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RAMP METER BYPASS FOR CARPOOLS

October 1976
Final Report

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This report will be of particular interest to urban traffic engineers who are involved with or are planning the installation of ramp meter bypass systems for carpools. The report presents an analysis of the installation of a ramp meter bypass for carpools at a downtown Minneapolis location. It was found that the time savings benefit did not provide enough incentive to create new carpools.

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16. Abstract

Beginning on November 18, 1975, carpools of three or more people were permitted to avoid queues at two metered ramps in downtown Minneapolis, Minnesota by using the Grant Street express bus bypass ramp. This incentive amounted to a maximum savings of about 90 seconds and was not sufficient to induce formation of a significant number of new carpools. About 19% of the 86 autos using the bypass ramp each day were not carpools. Changes in violation rates at other ramps in the I-35W corridor could not be attributed to the preferential treatment operation. A market analysis shows 49% of the auto users were already in carpools of two or more people, 37% of all route users were in buses and only 32% of all route users were alone in autos. A survey of the auto users shows favorable sentiment towards preferential treatment for express buses, vanpools and carpools of three or more persons. However, there is also sentiment against carpool preference, even amongst carpoolers.

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INTRODUCTION

Project Background

The Minnesota Highway Department activated a seventeen mile freeway traffic management system on I-35W in April, 1974. The system included closed circuit television, computer coordinated ramp meters and nine bypass lanes for express transit buses. The operation was evaluated as part of the I-35W Bus On Metered Freeway demonstration under the D.O.T. Urban Corridor Demonstration Program.(1) The system was successful in providing the high level of service desired for the line-haul portion of the trip, while the bypass ramps enabled transit users to avoid most of the metered ramp delay.

A concurrent but independent program to promote the formation of carpools was undertaken by the Department in cooperation with other State and local agencies. The desire to utilize the I-35W bypass ramps as a preferential treatment came early in this program, but implementation was defered pending completion of the U.C.D.P. evaluation effort. Prior to implementation of carpool bypasses an analysis was made of the costs, enforcement problems, safety problems, flow impact and practical advantages to be encountered. The conclusions were reported(2) along with a recommendation that the Grant Street express bus bypass ramp in downtown Minneapolis be opened to carpools of three or more persons as a "next step" trial.

Subsequent discussions with Federal Highway Administration staff involved with FCP Project 2D, "Priority Treatment for High Occupancy Vehicles" resulted in the Grant Street Bypass project being included in the Carpool Preference Demonstration Program. Coordination and funding were established by designating the project as Task Order No. Four to the MHD/FHWA Basic Agreement.

(1) "FINAL REPORT - I-35W URBAN CORRIDOR DEMONSTRATION PROJECT." August 1975, Minnesota Highway Department, Metropolitan Council & Metropolitan Transit Commission.

(2) "Preferential Treatment for Carpools on I-35W" Study #07-135 July 1975, Benke, R. J. Office of Traffic Engineering, Minnesota Highway Department.

Prior to the start of the bypass ramp use by carpoolers, a communication effort was conducted to let potential users know about the ramp, it's location and the limitations on it's use. Newspaper ads were placed in the large daily papers and in a weekly paper aimed at downtown workers. In addition, a brochure was prepared and distributed at the three downtown approaches to TH 65/freeway I-35W along with a card to be returned for carpool matching purposes. A copy of the brochure is shown on Page 8.

Project Objectives

The study of carpool preference feasibility on I-35W raised several important concerns primarily about non-carpooler acceptance and practical and policy constraints. The basic objective of this study, Ramp Meter Bypass for Carpools, was to evaluate the effect of permitting carpools of three or more persons to use the Grant Street express bus bypass ramp in downtown Minneapolis. Specific questions addressed were:

1. Will providing preferential treatment in the form of bypass of ramp meter delay induce Minnesota auto users to form new carpools?

2. Will non-carpool auto users tolerate provision of preferential treatment for carpoolers?

3. Will carpoolers assume "blanket" permission to use all nine express bus ramps?

4. Will traffic flow patterns and conditions be altered significantly due to the preferential ramp use?

5. What are the policy, operational and economic implications of the success or failure of this demonstration?

STUDY PLAN

STUDY AREA

The Trunk Highway (T.H.) 65 connection (Figure 1) to and from downtown Minneapolis serve trips from the entire south metro area using I-35W. The I-35W corridor was the site of the Bus on Metered Freeway Demonstration, and includes several parallel alternate routes. Thirty-eight entrances, including I-494 and I-94 freeway to freeway ramps are controlled by ramp meters. Sixteen closed circuit television cameras

FIGURE 1. DOWNTOWN TH 65 CONNECTIONS TO I-35W

provide operators visual surveillance capability over fifteen of the seventeen freeway miles. Express buses are permitted to bypass ramp meters at nine locations, eight at ramps in the corridor serving morning inbound buses and the ninth serving evening outbound buses at Grant Street. (Figure 2)

FIGURE 2. GRANT ST. BYPASS RAMP MERGE WITH 12TH ST. METERED RAMP

EVALUATION CONCEPT

Evaluation of the project results involved collection and analysis of before and after measurements of traffic parameters in the study area (Figure 3) and at several remote locations in the I-35W corridor (Figure 4). The before data were gathered in late October and early November, 1975, just prior to the November 18 start of preferential treatment for carpoolers at the Grant Street Ramp. After data were gathered in May and June, 1976, approximately six months later. With the exception of violation rate and occupancy rate data, data collection was limited to evening peak periods (1530-1800) and incremented either by 5 or 15 minutes. Manual counts, mechanical (tube) counts and computer/loop counts provided most of the data base. With few exceptions, the study proceeded as planned.

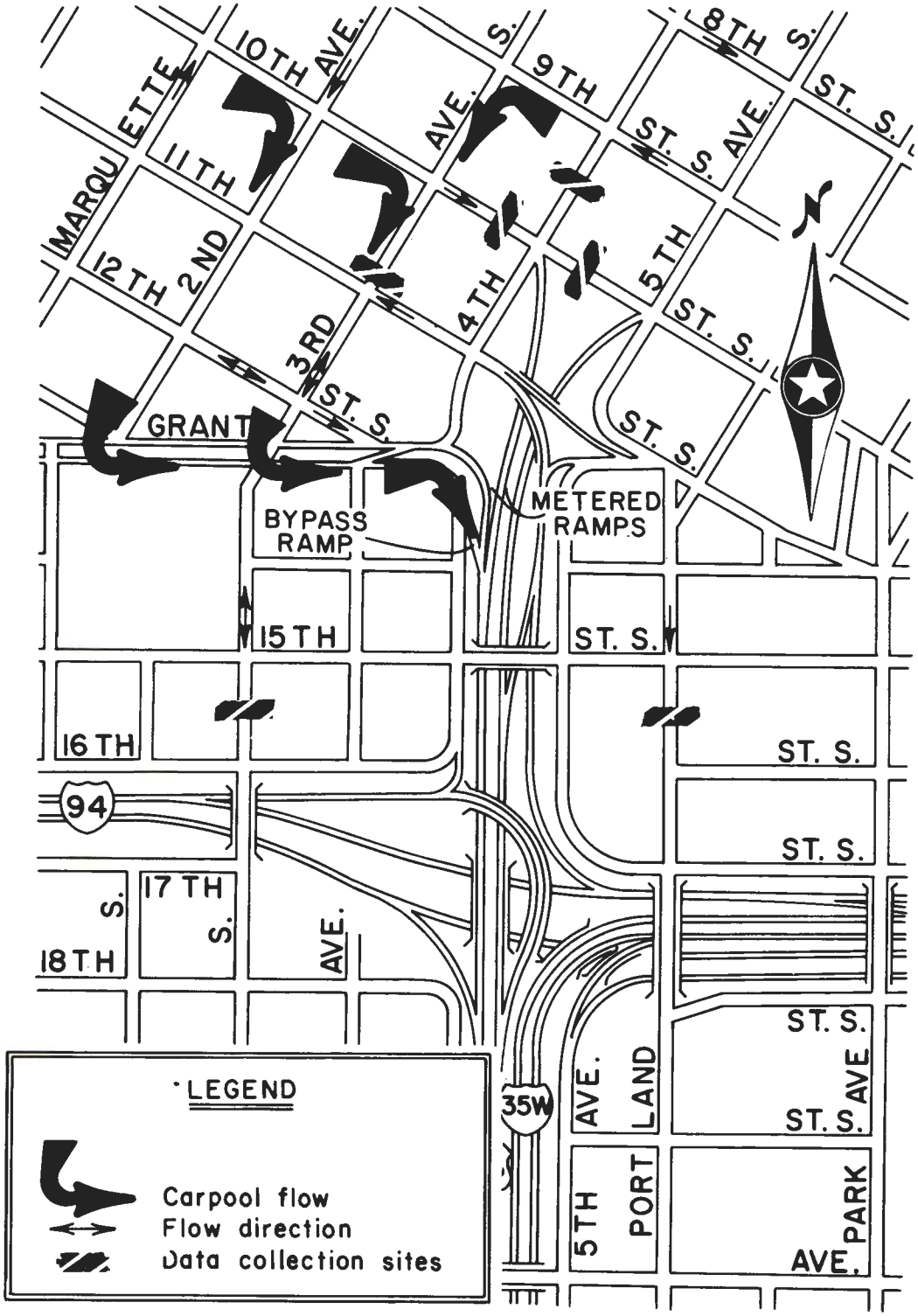


FIGURE 3, Downtown Minneapolis Study Area

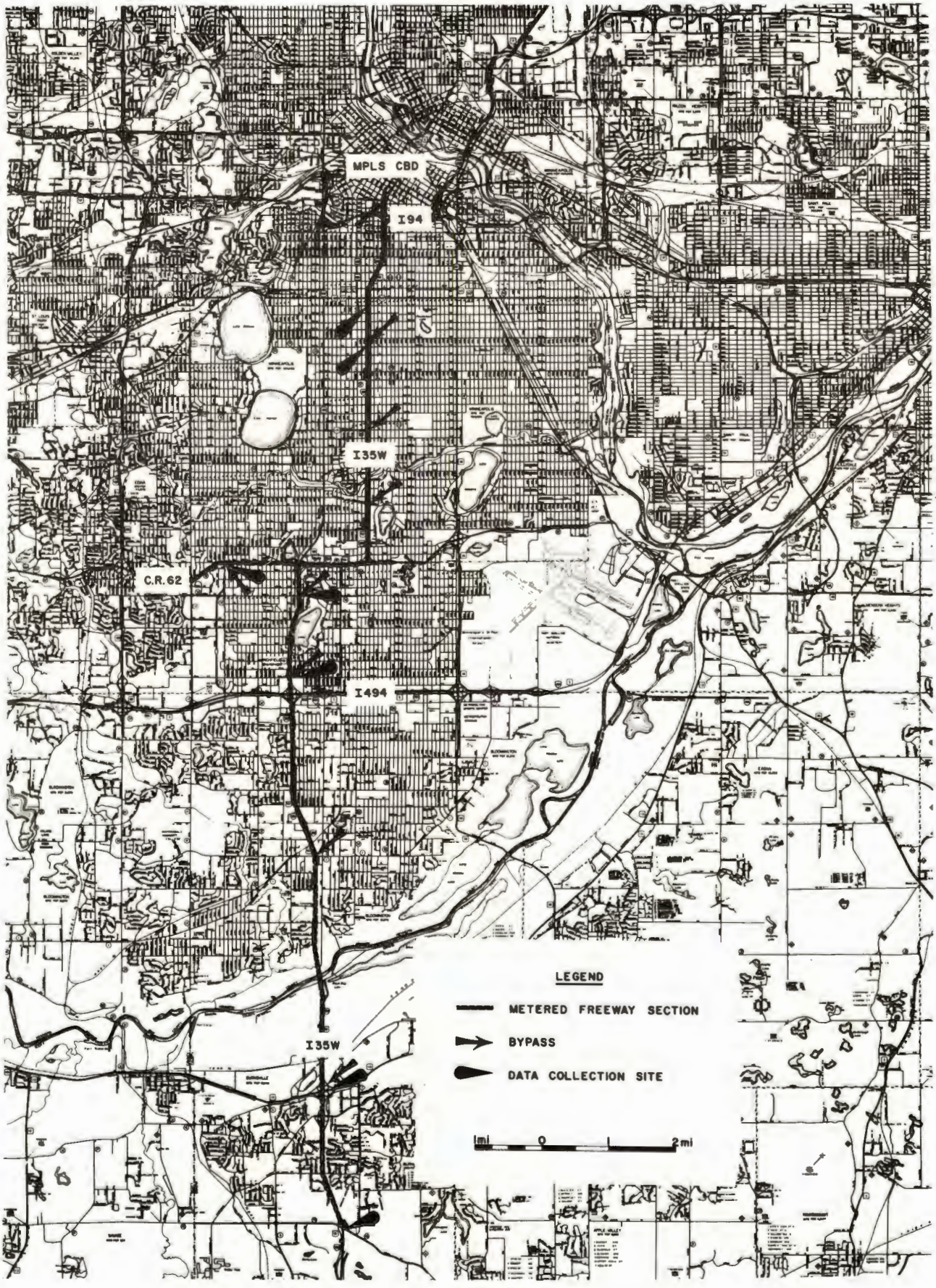


FIGURE 4, Ramp Meter Bypass Study Corridor

Study Parameters

The study parameters were selected to provide all or part of the answer to one of the five specific questions posed to address the project objective. The following parameters were selected with results to be presented in the following report section:

PARAMETER

1. Traffic Volumes
2. Auto Occupancy
3. Queue Sizes
4. Ramp Meter Delay
5. Fuel Consumption
6. Air Quality Factors
7. Violation Rates
8. Enforcement Problems
9. Transit Patronage Impact
10. Auto User Demographics/Attitudes

Study parameter analysis results will be drawn together in addressing each of the five questions in the Conclusions section of this report.

PROJECT START UP

Prior to permitting carpoolers to use the Grant Street express bus bypass ramp, a publicity program was carried out to inform drivers where the ramp was, what limitations on use were, and where they could go for help in forming carpools. A brochure prepared by a marketing firm was distributed to 90 percent of the vehicles entering the TH 65 area, along with a carpool information card that could be sent to the Departments carpool matching service. Full page ads were placed in local and downtown newspapers to inform other potential users of the new effort to promote carpooling. A copy of the materials developed is shown in Figure 5. The text and photos were the same for both newspapers and brochures.

As a further means to guide drivers to the bypass ramp, trail blazing signs were placed throughout the downtown area. The ramp itself was identified by a overhead sign and was controlled by ground mount signing (Figure 6).

Ask two friends to help you out of a jam. Now carpools of three or more have afternoon access to the express bus ramp on the Grant Street entrance to I-35W South.

The Minnesota Highway Department wants to make life a little easier for downtown commuters with a new experimental program. Starting the afternoon of November 18th, *carpools of three or more people* will have access to the express bus ramp on the Grant Street entrance to I-35W South. The special ramp will be marked and made available to carpools weekday afternoons from *3:30 p.m. to 6:00 p.m.* And all you have to do is to form a carpool on your own. Or call us at 296-5975 for help in finding some new friends to travel with.

If the experiment is successful, the program will be expanded to include additional entrance ramps. The final goal is to make travel throughout the Twin Cities faster, easier, cheaper and more convenient than ever before.

So get together with some friends, pool your resources, and help everyone out of a jam.

Minnesota Highway Department

FIGURE 5, Project Publicity Brochure

FIGURE 6, Project Signing

STUDY RESULTS

Traffic Volumes & Patterns

Vehicle volumes were measured at each approach to TH 65 S.B. and at four alternate route locations to determine if significant changes occurred due to the preferential treatment for carpool vehicles. The results indicate that there was no significant change in total period volume on TH 65 at I-94 but that there were changes in peaking times and in travel patterns. Table 1 presents a comparison summary of volumes at the entrance points and a combined total.

TABLE 1. STUDY AREA VOLUME COMPARISON

TIME	LOCATION	VOLUME		CHANGE	"t"	SIGNIF. LEVEL
		BEFORE	AFTER			
1530-1615	4th Ave. & 10th St.	1393	1373	- 20	0.427	Non
	12th St. & Grant St.	270	280	+ 10	0.713	Non
	Total	1663	1653	- 10	0.230	Non
1615-1715	4th Ave. & 10th St.	2034	1919	-115	1.479	Non
	12th St. & Grant St.	525	566	+ 41	4.148	99%
	Total	2559	2485	- 74	0.865	Non
1715-1800	4th Ave. & 10th St.	1309	1424	+115	1.255	Non
	12th St. & Grant St.	307	367	+ 60	4.850	99%
	Total	1616	1791	+175	1.799	Non
1530-1800	4th Ave. & 10th St.	4736	4716	- 20	0.115	Non
	12th St. & Grant St.	1105	1213	+108	4.163	99%
	Total	5841	5929	+ 88	0.475	Non

There was a diversion of traffic from the 4th Avenue/10th Street approach during the peak hour, due to the ramp metering operation. These diversions were primarily from the 4th Avenue approach. The 12th & Grant volumes shown in Table 1 include both the 12th Street metered ramp and auto volumes using the Grant Street bypass ramp (due to detector placement). Actual peak hour volumes on 12th Street declined from 531 to 492. Peak period volume on the 12th Street ramp increased very slightly from 1092 to 1114 (not significant).

Figure 7 presents a summary of data gathered by computer, mechanical counters and manual counts in the study area. The manual counts were made as part of the queue and delay analysis and were limited to the 1530-1730 time period. Results of this analysis show a slight volume loss on 3rd Avenue and on Portland Avenue. Therefore we can assume that the loss of traffic at 4th Avenue and 10th Street was a combination of diversions and seasonal variations.

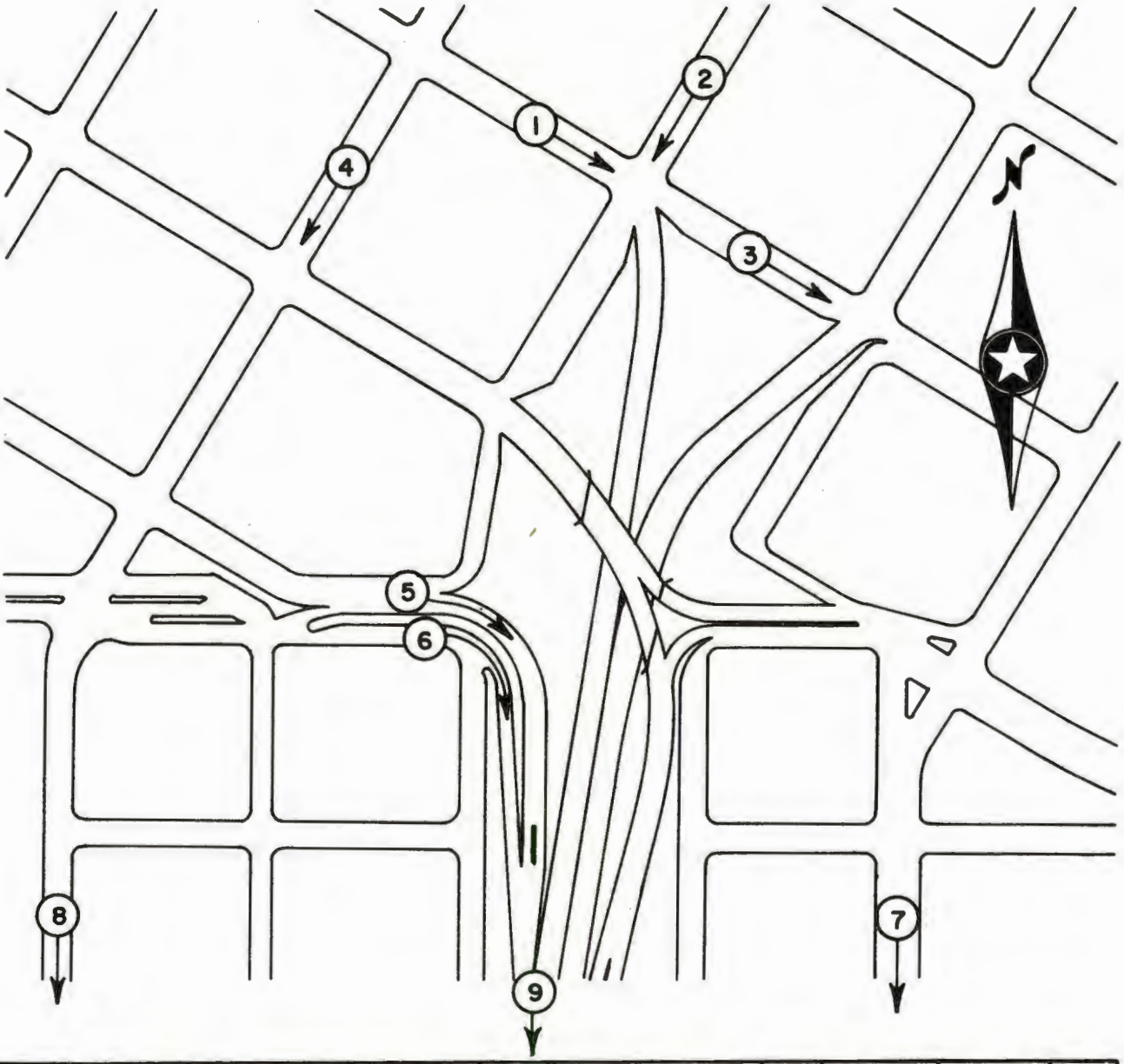
Auto Occupancy

A study of seasonal variations in occupancy rates conducted by the Department suggests that May occupancy rates typically would be slightly higher than in November, perhaps on the order of .01 or .02 persons per vehicle.(1) Therefore, increases in rates of occupancy measured for this study would be inflated by that amount. The actual measurements of CBD outbound traffic reveal that in fact there was only a slight increase (TABLE 2), so that we must assume that no real increase occurred due to the preferential treatment for carpoolers, even though the peak period increase was statistically significant at 99% confidence level.

TABLE 2. TH 65 OCCUPANCY RATE COMPARISON

TIME	Occupancy Rate		CHANGE	"t"	SIGNIF. LEVEL
	BEFORE	AFTER			
1530-1615	1.348	1.355	+0.007	0.601	NON
1615-1715	1.411	1.425	+0.014	1.407	NON
1715-1800	1.328	1.368	+0.040	3.575	99%
1530-1800	1.371	1.388	+0.017	2.700	99%

(1) "Auto Occupancy Parameter Variations" Study #07-132
Benke, R. J. and Sjoberg, R. A. May 1976



LOCATION		BEFORE	AFTER	Δ
① 10th STREET	PH	1320	1290	-30
	PP	2480	2470	-10
② 4th AVENUE	PH	1580	1470	-110
	PP	2990	2860	-140
③ 10th STREET	PH	580	560	-20
	PP	1100	1080	-20
④ 3rd AVENUE	PH	570	600	+30
	PP	1130	1100	-30
⑤ 12th ST RAMP	PH	480	470	-10
	PP	930	940	+10

LOCATION		BEFORE	AFTER	Δ
⑥ GRANT ST. RAMP	PH	0	50	+50
	PP	0	80	+80
⑦ PORTLAND @ I-94	PH	470	440	-30
	PP	880	850	-30
⑧ 3rd Ave. @ I-94	PH	1320	1340	+20
	PP	2520	2460	-60
⑨ T.H. 65 @ I-94	PH	2530	2540	-80
	PP	4840	4800	-40

(PH) PEAK HOUR = 1600-1700
(PP) PEAK PERIOD = 1530-1730

FIGURE 7, Study Area Volume Count Survey

This conclusion is supported by analysis results at the control stations as is shown in Table 3. The morning increase though not statistically significant was on the order of magnitude expected. The highly significant increase in the pm data suggests that the TH 65 data should have shown a large increase, further supporting the "no impact" argument.

The 1715-1800 occupancy rate increase includes a period when the ramp meters are normally not operating, suggesting the delay of some higher occupancy rate from the peak hour to the post peak period. This delay is suggested also by the volume pattern changes but does not explain the fact that the peak hour occupancy rate was unchanged. It is possible that the trip time changed for some people due to metering or other reasons but not to preferential treatment at the same time there was an increased occupancy rate for the remaining trips. The survey results shown later indicate that a few people (3.4%) increased carpool size or formed new carpools. This shift is of the order of magnitude that would be "lost in the shuffle" and could not be established with statistical certainty.

TABLE 3. OCCUPANCY RATE CONTROL STATION ANALYSIS RESULTS

TIME	OCCUPANCY RATE		CHANGE	"t"	SIGNIF. LEVEL
	BEFORE	AFTER			
AM PK HR	1.184	1.202	+0.018	1.371	NON
AM PK PD	1.182	1.198	+0.016	1.630	NON
PM PK HR	1.255	1.348	+0.093	3.285	99%
PM PK PD	1.253	1.338	+0.085	4.323	99%

The increase in the occupancy rate during the "post peak" period, primarily 1730 to 1800 apparently reflects a delayed departure time for persons making the work to home trip. Experience with the freeway traffic management system has shown that there are short term peaks during the evening rush. These occur during the 15 minute interval following typical shift end times. Although summary data showed only an increase for the post peak period there were other significant changes (TABLE 4) that coincided with the shift end peaks. It may be concluded that the work trip people did in fact increase their vehicle loads but very slightly. Further evidence to this possibility is the fact that the proportion of the vehicles carrying more than one occupant increased significantly (TABLE 5) as did the proportion of the people in autos with two or more occupants (TABLE 6). These increases cannot be credited to this project however, since

TABLE 4. OCCUPANCY RATE COMPARISON BY 15 MINUTES

TIME	OCCUPANCY RATE		CHANGE	"t"	SIGNIF. LEVEL
	BEFORE	AFTER			
1530-1545	1.334	1.346	+0.012	0.584	NON
1545-1600	1.350	1.343	-0.007	0.342	NON
1600-1615	1.358	1.373	+0.015	0.767	NON
1615-1630	1.396	1.344	-0.052	2.582	90%
1630-1645	1.393	1.449	+0.056	3.014	99%
1645-1700	1.458	1.447	-0.011	0.521	NON
1700-1715	1.104	1.459	+0.055	2.770	99%
1715-1730	1.346	1.362	+0.016	0.935	NON
1730-1745	1.300	1.336	+0.036	2.020	95%
1745-1800	1.345	1.410	+0.065	2.506	95%

the target-parameter, carpools of three or more people did not improve (TABLE 7). The mixed pattern of significant and non-significant changes, when taken in its entirety suggests that changes, if any, are normal & not related directly to preferential treatment.

TABLE 5. PERCENT OF VEHICLES CARRYING MORE THAN ONE PERSON

TIME	% MULTI-OCCUPANT VEHICLES		CHANGE	"t"	SIGNIF. LEVEL
	BEFORE	AFTER			
1530-1615	26.9	26.8	-0.1	0.109	NON
1615-1715	31.3	32.3	+1.0	1.593	NON
1715-1800	26.5	29.7	+3.2	4.134	99%
1530-1800	28.8	30.0	+1.2	2.980	99%

TABLE 6. PERCENT OF PEOPLE IN MULTI-OCCUPANT VEHICLES

TIME	% OF PEOPLE IN AUTOS W/2 OR MORE PEOPLE		CHANGE	"t"	SIGNIF. LEVEL
	BEFORE	AFTER			
1530-1615	45.8	46.0	+0.2	0.282	NON
1615-1715	51.3	52.5	+1.2	2.105	95%
1715-1800	44.7	48.6	+3.9	5.351	99%
1530-1800	48.1	49.6	+1.5	3.983	99%

TABLE 7. PERCENT OF VEHICLES CARRYING THREE OR MORE PERSONS

TIME	% OF VEHICLES W/3 OR MORE OCCUPANTS		CHANGE	"t"	SIGNIF. LEVEL
	BEFORE	AFTER			
1530-1615	5.1	5.2	+0.1	0.355	NON
1615-1715	6.5	6.8	+0.3	1.014	NON
1715-1800	4.5	4.7	+0.2	0.588	NON
1530-1800	5.5	5.7	+0.2	0 924	NON

Queue Size

The diversion of traffic from the 4th Avenue intersection with 10th Street did not result in reduced queuing at the ramp meters. In fact, average queue sizes increased. The increase was due to changes in control system algorithm parameters, not the preferential treatment process.

TABLE 8. AVERAGE QUEUE SIZE AT 4TH AVE. AND 10TH ST. METER

TIME	QUEUE SIZE		CHANGE	% CHANGE
	BEFORE	AFTER		
1530-1600	8.5	13.3	4.8	56.5
1600-1700	25.6	35.0	9.4	36.7
1700-1730	40.8	50.0	9.2	22.5
1530-1730	25.1	33.4	8.3	33.1

TABLE 9. AVERAGE QUEUE SIZE AT 12TH ST. METER

TIME	QUEUE SIZE		CHANGE	% CHANGE
	BEFORE	AFTER		
1530-1600	0.9	1.2	0.3	33.3
1600-1700	6.1	8.6	2.5	41.0
1700-1730	6.3	15.3	9.0	142.9
1530-1730	4.8	8.4	3.6	25.0

Metered Ramp Delay

Although the ramps sometimes filled with vehicles, as shown in Figure 1, actual delays per vehicle were not excessive. As shown in Table 10, the longest delay during a 15 minute period was about a minute and a half. For most carpoolers from the 4th Avenue area, this delay is less than the time it would take to get to the Grant Street bypass ramp. Each intersection on the diversion path (Figure 3) is signalized, with the signal system operating in a "simultaneous green" mode that precludes traveling the entire path without stopping at least once.

The lack of a significant delay means there is no real incentive provided at the downtown end of the carpool trip. Avoiding a large delay at one end of the trip or a smaller delay at each end of the trip would perhaps alter the reaction of auto users to the preferential treatment inducement. While potential reaction is speculative at this time, it is probable that auto users would welcome the opportunity to avoid a 20 minute delay that is not uncommon at a few ramps in the corridor.

TABLE 10. METERED RAMP DELAY

TIME PERIOD	DELAY PER VEHICLE		MANHOURS DELAY		CARPOOL DELAY	
	10th St.	12th St.	10th St.	12th St.	10th St.	12th St.
1530-1545	18.0	2.2	3.0	0.1	0.4	0
1545-1600	20.4	2.4	3.3	0.1	0.4	0
1600-1615	38.7	3.0	7.0	0.1	1.0	0
1615-1630	32.6	4.1	5.9	0.1	0.6	0
1630-1645	77.8	29.9	14.1	1.4	1.6	0.1
1645-1700	91.2	51.6	16.2	2.4	1.7	0.3
1700-1715	90.0	36.5	16.6	1 9	2.1	0.2
1715-1730	82.5	31.7	14.9	1.7	1.3	0.2
1730-1745	50.7	1.9	9.8	0.1	1 1	0
1745-1800	1.6	0.1	0.3	0	0	0
1630-1730	85.6	37.2	61.8	7.4	6.1	0.8
1530-1800	48.5	14.7	91.1	7.9	10.3	0.8

Fuel Consumption

The changes in carpool use are so slight and the time saving for ramp users are so questionable that it was not possible to accurately estimate changes in fuel consumption due to the preferential treatment operation.

Air Quality

As was the case with fuel consumption, air quality impact of the preferential treatment operation was not measurable. The CO_2 monitoring equipment located near the ramp was removed by the Minnesota Pollution Control Agency due to technical problems, making direct measurement impossible.

Violation Rates

Two types of violations were feared in permitting carpools to use the Grant Street bypass ramp. First, it was feared that carpoolers would assume they had blanket permission to use all of the bypass ramps in the corridor, despite the absence of the permissive signing. Second, it was feared that "lowering the standard" for bypassing vehicles would cause some metered ramp users to feel less obligated to obey the ramp signal.

Prior to starting the bypass demonstration, violations of the bypass at Grant Street amounted to no more than three or four per day. As shown in Table 11, that volume increased to about 16 per day, a 18.7% violation rate. Six of these violations occur during the periods when metered ramp delays are not severe, indicating a tendency to flaunt the system.

TABLE 11 BYPASS RAMP USE

TIME PERIOD	# CARPOOLS	# VIOLATORS	TOTAL AUTOS	% VIOLATORS	# BUSES	TOTAL VEHICLES
1530-1615	4.6	3.6	8.2	43.9	7	15
1615-1715	60.0	9.8	69.8	14.0	80	150
1715-1800	5.8	2.8	8.6	32.6	42	51
1530-1800	70.4	16.2	86.6	18.7	129	216

Also, as indicated in Table 12, half of the violators are two person carpools who may incorrectly feel justified in using the ramp.

Table 13 provides available results in three bypass locations in the I-35W corridor; and shows increases ranging from 39 to 200%. These violators were both carpoolers and non-carpoolers. When apprehended, the driver of one carpool stated his belief that carpools were permitted to use the other ramps also. If he was being honest, and not just using that as an excuse, misconception did occur, but not in great numbers.

TABLE 12. VIOLATOR TYPES

TIME PERIODS	VIOLATIONS PER WEEK	# ONE OCCUPANT	% ONE OCCUPANT
1530-1615	18	11	61.1
1615-1715	49	25	51.0
1715-1800	14	4	28.6
1530-1800	81	40	49.4

TABLE 13. BUS ONLY BYPASS RAMP VIOLATION RATES

RAMP	PEAK TIME	VIOLATION RATE (%)		CHANGE	% CHANGE
		BEFORE	AFTER		
76th St. NB	A.M.	0.4	1.2	0.8	200
66th St. NB	A.M.	0.9	2.3	1.4	156
Xerxes EB	A.M.	3.3	4.6	1.3	39

Checks were also made at several ramp meters to determine if those violations had increased. Results show (TABLE 14) that they had. The most serious increase in terms of absolute change occurred at 31st Street, a chronically congested ramp with many incentives to violate the meter and virtually no chance of being apprehended. It is felt that the violation rate increases are most probably due to general system delay conditions, since demands have been growing and delays have increased, thus increasing driver frustrations. It cannot be shown that the increase was due to preferential treatment granted carpools.

Enforcement Problems

Apprehension of violators at the Grant Street bypass ramps was complicated by two factors - availability of State Patrol manpower and location of the waiting patrol vehicle. These problems are common to both bypass violation and metered ramp violation problems. The officers patrolling the I-35W system included surveillance of the ramps as part of their routine, but properly spend the majority of their time in assisting motorists and other enforcement activity.

TABLE 14. METERED RAMP VIOLATION RATES

RAMP	PEAK TIME	VIOLATION RATE (%)		CHANGE	% CHANGE
		BEFORE	AFTER		
31st St. SB	PM PK	1.2	4.0	2.8	233
Xerxes SB	PM PK	0.7	0.7	0	0
TH 13 Leg NB	AM PK	0.5	1.5	1.0	200
Xerxes EB	AM PK	0.2	0.7	0.5	250
Combined	ALL	0.7	1.9	1.2	171

Actual apprehension of violators is a difficult, if not impossible task. At most locations, potential violators can see if a patrol car is near the entrance. But if the patrol trooper waits out of view, heavy traffic flows make it extremely difficult to get to the violator. If a violator is apprehended the presence of a patrol car near the freeway can cause a greater problem than did the violation.

For a period of time, officers daily parked on the Grant Street ramp. Subsequent checks showed a significant decrease in violations but a return to previous levels after a few days of no presence.

Contacts with State Patrol troopers responsible for patrolling I-35W revealed that many had issued citations for violations of the ramp signals or bypass lanes. Those that had issued tickets (including at Grant Street) reported that a few had been successfully challenged in court because of a feeling that the violation is not serious. The specific violation for which drivers were tagged was "failure to obey a regulatory sign".

Transit Patronage Impact

One concern of the Department in conducting this demonstration was that transit patrons would be drawn back to automobiles due to the preferential treatment making carpooling more convenient. While 14% of the survey respondents answering the question (26 of 180) said that they had quit riding buses to join a carpool, it is felt that the response was not representative. Nevertheless there were 26 of the 1955 respondents (1.3%) who said yes they had quit the bus, which means that diversion is a factor to be considered.

TABLE 15. CARPOOL MARKET ANALYSIS COMPARISON

PARAMETER	BEFORE	AFTER	CHANGE	% CHANGE
EXPRESS BUS PATRONS	4499	4771	+272	+6.0
PEOPLE RIDING ALONE	4143	4133	- 10	-0.2
PEOPLE IN 2 OCC. AUTOS	2704	2858	+154	+5.7
PEOPLE IN 3+ OCC. AUTOS	1128	1183	+ 55	+4.9
TOTAL PEOPLE ON TH 65	12474	12945	+471	+3.8
% IN EXPRESS BUS	36.1	36.9	+0.8	+2.2
% ALONE IN AUTO	33.2	31.9	-1.3	-3.9
% IN CARPOOLS (2+)	30.7	31.2	+0.5	+1.6
% CARPOOLS + TRANSIT	66.8	68.1	+1.3	+1.9
% AUTO USERS IN CARPOOLS	48.1	49.4	+1.3	+2.7
% IN CARPOOLS (3+)	9.0	9.1	+0.1	+1.1

In context with total volumes of people using TH 65 during the p.m. peak the diversion is insignificant. The 26 people were just 0.2% of the total peak period volume of people as shown in Table 15. In fact, the proportion of TH 65 users on the express buses was unchanged (+0.8%) but the proportion in either transit or in carpools did increase significantly. Therefore we can assume that preferential treatment did not draw a significant number of patrons from transit.

Auto User Demographics and Attitudes

A 14 question survey (Figure 8) of auto user demographics and opinions was conducted in May 1976, about 6 months after the bypass ramp was opened to carpools of three or more people. The purpose of this survey was to determine who the auto users were in terms of age, sex, trip length and carpool status, to determine if they had made any changes in their travel status due to the project, and to determine what their attitudes were towards carpooling and toward preferential treatment of high occupancy vehicles.

TO THE AUTO USER:

The Minnesota Highway Department is conducting this survey to help determine future policies regarding preference for carpools. Please help us by answering the following questions and returning the form to us. Respond only for the day you received this card unless the question is of a general nature. Thank you.

This Column For Dept. Use Only

ON THE DAY YOU RECEIVED THIS CARD –

1. HOW MANY PEOPLE WERE IN THE CAR INCLUDING YOURSELF?_____
2. WERE YOU THE DRIVER? ☐ A PASSENGER? ☐
3. HOW LONG WAS THE TRIP (MILES)? ☐0-5 ☐5-10 ☐10-15 ☐15-20 ☐20+
4. WAS THIS TRIP TO OR FROM WORK? ☐YES ☐NO
5. HOW MANY DAYS PER WEEK DO YOU COMMUTE TO WORK DOWNTOWN? _____

IF YOU WERE NOT IN A CARPOOL (2 OR MORE PEOPLE) ANSWER #6, 7 & 11-15

6. WHY DON'T YOU CARPOOL? (one answer only) ☐DON'T WANT TO ☐WORK HOURS VARY FROM DAY TO DAY ☐USE CAR FOR WORK DURING THE DAY ☐INCONVENIENT ☐OTHER ☐NOBODY TO POOL WITH
7. WOULD YOU CONSIDER RIDING TO WORK IN A CARPOOL IF IT WERE POSSIBLE? NO ☐ MAYBE ☐ YES ☐

IF YOU WERE IN A CARPOOL (2 OR MORE PEOPLE) ANSWER #8-15

8. HOW LONG HAVE YOU CAR POOLED? ☐0-6 MO. ☐6 M-1 YR. ☐1-3 YRS. ☐3+ YRS.
9. WHY DO YOU CAR POOL? (one answer only) ☐SAVE ENERGY ☐CONVENIENT ☐OTHER ☐SAVE MONEY ☐HAVE TO
10. BECAUSE CARPOOLS OF 3 OR MORE PEOPLE WERE ALLOWED TO USE THE GRANT ST. BUS RAMP, DID YOU a) ☐START A NEW POOL? ☐ADD TO AN EXISTING POOL ☐NO CHANGE
    b) QUIT RIDING A BUS TO JOIN A CARPOOL? ☐YES ☐NO

EVERYONE PLEASE ANSWER QUESTIONS 11 OR 12 AND 13-15

11. IF YOU DIDN'T USE THE GRANT STREET BUS RAMP, WHY NOT?
    ☐DIDN'T HAVE 3 PEOPLE IN AUTO ☐TOO INCONVENIENT ☐COULDN'T FIND IT ☐DIDN'T KNOW ABOUT IT ☐NO TIME BENEFIT ☐OTHER
12. IF YOU DID USE THE GRANT STREET BUS RAMP WHAT WAS YOUR REACTION?
    a) WAS IT ☐INCONVENIENT ☐OK ☐CONVENIENT TO USE?
    b) DID YOU ☐SAVE TIME ☐LOSE TIME OR ☐TAKE THE SAME TIME?
    c) WAS IT ☐SAFE ☐UNSAFE ☐OK TO USE?
13. DO YOU FAVOR GIVING PREFERENTIAL TREATMENT TO

	ABSOLUTELY NO	NO	MAYBE	YES	ABSOLUTELY YES
a) EXPRESS BUSES	☐	☐	☐	☐	☐
b) VAN POOLS	☐	☐	☐	☐	☐
c) CARPOOL (3 OR MORE PERSONS)	☐	☐	☐	☐	☐
d) CARPOOL (2 OR MORE PERSONS)	☐	☐	☐	☐	☐

FOR STATISTICAL PURPOSES:

14. YOUR AGE _____ SEX ☐M ☐F
15. COMMENTS: _____

Figure 8, Auto User Survey Form

The survey was distributed to 6200 auto users (76%) on the three entrance ramps. Of these, 1955 were returned (32%) in time to be used in the analysis. The returned cards were edited, coded, keypunched and processed by computer. For some analyses, only those responses indicating an age 18 or older and work trip purpose were included. The opinion question analysis included all usable replies. Some questions were not answered on all forms so that sample totals will vary from question to question.

The first set of questions was set up to determine the nature of the work trips being made. Question #1 asked the number of occupants in the auto. The result, Table 16, was an average occupancy rate of 1.58 persons per auto. This rate is higher than the 1.39 rate measured by the observers which suggests that the response by carpoolers was greater proportionally than by the non-carpoolers.

TABLE 16. NUMBER OF OCCUPANTS PER AUTO

PEOPLE PER AUTO	WORK TRIPS		NON WORK TRIPS		ALL TRIPS	
	#	%	#	%	#	%
1	1011	61.7	180	65.9	1191	62.3
2	406	24.8	72	26.4	478	25.0
3	123	7.5	13	4.8	136	7.1
4	62	3.8	5	1.8	67	3.5
5	32	2.0	3	1.1	35	1.8
6	4	0.2	0	0	4	0.2
7+	0	0	0	0	0	0
TOTAL	1638	100.0	273	100.0	1911	99.9
OCCUPANCY RATE		1.60		1.46		1.58

Question #2 sought to determine the status of the sample with regard to whether the respondents were drivers or passengers. Table 17 shows the results cross tabulated by sex as indicated in question 14. This response is for work trips by persons 18 years old or older. Of the 1486 replies 67.4% were males, 32.6% were females.

TABLE 17. DRIVER/PASSENGER DISTRIBUTION

	MALE		FEMALE		TOTAL	
	#	%	#	%	#	%
DRIVERS	875	87.2	320	66.1	1195	80.4
PASSENGERS	127	12.7	164	33.9	291	19.6
TOTALS	1002	100.0	484	100.0	1486	100.0

Question #3 sought to determine the trip length, since this parameter was thought to be a factor in the carpooling tendency. The average trip length for carpoolers was 13.3 miles but for non-carpoolers it was 12.6 miles. The only statistically significant differences occurred in the 0 to 5 miles and the 20+ miles categories, as shown in Table 18.

TABLE 18. TRIP LENGTHS

LENGTH OF TRIP (MILES)	% OF CARPOOLS	% OF NON CARPOOLS	% OF WORK TRIPS	% OF NON WORK TRIPS	% OF ALL TRIPS
0-5	5.6	9.2	7.7	9.1	7.8
5-10	32.1	30.0	31.0	28.7	30.8
10-15	29.5	30.4	31.7	20.7	30.1
15-20	15.3	16.8	16.4	15.6	16.2
20+ MILES	17.4	13.6	13.2	25.8	15.1
SAMPLE SIZE	731	1202	1639	275	1933

The work trip/non work trip comparison of trip lengths was influenced greatly by a relatively large number of single occupant, long distance non-work trips.

Questions #4 and #5 were included to determine the purpose and frequency of the trips to or from downtown. Tables 19 and 20 show the response that indicates the sample included a high proportion of daily commuters.

TABLE 19. TRIP PURPOSE

PURPOSE	#	%
WORK	1644	85.5
OTHER	278	14.5
TOTAL	1922	100.0

TABLE 20. CBD TRIP FREQUENCY

DAYS/WEEK	#	%
1	52	3.1
2	45	2.7
3	63	3.8
4	61	3.7
5	1358	82.3
6	64	3.9
7	8	0.5
TOTAL	1651	100.0

Questions #6 and #7 were included to determine the sample populations reasons for not carpooling and tendency to carpool if the obstacles were removed. The response indicates a high proportion of the males 64.3% don't carpool because their work hours vary or they use the car for work during the day. Only 4.1% of the sample indicated that they just didn't want to carpool. Results for Question #6 are presented in Table 21.

TABLE 21. REASONS FOR NOT CARPOOLING

REASON	MALES (%)	FEMALES (%)	TOTAL
DON'T WANT TO	3.3	5.7	4.1
WORK HOURS VARY	24.3	32.7	27.0
USE CAR FOR WORK	40.0	14.1	31.8
INCONVENIENT	10.4	14.8	11.8
NOBODY TO POOL WITH	10.7	22.8	14.6
OTHER	11.3	9.9	10.8
SAMPLE SIZE	568	263	831

The respondents were asked to indicate one reason only so that the response would represent their most important reason. Some replies included more than one reason and were not included in this summary.

The nature of the response to Question #7 is an indication of the marketing strategy needed to "convert" these non-carpoolers to carpool use. The option "maybe" was included to complete the "state of mind" possibilities typically encountered. Only 42% of the sample said no to the possibility of carpooling if they could. About 58% said either that they would or that they would consider it (maybe). If a program can be designed to resolve the variable work hour, inconvenience and, nobody to pool with problems, future carpool promotion efforts should have some positive results based on the responses summarized in Table 22. However, the probable maximum market for carpool formation is probably only 58% of those who indicated (TABLE 21) other than work hours or car use as reasons for not pooling or about 24% of those currently traveling alone, or 7.7% of all TH 65 users.

TABLE 22. POSSIBLE CARPOOL USE

WOULD YOU CARPOOL IF YOU COULD?	MALES (%)	FEMALES (%)	SAMPLE TOTAL (%)
YES	33.9	36.9	34.8
MAYBE	19.3	32.6	23.3
NO	46.8	30.5	41.9
SAMPLE SIZE	699	298	997

Question #8 was asked of carpoolers to determine the extent of carpool formation during the life of the project. As indicated in Table 23, 17.6% of the sampled carpools formed during the previous six months. In addition it can be seen that 47% of the male carpoolers have been carpooling more than 3 years but 48% of the females have carpooled less than one year.

TABLE 23. CARPOOL LIFE SPAN

# OF YEARS	MALES (%)	FEMALES (%)	TOTAL (%)
0 TO 6 MO.	12.9	23.9	17.3
6 MO. TO 1 YR.	11.1	23.9	16.2
1 TO 3 YRS.	28.8	26.1	27.7
MORE THAN 3 YRS.	47.2	26.1	38.8
SAMPLE SIZE	271	180	451

Reasons given for carpooling, in response to Question #9 were primarily for convenience and to save money. The male/female distribution followed the driver/passenger response distribution, due to the preponderance of male drivers in the sample shown in Table 24.

Carpool lifespan did not appear to influence the reason distribution, however, there were a disporportionate (higher) number of responses to "save energy" among the newest (0-6 mo.) carpoolers. Trip length was also not a significant variable affecting this sample response.

TABLE 24. REASONS FOR CARPOOLING

REASON GIVEN	DRIVERS (%)	PASSENGERS (%)	TOTAL (%)
SAVE ENERGY	5.2	5.3	5.2
SAVE MONEY	41.1	35.9	38.4
CONVENIENCE	37.0	47.8	42.6
HAVE TO	3.6	5.3	4.5
OTHER	13.0	5.7	9.2
SAMPLE SIZE	192	209	401

Question #10a & 10b were posed to determine if the preferential treatment of carpools had any influence on carpool formation or if transit patrons were drawn to autos. The responses indicate a very minimal effect in both cases. There was a small increase in carpooling but not enough to measurably affect traffic flow. The response to Question 10b was very low, indicating people may have missed reading it. Only 180 of about 732 carpoolers responded, therefore the 14% response indicating they quit riding the bus to join a carpool because of the preferential treatment is highly suspect.

TABLE 25. CHANGES DUE TO PROJECT

ACTION	DRIVERS (%)	PASSENGERS (%)	TOTAL (%)
STARTED NEW POOL	0.5	0.5	0.5
ADDED TO EXISTING POOL	1.0	4.5	2.9
MADE NO CHANGE	98.5	95.1	96.7
SAMPLE SIZE	195	223	418

TABLE 26. TRANSIT DIVERSION

ACTIONS TAKEN	DRIVERS (%)	PASSENGERS (%)	TOTAL (%)
QUIT USING BUS	9.9	19.1	14.4
DIDN'T QUIT USING BUS	90.1	80.9	85.6
SAMPLE SIZE	91	89	180

Questions #11 and #12 were asked to ascertain user and non-user reaction to the actual use of the bypass route and ramp. It was known that the bypass maneuver would be out of the way for traffic using 4th Avenue or coming from the east side of downtown Minneapolis. As it turned out, there were a significant number who didn't know about the project despite initial publicity and advertising, trailblazing in downtown Minneapolis and frequent followup publicity.

TABLE 27. REASONS FOR NOT USING BYPASS RAMP

REASON GIVEN	#	%
DIDN'T KNOW ABOUT IT	177	33.8
INCONVENIENT	154	29.4
NO TIME SAVED	88	16.8
COULDN'T FIND IT	19	1.9
OTHER	94	18.0
SAMPLE SIZE	523	99.9

Those carpoolers who did use the Grant Street Bypass ramp were generally satisfied with the convenience, safety and time savings. There were those however as indicated in Table 28, that were not satisfied and felt the operation was unsafe, inconvenient and/or took longer.

TABLE 28. BYPASS RAMP USER REACTIONS

FACTORS CONSIDERED		DRIVERS (%)	PASSENGERS (%)	TOTAL (%)
a)	INCONVENIENCE	17.6	4.9	11.2
	OK	31.4	10.7	21.6
	CONVENIENT	51.0	84.5	67.8
	SAMPLE SIZE	102	103	205
b)	SAVED TIME	63.9	90.5	77.7
	SAME TIME	22.7	9.5	15.8
	LOST TIME	13.4	0	6.4
	SAMPLE SIZE	97	105	202
c)	SAFE	64.4	82.0	73.7
	OK	27.8	17.0	22.1
	UNSAFE	2.8	1.0	4.2
	SAMPLE SIZE	90	100	190

Since the operational success of the bypass ramp preferential treatment policy for carpoolers does and in future systems will require voluntary acceptance of the concept, Question #13 was posed to ascertain auto user reaction. The results, TABLE 29, show that the majority of the auto users favor giving preferential treatment to express buses, vanpools and carpools of 3 or more people but not to carpools of 2 people. The carpool of 2 or more people case received the greatest proportion of "maybe" replies or no answers indicating a high degree of uncertainty. The express bus priority issue was enthusiastically endorsed by 39% of those who expressed an opinion.

TABLE 29. AUTO USER REACTION TO PREFERENTIAL TREATMENT

OPINION REPLY (%)	EXPRESS BUS	VANPOOLS	CARPOOLS (3+)	CARPOOLS (2+)
ABSOLUTE NO	8.1	9.1	10.2	13.9
NO	5.5	10.3	14.5	28.0
MAYBE	7.0	13.8	14.7	20.7
YES	37.4	34.1	32.1	17.0
ABSOLUTE YES	36.4	24.1	20.5	9.3
NO ANSWER	5.6	8.6	8.1	11.2
SAMPLE SIZE	1955	1955	1955	1955

Among those expressing opinions, there were slight differences of opinion. Generally, carpoolers, passengers, females and non-work trip people were more positive in their acceptance of preferential treatment.

TABLE 30 PREFERENTIAL TREATMENT FOR EXPRESS BUSES

(%) RESPONSE	DRIVERS	/PASSENGERS	CAR-POOLERS	NON-CAR POOLERS	MALES	FEMALES	WORK TRIPS	NON-WORK TRIPS
ABS. NO	10.2	5.5	7.3	11.2	10.2	7.5	9.4	6.1
NO	6.4	3.7	5.8	5.9	5.3	7.0	5.9	5.4
MAYBE	8.0	4.4	6.7	8.0	6.7	9.0	7.2	8.0
YES	39.7	44.0	39.7	41.4	40.9	39.9	40.5	36.6
ABS. YES	35.6	42.5	40.5	33.5	36.8	36.6	36.9	43.9
SAMPLE SIZE	1153	273	686	741	972	456	1421	424

TABLE 31. PREFERENTIAL TREATMENT FOR VANPOOLS

(%) RESPONSE	DRIVERS	/PASSENGERS	CAR POOLERS	NON-CAR POOLERS	MALES	FEMALES	WORK TRIPS	NON-WORK TRIPS
ABS. NO	11.9	6.7	8.2	13.4	11.5	9.5	10.9	6.4
NO	12.5	8.2	9.4	13.8	11.2	12.4	11.6	10.1
MAYBE	15.8	12.7	14.2	16.2	15.0	15.8	15.1	15.1
YES	37.0	36.6	36.4	37.4	37.6	35.5	36.9	38.8
ABS.YES	22.8	35.8	31.8	19.2	24.6	26.7	25.4	29.6
SAMPLE SIZE	1119	268	670	717	946	442	1382	405

TABLE 32. PREFERENTIAL TREATMENT FOR CARPOOLS OF 3 OR MORE PEOPLE

(%) RESPONSE	DRIVERS	PASSENGERS	CAR-POOLERS	NON-CAR POOLERS	MALES	FEMALES	WORK TRIPS	NON-WORK TRIPS
ABS. NO	13.3	6.9	7.9	16.0	13.3	9.4	12.1	7.4
NO	18.0	8.4	11.4	20.4	16.0	16.3	16.1	14.6
MAYBE	17.3	9.9	13.4	18.2	16.5	14.5	15.8	16.6
YES	33.7	35.0	35.3	32.8	33.2	35.9	34.0	38.4
ABS. YES	17.6	39.8	32.0	12.6	21.0	23.9	22.0	23.0
SAMPLE SIZE	1124	274	674	725	952	448	1393	404

TABLE 33. PREFERENTIAL TREATMENT FOR CARPOOLS OF 2 OR MORE PEOPLE

(%) RESPONSE	DRIVERS	PASSENGERS	CAR-POOLERS	NON-CAR POOLERS	MALES	FEMALES	WORK TRIPS	NON-WORK TRIPS
ABS. NO	18.2	11.2	11.9	21.4	18.4	12.9	16.8	11.5
NO	34.2	20.1	26.1	36.4	33.1	27.7	31.4	31.7
MAYBE	22.8	22.7	22.0	23.8	22.8	23.3	22.8	25.1
YES	16.6	29.7	24.9	13.7	17.1	23.6	19.2	19.2
ABS YES	8.1	16.4	15.1	4.7	8.5	12.5	9.8	12.5
SAMPLE SIZE	1081	269	663	686	916	433	1345	391

CONCLUSIONS

Carpool Formation

The provision of preferential treatment for carpool vehicles did not result in a measurable increase in the number of carpools using the TH 65 route from downtown Minneapolis. The delays encountered at the metered entrance ramps were not great enough to induce many carpoolers to divert to the bypass nor to form new carpools so they could use the ramp. Primary use of the bypass ramp was by previously existing carpoolers who found it convenient to divert.

Non-User Acceptance of Preferential Treatment

Non-carpoolers expressed some disfavor with the preferential treatment of carpoolers but did not react by violating either the bypass ramps or the ramp meter signals to any great extent because of it. The violation rate increases are most likely due to general delay increases caused by growth in system demand.

Carpooler Use of Other Bypass Ramps

Although a significant number of survey respondents requested or suggested that carpoolers be permitted to use the other ramps also, they did not begin doing so. Violation rates did increase, however, the overall violation problem is not severe. The compliance has been helped by enforcement by State Patrol officers as their duties permitted. Concentrated efforts were applied only in response to specific requests.

Traffic Pattern and Condition Changes

Changes in volume and patterns due to the demonstration were minor, consisting of diversion of about 70 vehicles from the two metered ramps during the peak period. Other changes if any, were due either to seasonal variation or to changes in control strategies for the metering system.

Project Result Implications

The lack of response to this preferential treatment project can be attributed to a lack of incentive. For many of the potential carpoolers there

are no acceptable alternative control strategies at the TH 65 entrances that would provide the time benefit incentive needed to induce a significant number of new carpools. Imposition of additional delay at the entrance meters would serve only to create congestion and related air quality problems downtown and further erode the auto user compliance to the controls.

The fact that this priority treatment operation was an apparent failure with respect to formation of new carpools while similar demonstrations in other cities have been apparent successes serves to point out the need for a case by case analysis of potential applications. A blanket policy to provide preferential treatment at every metered ramp then is clearly unworkable. Not only are there instances of practical or physical undesireability, there are instances where the market does not exist.

The data here suggest that the probably potential market for carpool promotion efforts on TH 65 is small, only 24% of current non-poolers and just 8% of all peak period route users. Complete capture of this potential could result in an occupancy rate of 1.5 people per auto or 1.55 during the peak hour. Reaching these non-poolers in specific, targeted programs may be more effective than was this generally applied treatment. In any event, attainment of the 1.5 occupancy rate is not probable without major changes in fuel availability or other restrictive measures.

While there is a high level of auto user support for the preferential treatment concept, the acceptance is not universal. This fact must be remembered in future concept applications since user support is critical to control system success. It may be necessary to regulate priority treatment to an incidental rather than a primary thrust in achieving increased occupancy levels.

Since there were no changes in traffic parameters due to this demonstration, there are no calculable benefits due to reduced fuel consumption, delay, etc. These same criterion must be applied in future considerations of potential preferential treatment applications with respect to existing carpools since benefits due to induced carpooling will be too highly speculative.

APPENDIX A

Statistical Analysis of Evaluation Measures

For this study several measures of effectiveness were sampled both before and after and statistically tested for significant differences. The following notation is used:

$\bar{X}_i$ = mean of sample i

S_i^2 = variance of sample i

S_i = standard deviation of sample i

$S_{\bar{X}i}$ = standard error of the mean of sample i

N_i = sample size of sample i

t = students "t"

Equations used:

Eqn. 1 Variance of proportion

$$S_i^2 = P_i (1 - P_i) \qquad P = \text{Portion}$$

Eqn. 2 Variance of ungrouped data

$$S_i^2 = \frac{N_i (\Sigma X_i^2) - (\Sigma X_i)^2}{N_i (N_i - 1)}$$

Eqn. 3 Variance of grouped data

$$S_i^2 = w^2 \left(\frac{N(\Sigma f_i Y^2) - (\Sigma f_i Y)^2}{N(N-1)} \right)$$

where f_i = the class frequency

Y = the deviation of the class

In class interval units from an assumed mean, w = the width of class interval.

Eqn. 4 Standard error of the mean of sample

$$S_{\bar{x}i} = \sqrt{S^2_i / N}$$

Eqn. 5 Standard error of the product of two or more means.

$$\bar{Y} = (\bar{X}_1)\ (\bar{X}_2) \ldots\ldots (\bar{X}_t)$$

$$S_{\bar{y}} = \sqrt{\left[(\bar{X}_2)^2 \ldots (\bar{X}_t)^2 (S_{\bar{X}_1})^2\right] + \left[(\bar{X}_1)^2 (\bar{X}_3)^2 \ldots (\bar{X}_t)^2 (S_{\bar{X}_2})^2\right] + \ldots}$$

$$\ldots + \left[(X_1)^2 \ldots (X_{t-1})^2 (S_{X_t})^2\right]$$

Eqn. 6 Students "t"

$$(6A) \quad S_c = \sqrt{\frac{S_1^2 (N_1 - 1) + S_2^2 (N_2 - 1)}{(N_1 - 1) + (N_2 - 1)}}$$

$$(6B) \quad S_d = S_c \sqrt{\frac{N_1 + N_2}{N_1 N_2}}$$

$$(6C) \quad t = \frac{X_1 - X_2}{S_d}$$

Eqn. 7 Standard error of difference between two means.

$$S_{\bar{Y}} = \sqrt{(S_{\bar{X}_1})^2 + (S_{\bar{X}_2})^2}$$

Eqn. 8 Significance of change in standard deviations.

(8A) $$\bar{Y} = \ln (S_1 / S_2) = \ln (S_1) - \ln (S_2)$$

(8B) $$S_{\bar{Y}} = \sqrt{\frac{1}{2}\left(\frac{1}{(N_1 - 1)} + \frac{1}{(N_2 - 1)}\right)}$$

(8C) If $\bar{Y} - t\,(S_{\bar{Y}}) > 0$, the difference in standard deviations is significant

Standard deviation of sample

$$S_i = \sqrt{S_i^2}$$

Summary Data Collection and Analysis

	Measure	Method Obtained By	Equations Used
A	Volume	Computer & Tube Counts	2 6 8
B	Vehicle Occupancy	Manual Counts	3 6
B1	Vehicle Loadings	" "	1 7
B2	People Loadings	" "	1 7
C	Vehicle Classification	" "	1 7
D	Queue Lengths	" "	2 6 8
E	Meter Cycle Lengths	Computer	2 6 8
F	Violations	Computer & Manual Counts	1 7
G	Passenger Volumes	A x B x C	5 7
H	Average Ramp Delay/Veh	D x E	5 7
I	Total Ramp Delay Vehicle Hours	B1 x H x A x C	5 7
J	Total Ramp Delay People Hours	I x B	5 7

APPENDIX B

TREND DATA

The following trend data figures are taken from reference 2, page 11, "Auto Occupancy Parameter Variations". The volume data are from I-35W Traffic Management System files.

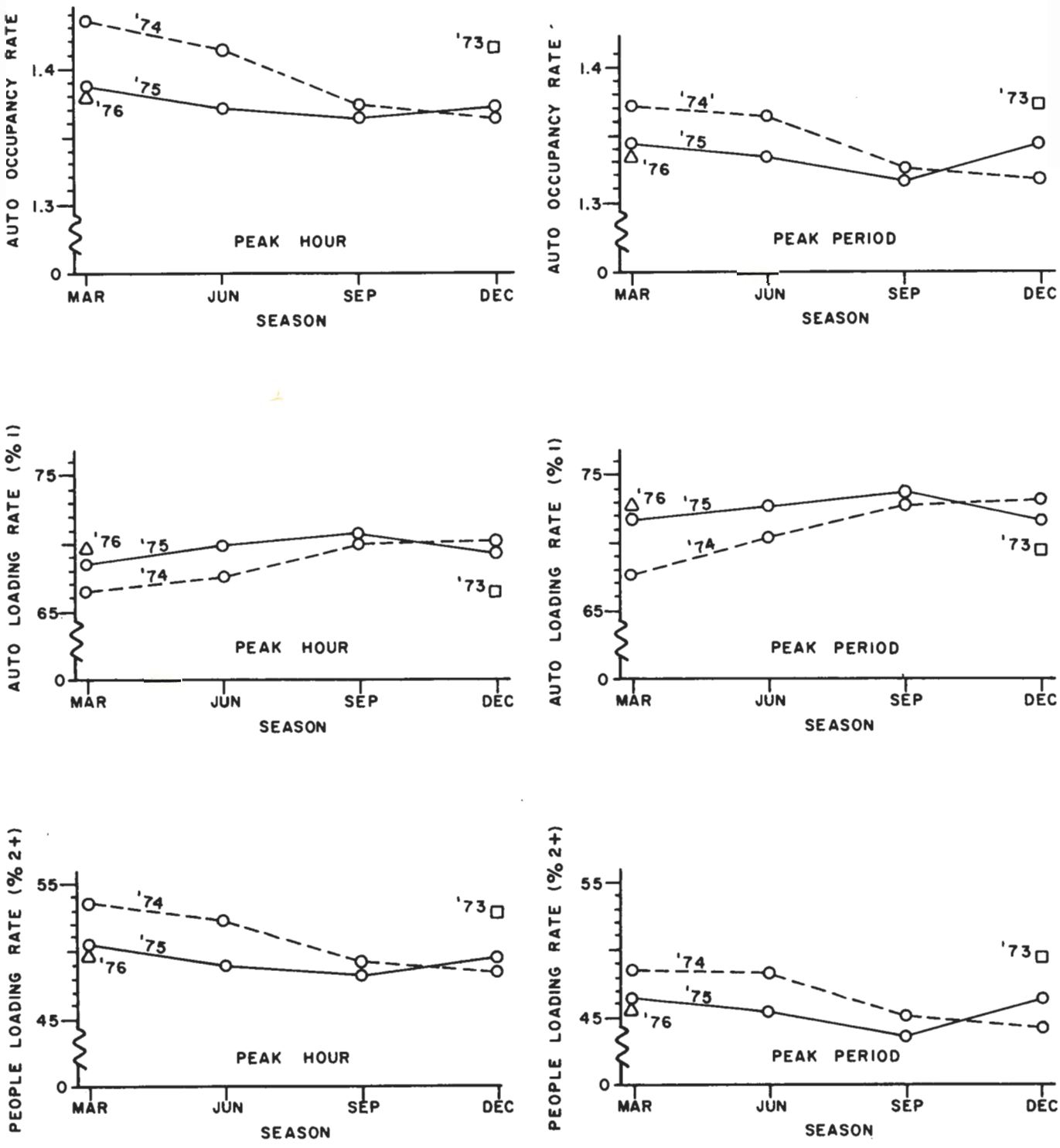
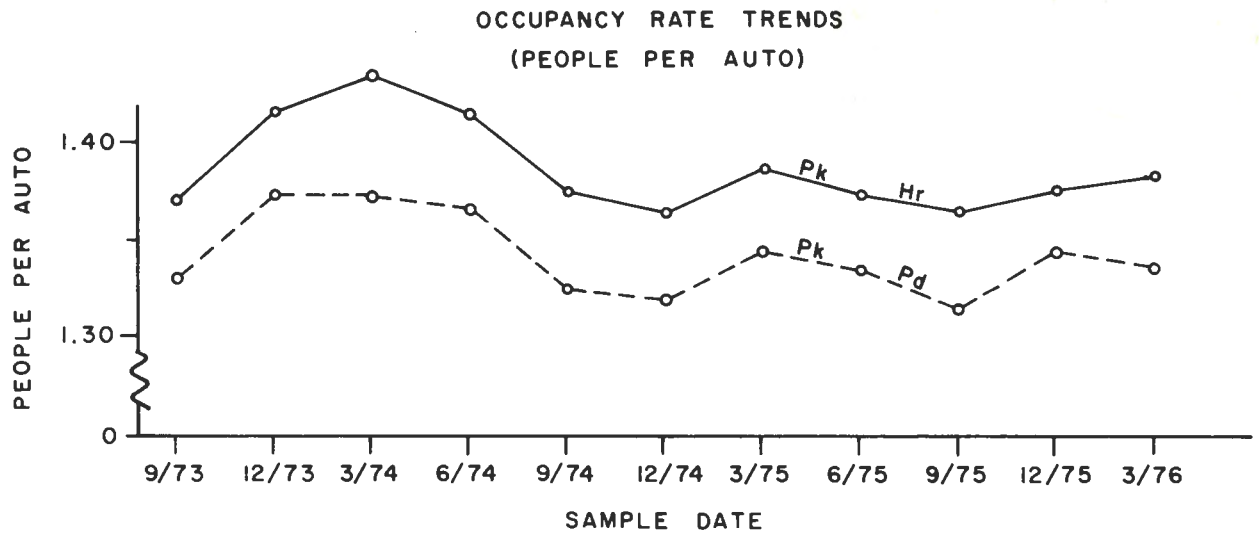
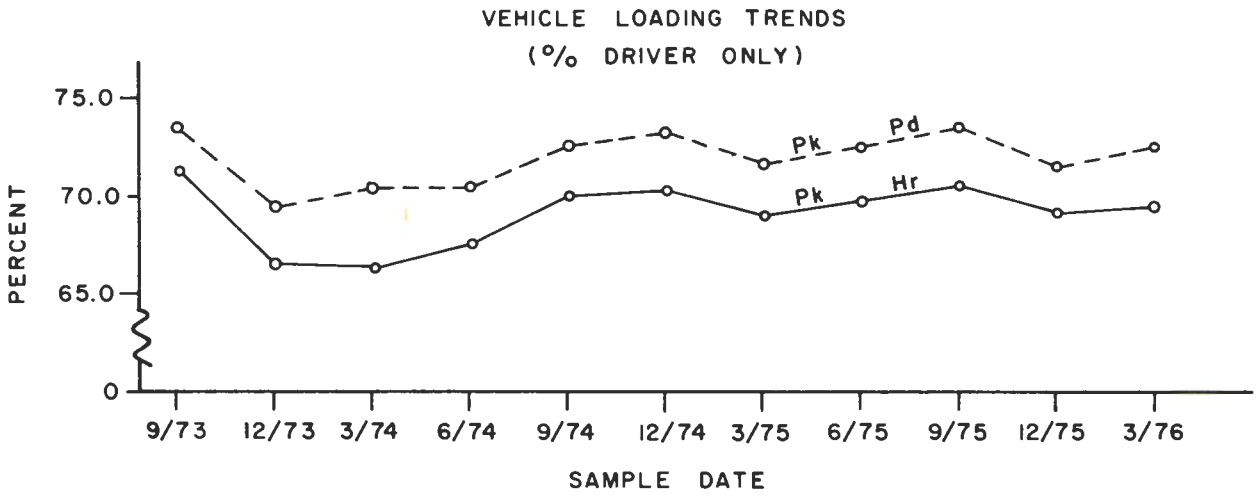


FIGURE 2, Comparison of Occupancy Parameters by Season by Year





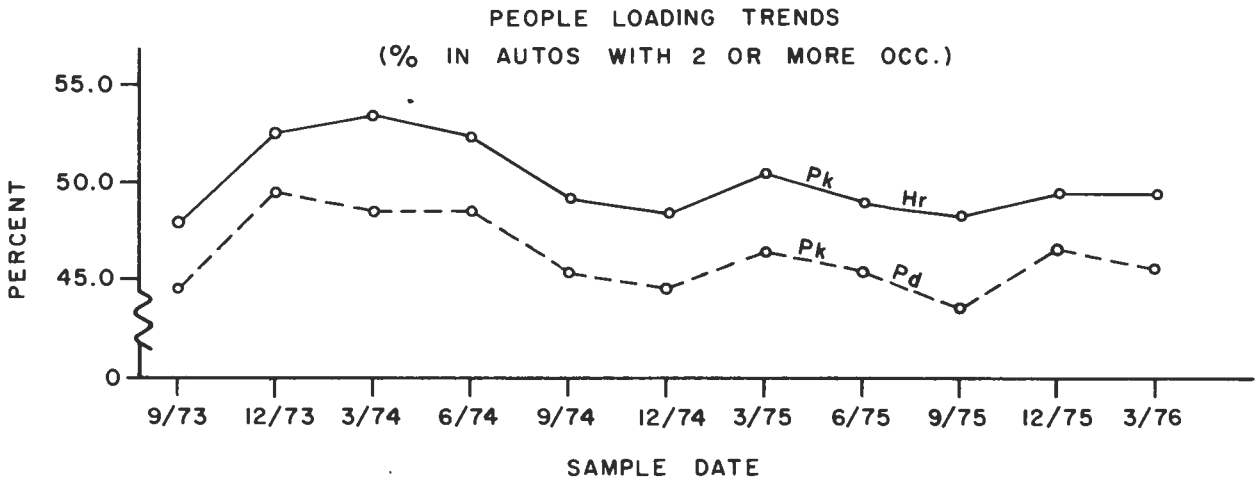


FIGURE 3, Morning Peak Occupancy Parameter Trends

I -35W 24-HOUR VOLUME	8 LANE AT LAKE ST.	6 LANE AT LYNDALE	4 LANE 86th ST.	4 LANE MINN. RIVER
FEB 13, 74	108,220	89,422	64,490	
MAR 14	102,445	86,177	65,352	
APR 10	107,855	95,342	74,367	65,972
MAY 15	113,615	97,619	74,423	63,542
JUN 27	118,031	102,562	80,155	69,270
JUL 17	117,678	103,034	78,981	67,149
AUG 15	118,536	103,601	81,605	69,980
SEP 18	115,847	101,439	77,340	65,880
OCT 2	115,453	99,937	75,153	63,514
NOV 6	117,824	101,292	75,778	64,176
DEC 4	116,812	100,378	74,357	62,453
JAN 8, 75	107,459	90,722	67,219	56,311
FEB 12	108,016	92,251	69,525	58,447
MAR 5	112,179	94,842	73,424	59,948
APR 9	106,225	90,353	69,545	52,314
MAY 7	114,493	99,079	77,593	62,872
JUN 4	119,457	102,504	80,398	67,683
JUL 9	101,286	89,310	58,974	57,182
AUG 27	101,698	83,321	58,508	64,738
SEP 10	105,294	93,257	72,661	63,278
OCT	117,053	102,518	68,341	66,973
NOV 5	114,878	100,145	74,767	66,204
DEC 3	114,140	98,398	72,897	61,899
JAN 7, 76	103,237	91,333	63,632	54,295
FEB 4	109,424	94,047	69,926	59,153
MAR 10	117,134	99,689	74,324	61,456
APR 7	121,382	106,495	78,722	66,549
MAY 12	124,821	108,937	79,267	68,373
JUN 9	122,990	113,496	85,473	74,008
JUL 14	126,124	112,615	84,010	73,726
AUG 12	127,054	114,643	84,157	76,313
SEP 15	127,388	115,577	84,153	76,364
RECORD	137,284	121,197	93,935	83,682

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