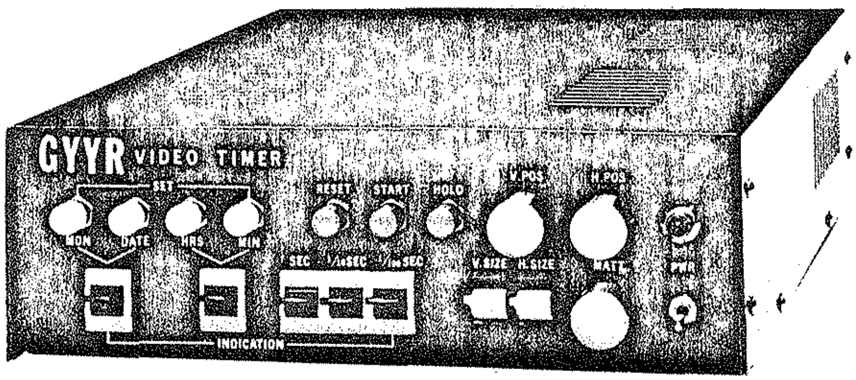
An AC power adaptor which also serves to charge the battery, makes it possible to run the recorder on 115 volt current. Additional features include stop action, and audio that can be added after recording of video.

Tapes are inter-changeable with those of any video tape recorder with the E.I.A.-J format.

VIDEO TIMER
MODEL G-77

ODETICS Video Timer!

The G-77 Video Timer is a compact, full feature electronic system which superimposes numerical date and time information on any video image being viewed and/or recorded.



Broad Compatability!

The G-77 is compatible with most CCTV/VTR systems, including color, monochrom and random or 2:1 interlace.

Front Panel Control!

All functions, including desired date and time information, start-hold-and reset of time count, horizontal and vertical positioning, character height and width, and power on/off are conveniently located on the unit's front panel.

Convenient Installation!

The G-77 is easily added to any existing video system. Merely loop the G-77 into the system between the signal source, such as a camera or VTR and the display or recording equipment.

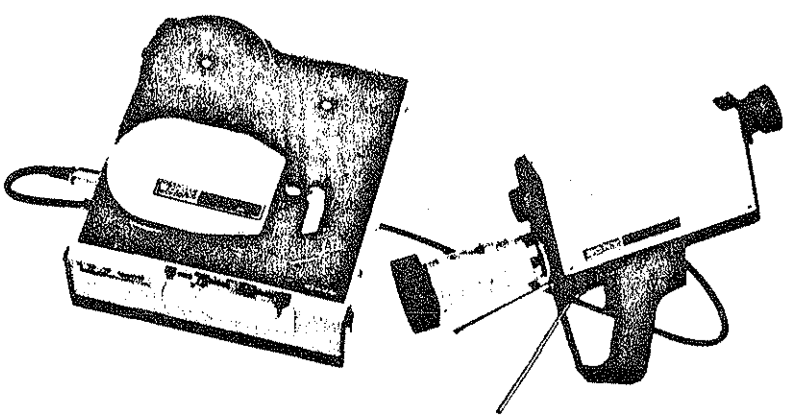
Remote Control!

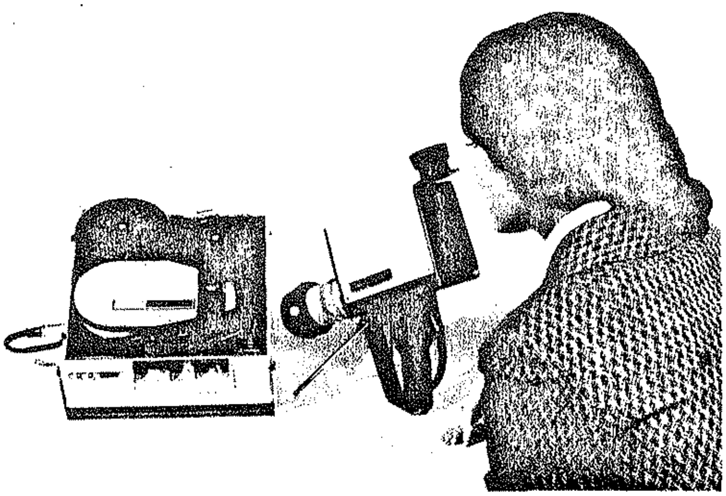
Remote control of counting functions (start-hold-reset) are completely remote controllable using the six pin remote connector provided on the back of the unit.

SONY®

VIDEOROVER II

MODEL AV-3400/AVC-3400





The VideoRover II is a completely portable, battery-operated ½-inch VTR system that can be carried and operated by one person. It consists of a hand-held video camera (with zoom lens and built-in electret condenser microphone) connected to a shoulder- or back-carried Videocorder® video tape recorder. The latter is used both to record picture and sound and to play them back—on a monitor or, with the optional RF modulator, on a regular TV set.

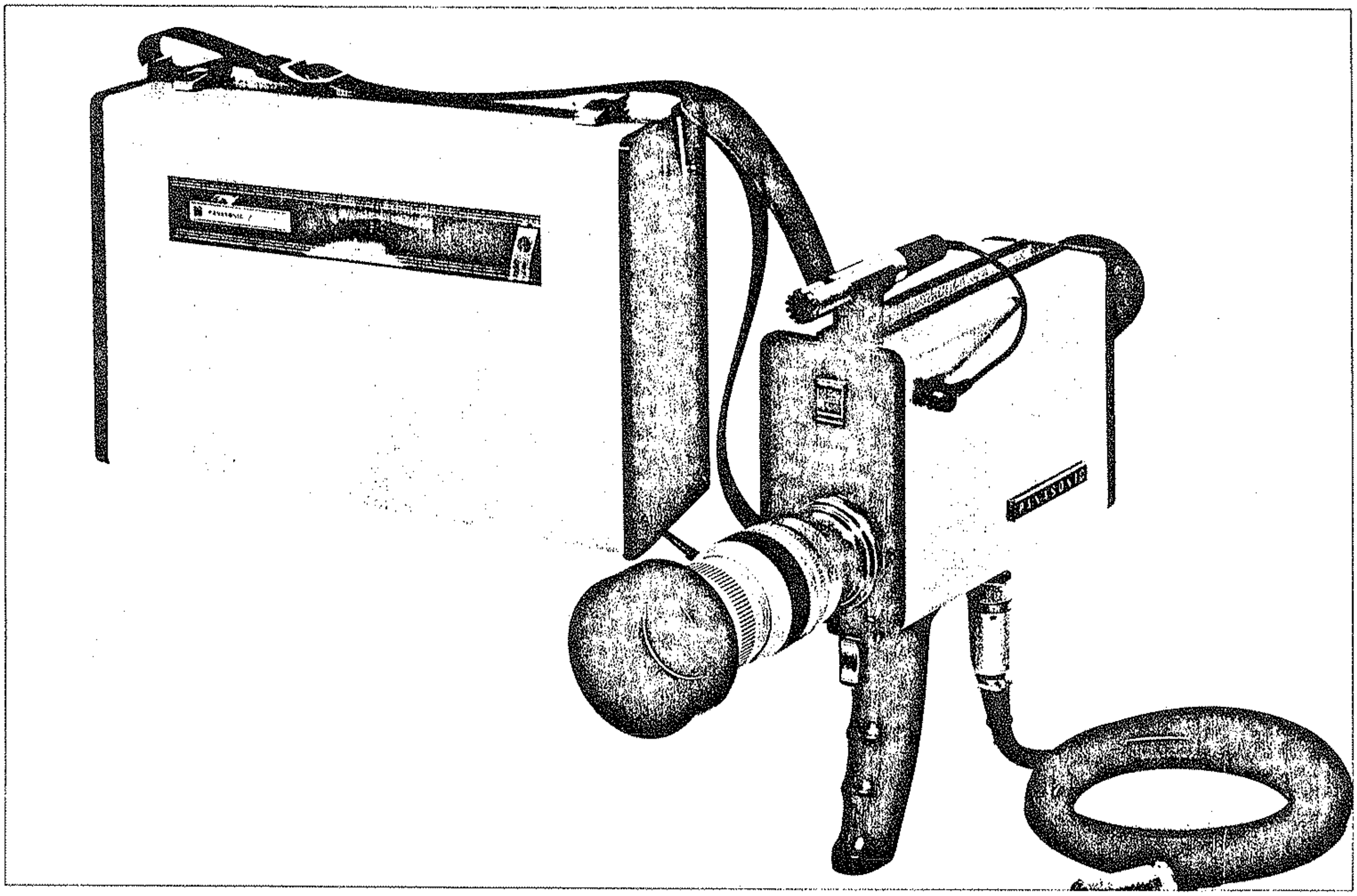
The Videocorder can likewise be used to record TV programs off the air. The camera has a zoom lens and an electronic viewfinder that shows the operator his picture exactly as it will appear on the TV screen. This viewfinder, moreover, can be used for playback to check the tape as soon as it has been recorded. An AC power adaptor, which also serves to charge the battery, makes it possible to run the VideoRover II on house current. Special features include stop action, audio that can be added after recording of video, and a recording and playback time better than 30 minutes on one reel of tape. Horizontal resolution is more than 300 lines. Tapes are interchangeable with those of any AV Series VTR.

FEATURES

- Compact, lightweight record/playback system that can be operated in any position and carried on operator's shoulder or back
- Stable, clear picture with more than 300-horizontal-line resolution
- Automatic Gain Control for video and audio
- RF modulator (optional) enables AVC-3400 to play back on regular TV sets
- More than ½ hour continuous recording and playback time on one reel of tape
- Stop action
- Immediate playback with picture seen through camera viewfinder
- Camera has self-contained stand for easy viewing during playback
- Audio dubbing
- 100% tape interchangeability with all Sony AV Series VTR
- Complete trigger control from camera for recording
- Single cable connection from camera to VTR
- Automatic end-of-tape shutoff
- Can be run on internal battery, AC current, or (with optional cord) on car battery
- Internal rechargeable battery provides 45 minutes of continuous operation
- Can record TV programs with optional connecting cable
- AC adapter/battery charger is standard accessory

- Panasonic -

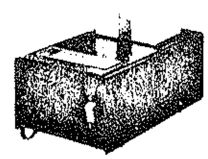
PORTABLE VIDEO TAPE RECORDER



MODEL NV-8080 and MODEL WV-8080

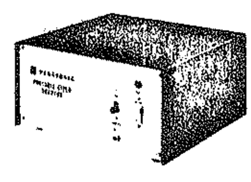
Panasonic customer enjoys the additional and vital feature to their VTR-CCTV lines. . . . PORTABLE VTR and TV camera with its outstanding features and design allows you exceptional, dependable performance of ½" video tape recording. PANASONIC portable video tape recorder housed in a compact cabinet weighing less than fifteen pounds permitting any video shooting at any instance through its high resolution TV camera. You can achieve perfect video recording with simplified operation by full automatic controls both in video and audio levels. Equipped with a pair of PANALOID battery to offer long life for more than one hour and a half recording operation in succession. The batteries are chargeable by the PANASONIC battery charger NV-B32 in a short period of five to ten hours. Completely interchangeable with any PANASONIC ½" video tape recorder.

BATTERY CHARGER



NV-B32

PORTABLE VIDEO ADAPTOR



NV-B33

SPECIFICATIONS NV-8080 (See page 24 for Portable Camera, WV 8080 Specifications)

RECORDING SYSTEM	Two rotary HPF heads, slant scanning
TAPE SPEED	12 inches per second
TAPE WIDTH	½ inch wide
REEL SIZE	4.5 inch max.
RECORDING TIME	14 minutes w/840 ft. long tape
HORIZONTAL RESOLUTION	260 lines
VIDEO S/N RATIO	Better than 40 db
AUDIO FREQUENCY RESP.	80~10,000 Hz
POWER REQUIREMENT	DC 12 ±1 V
POWER CONSUMPTION	Approx. 7 W
AUDIO/VIDEO CONTROL	Fully automatic
AUDIO/CONTROL HEAD	Stationary two tracks
ERASE HEAD	Full track
BATTERY OPERATING TIME	1.5 hour in continuous operation
BATTERY CHARGING TIME	8 hours
OPERATING TEMP. RANGE	40°~104° degrees F
TAPE USED	PANASONIC video tape, NV-P45
SERVO SYSTEM	Phase servo-controlled motors
OPERATING POSITION	Horizontal or vertical
RECORDING SIGNAL	Composite video based on American TV standard as produced by any made and any standard TV camera
TRANSISTOR & DIODE	53 transistors, 21 diodes plus one IC
RECORDING METHOD	Both side band FM
VIDEO INPUT LEVEL	1 Vp-p into 75 Ω sync negative
MIC INPUT LEVEL	−75 db, 1 KΩ unbalanced
DIMENSIONS	14⅜"(W) ×9¼(D) ×4⅝"(H)
WEIGHT	Approx. 15 lb (batteries included)
CASE COLOR	Two-tone color in black and silver

STANDARD ACCESSORIES

1 pc. Deluxe carrying case	1 pc. Empty reel, NV-R45
1 pc. Battery charger, NV-B32	1 pc. Earphone
2 pcs. PANALOID Battery, TY-365C	1 pc. Splicing tape, 1 ft.

VT-100

THE WORLD'S MOST PORTABLE V.T.R.

UTILIZES 1/4" TAPE !!

AKAI

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