TECHNICAL MEMORANDUM

From: Michael R. Abend

Date: March 28, 2002

SUBJECT: TRAFFIC UPDATE TO ACCOMPANY
NOTICE OF PROJECT CHANGE
HOPPING BROOK BUSINESS PARK
HOLLISTON, MASSACHUSETTS

INTRODUCTION

This memorandum has been prepared to accompany the Notice of Project Change for the Hopping Brook Business Park, along Route 16 (Washington Street) in Holliston, Massachusetts. The project change calls for the expansion of the park's area and changes to the roadway layout. No change is proposed regarding the overall building square footage of the development or the specific mix of land uses that would be included in the park. This memorandum discusses the traffic projections associated with the project as originally projected in 1982 and compares them with current estimates, based on various assumptions. The analysis includes updated traffic counts done at the site access along Route 16. It also considers the current mix of land uses within the park, including office, research and development, manufacturing, and warehouse space.

This comparison also considers the operating conditions at the site access intersection along Route 16. The original proposal called for three phases of the project, ultimately requiring the need to provide turning lanes in both directions along Route 16 and the installation of a traffic signal. This update confirms that the proposed mitigation will be adequate to accommodate the project based on updated trip generation estimates and updated intersection capacity analysis methodologies.

REVIEW OF 1982 FEIR ESTIMATES

The Final EIR was completed in 1982. The estimated traffic was based on an analysis of several similar parks in the area, and did not rely on the Institute of Transportation Engineers (ITE), publication **Trip Generation**. At the time, the ITE report was in its third edition. The estimated trips during the peak hours were based on calculations of the number of employees found in

similar parks. At the time, there were expected to be 1,900 morning peak hour trips (in and out combined) and 2,750 evening peak hour trips (in and out combined). Although the FEIR did not include a specific estimate regarding daily volumes, a review of the ITE data suggests an estimate of 20,910 vehicles per day (half inbound and half outbound). This estimate is based on the current land use mix at the site and the ITE rates in effect in 1982. These were the volumes on which the proposed mitigation at the site entrance was based. The expected volumes along Route 16 past the site for a future Build year of 1987 were also evaluated in the FEIR.

At the time that those estimates were made, there were no specific assumptions regarding the mix of land uses within the business park. Instead, it was assumed that the mix would be similar to the parks from which the other data had been collected. This was, and still is, a reasonable basis for estimating a land use mix. The FEIR analysis projected that the volumes along Route 16 during the peak hours in 1987 for the Build conditions (unrelated to the project) would amount to 460 vehicles during the morning peak hour and 940 trips during the evening peak hour.

The original estimates in 1982 also expected that 45 percent of the traffic would be oriented to the west and 55 percent toward the east. Interestingly, at the time of that study, it was noted that the use of a relatively high general traffic growth rate of 2.6 was as high as it was because of growth along the Route 495 corridor. Nonetheless, the estimated distribution assumed that the orientation of trips would be more to the east than to the west.

CURRENT CONDITIONS

Currently the park has 558,000 square feet of space occupied, including approximately 30 percent office, 14 percent research and development, 17 percent manufacturing, and 38 percent warehouse. These percentages are expected to change slightly based on discussions with current businesses that indicate that they collectively plan to expand from 558,000 square feet to 750,000 square feet. Based on the type of expansion they currently expect, it is estimated that the land use mix at that point will be 35 percent office, 35 percent warehouse, 20 percent research and development, and 10 percent manufacturing. It is this mix that is used in estimating the trips for the overall business park for this traffic update.

A turning movement count was done at the access driveway at Route 16 during the peak hours in 2001. In addition, an automatic traffic recorder (ATR) count was done along the site access roadway, near Route 16, to capture the daily volumes. This information is summarized in Exhibit 1. [Note, that the counts done in 2001 were done before September 11th.]

The project currently has 558,000 square feet of occupied space; this is 19 percent of the full-build out. Comparing the existing volumes at the site to 19 percent of the original trip generation shows that the existing volumes are significantly below what was originally projected for the business park. The morning peak hour has approximately 47 percent less traffic than what would be expected, the evening peak hour has volumes 61 percent less than the expected volumes, and the daily estimate shows a volume of 39 percent less than the expected volumes. Based on these current volumes, it is reasonable to conclude that the original projections were high. However, to be conservative, this update considers more conservative (i.e., higher) traffic levels.

Since the original analysis was done in 1982, several things have changed that might effect the estimated trip generation of the project. First, the project is about twenty percent complete, which provides actual data at the site as well as information on the mix of tenants and land uses. Further, the Institute of Transportation Engineers has updated their **Trip Generation** report several times; the current version is the 6th edition, updated in 1997.

The existing information at the site provides data related to the distribution of traffic as well. With all this information it would be inappropriate to simply rely on the old trip generation projections for this update. There is more than one method of estimating traffic generation for this update. Three alternative methods are presented below:

1. **Current Trip Rates Only**
   The analysis above of existing volumes and existing square footage indicates that the project currently is generating traffic at rates that are significantly less than what was anticipated. Nonetheless, this is a legitimate basis for estimated future trips for a project. Therefore, this first alternative exclusively relies on the current trip rates at the site. The project will have a significantly lower impact than expected. Projecting the current low trip rates for the entire park would amount to 46 percent fewer trips during the morning peak hour, 61 percent fewer trips during the evening peak hour, and 39 percent fewer trips on a daily basis. These volumes were shown in Exhibit 2.

2. **Comparing Current ITE Projections to 1982 ITE Projections**
   As noted, the original analysis did not rely on the ITE report for its trip generation projections; it is not clear why this was the case. Nonetheless, those rates are relevant since they represent the most current information at the time. It is assumed that the breakdown of land uses is 35 percent for office, 35 percent for warehouse. 20 percent for research and development, and 10 percent for manufacturing. If that breakdown had

been known then, and if the ITE data had been used, a reasonable trip projection would have been calculated. A current estimate could then be compared to it based on that same information and the current ITE report. This information is shown in Exhibit 3. The purpose of this alternative is to compare the available information in 1982 to the available information in 2002.

This approach demonstrates that if the project had been evaluated using ITE data in 1982, then the current updated ITE information suggests that the peak hour and daily trips will be lower than expected. That is, the morning peak hour would have 35 percent few trips, the evening peak hour would have 46 percent fewer trips, and the daily volumes would be 14 percent lower than might have been originally projected based on ITE data and the assumed land use splits. The key point to this alternative comparison is that ITE projections are considered to be more accurate now than they were in 1982, since they now take into account the size of a development and not just each land use's overall trip rate. Reviewing agencies and traffic engineers/planners recognize that trip rates decrease as a development increases in size. Thus, with such a large project as this one, the decrease in the rate would be significant; thus, the lower overall projections. The original projections in the FEIR were overly conservative, even compared to the ITE analysis available at that time.

3. **Existing Volumes for Current Uses and Add-On Trips Based on ITE Rates**

The third alternative is to accept the trips to the existing building in the park and to add trips for the remaining 2,442,000 square feet based on current ITE data and assuming the land use mix for the rest of the park is consistent with the current mix. This information is shown in Exhibit 4. The results show that the expected volumes during the morning peak hour will be 22 percent higher than the original 1982 projections; evening peak hour volumes will be 17 percent below the original projections, and daily trips will be 16 percent below original projections.

It is noteworthy that this projection for the morning peak hour is still eight percent less than if the entire 3,000,000 square feet were estimated based on current ITE rates. Further, if the 1982 rates were considered, this projection would be 40 percent below those volumes. That is likely the result of a significant underestimate in the original projections for this peak hour.

Summary of Alternative Trip Projections

Each of the possible methods of estimating future trips suggests that traffic will be lower on a daily basis and during the evening peak hour. For the morning peak hour, two of the three methods also suggest lower volumes. The third alternative – relying on current ITE rates for the remainder of the project – is the most conservative estimate and suggests that morning peak hour volumes will be higher than originally estimated. Keep in mind that this does not mean that this method is the most accurate, it simply means it results in the highest estimated volumes. To be conservative, these numbers are used for this update. It is our opinion that these highest estimates are not the most accurate since the existing volumes should be relied on more significantly. It is also our opinion that the location is not a "high profile location" that will attract a high density of office uses. That is, it is expected that the overall land use mix within the park will tend toward the manufacturing and/or warehouse uses or other similar uses that are less employee intensive. Nonetheless, the highest projections are used in this update as a basis for confirming that this notice of project change does not require a full, updated review.

THE UPDATED ANALYSIS

In evaluating the adequacy of the proposed access to accommodate the project, the existing traffic counts along Route 16 are used along with an estimated growth rate to account for a five year build-out, as would normally be done in an EIR analysis. Thus, the 2001 volumes have been increase by 15 percent to reflect the MHD documented regional growth rate of 2.9 percent per year. This increase is applied to the Route 16 through traffic at the site driveway. These volumes are shown in Exhibit 5. To these volumes are added the site-related trips documented in Alternative 3 above and distributed inbound and outbound, to the east and to the west, based on the existing volumes at the site driveway. The updated Build volumes are shown in Exhibit 6.

The evaluation of the traffic operations at the site entrance has been done using ***Synchro5*** and following the methodology of the 2000 **Highway Capacity Manual**. The calculations are included in the appendix to the memorandum.

The original proposal for mitigation at the site entrance called for the installation of a traffic signal along with the construction of dedicated turn lanes along Route 16: this includes an eastbound right-turn lane and a westbound left-turn lane. Out of the site there is a wide enough roadway to allow for a left-turn lane and a right-turn lane out of the site. Based on these design

assumptions, the morning peak hour is expected to operate at Level of Service *C* with an average delay of 33 seconds per vehicle. The only specific movement that would operate at less than Level of Service *D* would be the left turn out of the site which would operate with a delay of 56 seconds, Level of Service *E*.

In the evening the operations are expected to be at Level of Service *E* for the intersection as a whole, with an average delay of 62 seconds per vehicle. As with the morning peak hour, the only flow that would operate at worse than Level of Service *D* would be the left turns out of the site, at Level of Service *F*. This information is summarized in Exhibit 7.

Discussion

While Level of Service *D* is generally desirable, it is considered that the proposed project will have a generally sharp peak during the evening and that designing a larger intersection would require significant investment for little gain in capacity. An alternative would be to provide police officer control during the evening peak hour if the signal is unable to accommodate the volumes; a traffic control officer would be able to enhance operations modestly compared to a signal enough to bring the overall Level of Service to a *D*. Considering that a Level of Service *D* has an average delay of up to 55 seconds, the current estimate of 62 seconds per vehicle is not significantly worse particularly when only traffic leaving the site experiences and Level of Service worse than *D*. It is likely that implementing reasonably aggressive Traffic Demand Management (TDM) measures within the park would have the effect of improving conditions enough to meet the Level of Service *D* criteria for the evening peak hour.

It is noteworthy that the evening peak hour volumes for the site are expected to be less than the original projections, yet this is the peak hour that shows an apparently worse operating condition than originally expected. The morning peak hour, even with 22 percent more traffic than originally expected, is still expected to operate at Level of Service *C*.

To some extent, it is beneficial that the project did not move forward as originally planned. It is likely that if it had been completed in five-to-ten years from its original approval, then the previously proposed traffic signal would not have been as sophisticated as current modes are. A more sophisticated signal will more appropriately control traffic flows during both peak and off peak hours.

SUMMARY

Based on this updated analysis, it is concluded that the proposed project change is not expected to result in a significant change to the traffic impact originally evaluated. The project change itself does not alter the square footage build-out of the project nor does it change the access proposal. There are several alternative ways to estimate the full build-out traffic generation of the site. Using the most conservative way, the operations at the site driveway are still expected to operate at a reasonable level. While it is possible that the evening peak hour will be slightly below Level of Service *D*, it is believed that the overall results will be similar to what would have been expected under the original proposal, possibly better. Therefore, no changes are proposed related to the traffic mitigation package.

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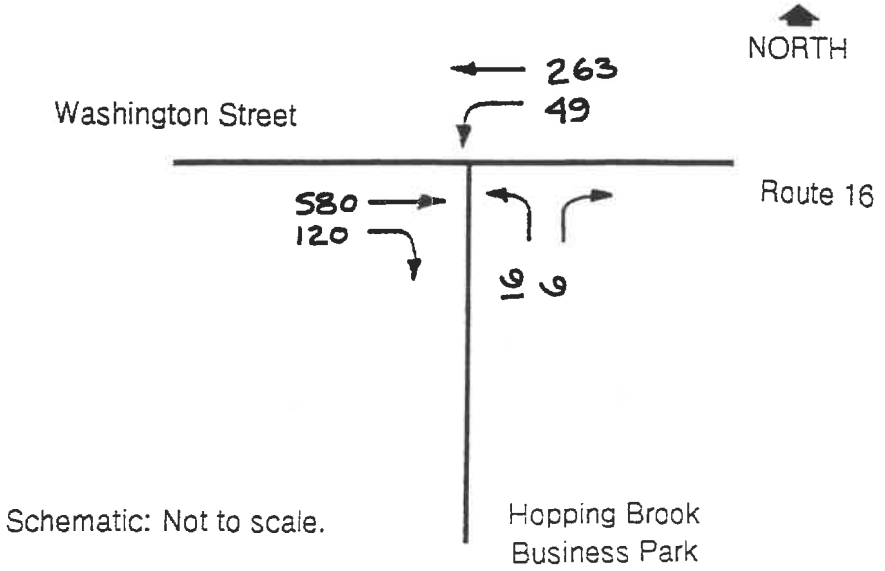
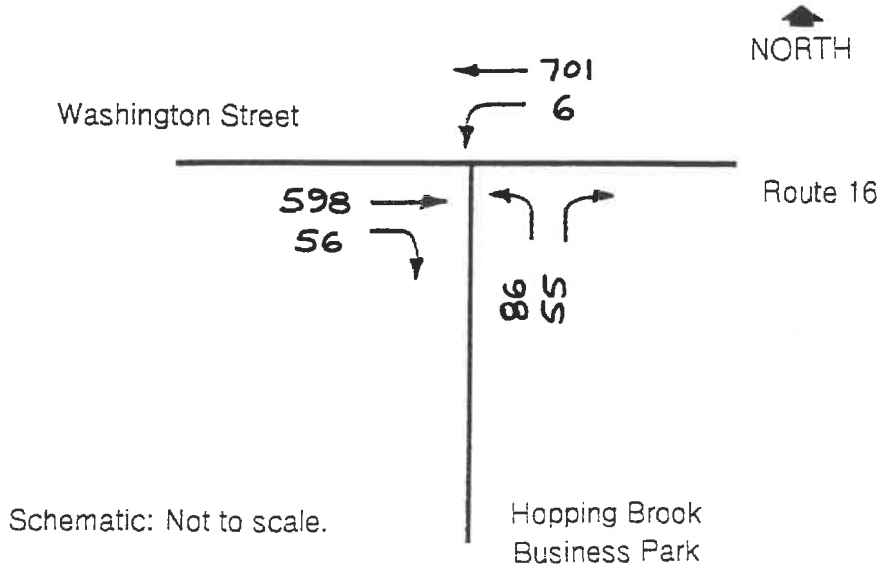
Morning Peak Hour



Evening Peak Hour



EXISTING VOLUMES

Hopping Brook Business Park
Holliston, Massachusetts

Exhibit 1

Abend Associates

Current Volumes vs. Original Projections

		Peak Hour Trips		Daily
		Morning	Evening	Trips
Actual Counts (2001)		191	203	2,425
trips/ksf at 558,000 SF		0.34/ksf	0.36/ksf	4.35/ksf
Existing Trip Rate x 3,000,000 SF		1,027	1,091	13,038
vs. 1982 Projections		1,900	2,750	20,910
Difference:	#	**- 873**	**- 1,659**	**- 7,870**
	%	**- 46%**	**- 60%**	**- 38%**

Actual counts from 2001.

ksf = 1,000 square feet

PROJECTED VOLUMES
ALTERNATIVE 1

Hopping Brook Business Park
Holliston, Massachusetts

Exhibit 2

Abend Associates

ITE Rates in 1982 vs. ITE Rates in 2002

		Peak Hour Trips		Daily
		Morning	Evening	Trips
1982 ITE Rates @ 3,000,000 SF		3,870	4,620	20,910
2002 ITE Rates @ 3,000,000 SF		2,518	2,500	17,904
Difference:	#	**- 1,352**	**- 2,120**	**- 3,006**
	%	**- 35%**	**- 46%**	**- 14%**

Source: Trip Generation, 3rd edition 1982 and 6th edition 1997

Notes:

Trips include inbound and outbound combined.

Based on the following land use codes:

140, ***Manufacturing,*** (10%)

150, ***Warehousing,*** (35%)

710, ***General Office,*** (35%)

760, ***Research and Development,*** (20%)

Combined Existing Volumes with ITE-Based Projections for Balance of Project

		Peak Hour Trips		Daily
		Morning	Evening	Trips
Existing Volumes [1] (558,000 SF)		191	203	2,425
ITE Based Volumes for Balance of Project [2] (2,442,000 SF)		2,126	2,085	15,110
Total Projected Site Trips		2,317	2,288	17,535
vs. 1982 Projections		1,900	2,750	20,910
Difference:	#	**+ 471**	**- 462**	**- 3,375**
	%	**+ 22%**	**- 17%**	**- 16%**

1 Existing volumes based on 2001 counts.
Balance of Park based on ITE rates and existing land use mix (see Exhibit 3).

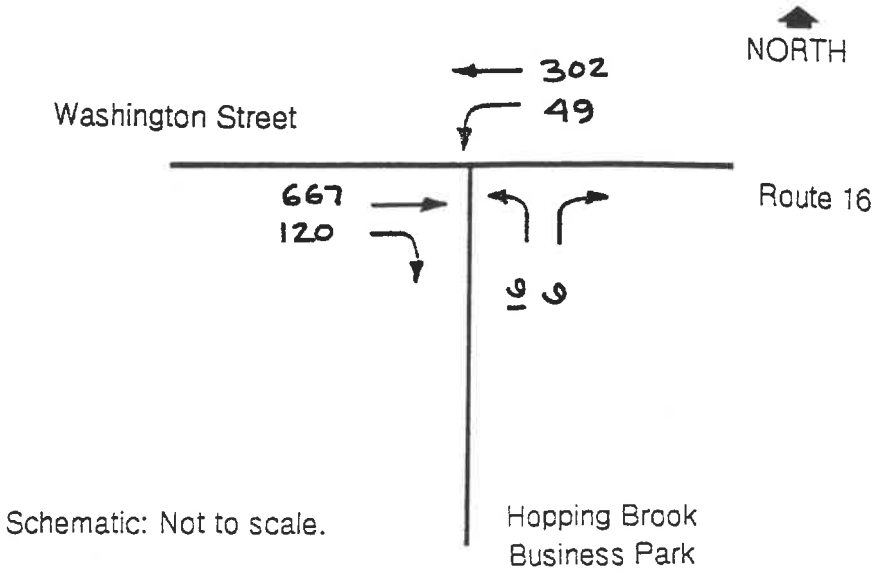
PROJECTED VOLUMES
ALTERNATIVE 3

Hopping Brook Business Park
Holliston, Massachusetts

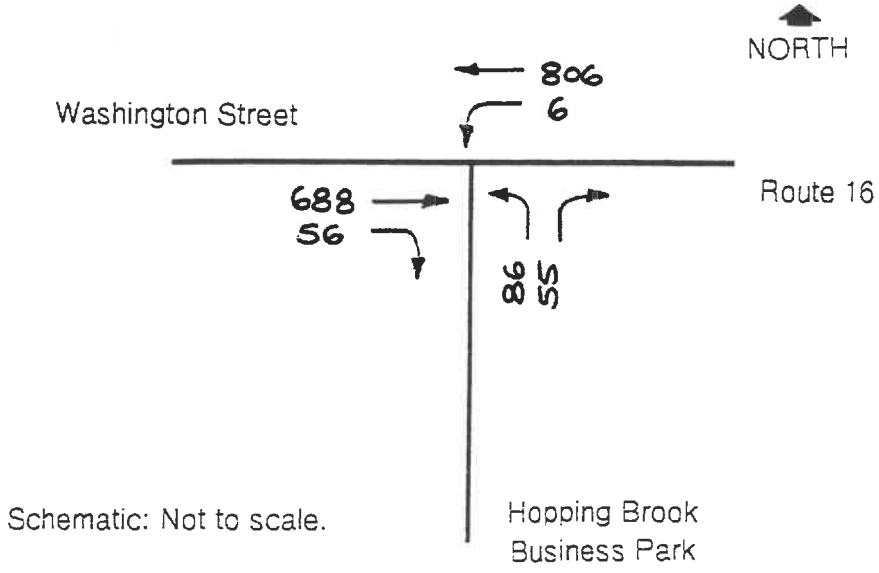
Exhibit 4

Abend Associates

Morning Peak Hour



Evening Peak Hour



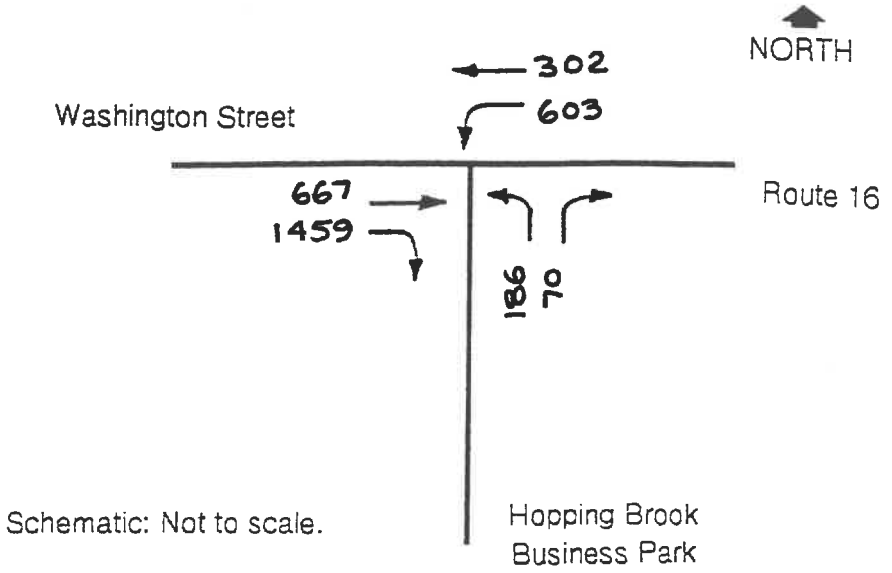
FUTURE NO BUILD VOLUMES

Hopping Brook Business Park
Holliston, Massachusetts

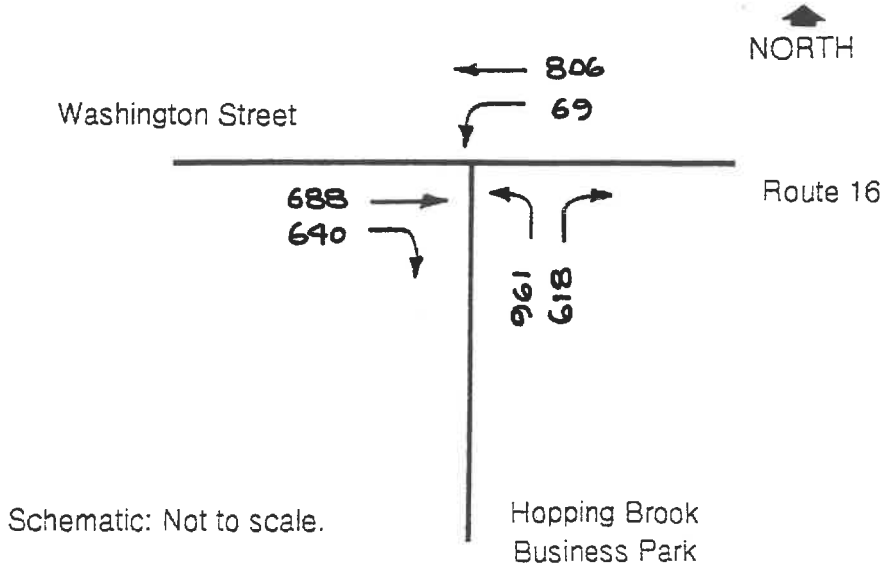
Exhibit 5

Abend Associates

Morning Peak Hour



Evening Peak Hour



FUTURE BUILD VOLUMES

Hopping Brook Business Park
Holliston, Massachusetts

Exhibit 6

Abend Associates

Future Build Conditions
Peak Hour Level of Service Summary

	Morning		Evening	
	LOS	**Delay**	**LOS**	**Delay**
Route 16 at Site Driveway				
Overall	C	33	E	66
Route 16 Eastbound				
thrus	D	50	D	46
rights	C	21	A	0
Route 16 Westbound				
lefts	E	56	D	48
thrus	A	3	D	45
Site Driveway				
lefts	D	45	F	154
rights	A	3	C	22

LEVEL OF SERVICE SUMMARY

Hopping Brook Business Park
Holliston, Massachusetts

Exhibit 7

Abend Associates

APPENDIX

Count Data

Traffic Counting Unlimited

FILE: hop4rt16

Site Code : 775-Van V.
N-S Street: Hopping Brook Road
E-W Street: Rt.16, Holliston, MA.
Weather : Cloudy

Sum of the Primary and Secondary

DATE: 8/27/01

Time Begin	From North RT	THRU	LT	From East RT	THRU	LT	From South RT	THRU	LT	From West RT	THRU	LT	Vehicle Total
7:00 AM	0	0	0	0	52	9	1	0	3	20	146	0	231
7:15	0	0	0	0	74	12	3	0	4	33	158	0	284
7:30	0	0	0	0	69	12	1	0	3	29	165	0	279
7:45	0	0	0	0	68	16	1	0	6	38	111	0	240
HR TOTAL	0	0	0	0	263	49	6	0	16	120	580	0	1034
8:00 AM	0	0	0	0	46	17	0	0	2	33	79	0	177
8:15	0	0	0	0	46	13	2	0	4	41	72	0	178
8:30	0	0	0	0	57	8	2	0	7	27	70	0	171
8:45	0	0	0	0	83	7	7	0	8	26	102	0	233
HR TOTAL	0	0	0	0	232	45	11	0	21	127	323	0	759
DAY TOTAL	0	0	0	0	495	94	17	0	37	247	903	0	1793

Traffic Counting Unlimited

Site Code : 775-Van V.
N-S Street: Hopping Brook Road
E-W Street: Rt.16, Holliston, MA.
Weather : Cloudy

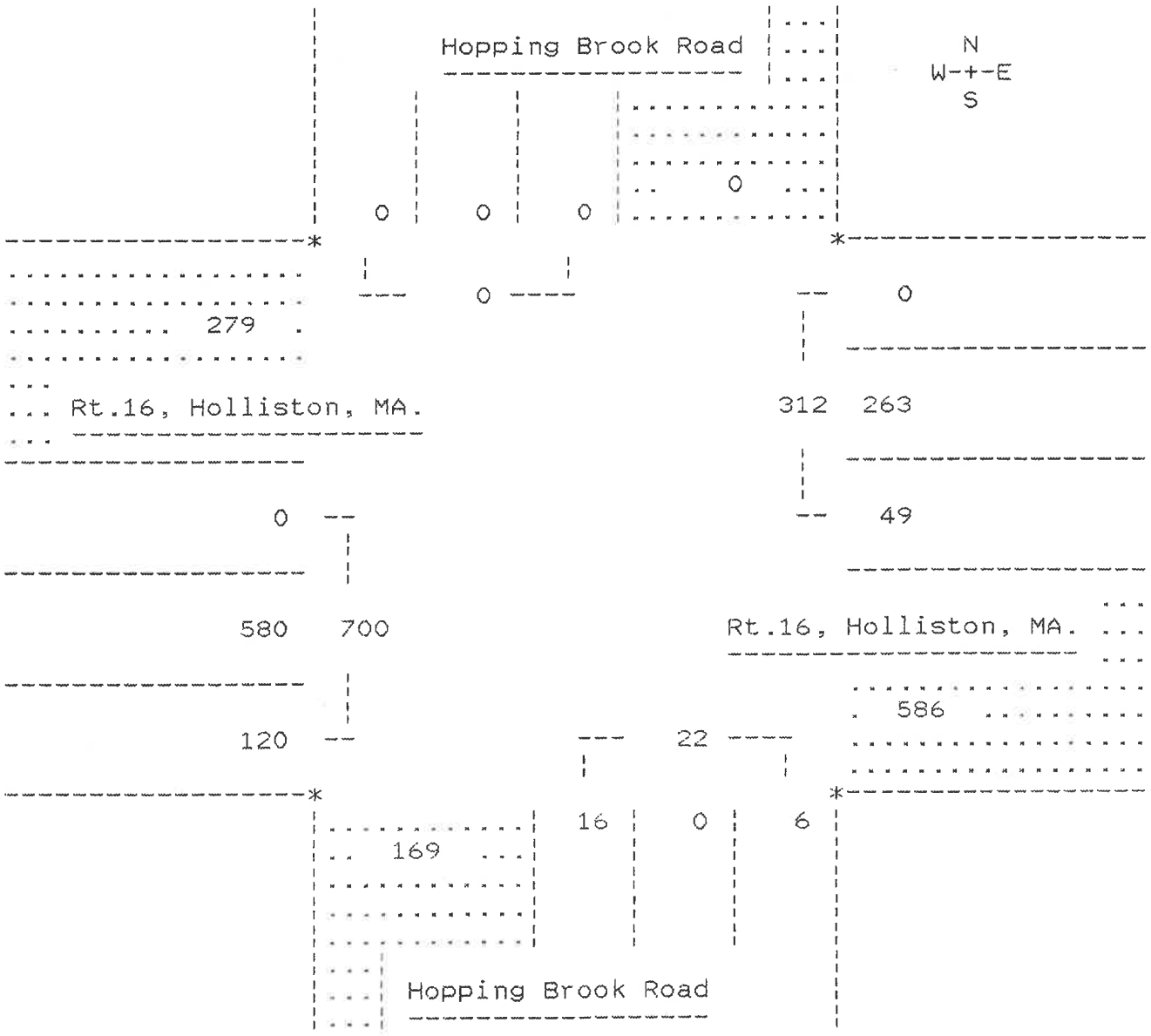
Sum of the Primary and Secondary

PAGE: 1
FILE: hop4rt16

DATE: 8/27/01

PEAK PERIOD ANALYSIS FOR THE PERIOD: 7:00 AM - 9:00 AM

DIRECTION FROM	START PEAK HOUR	PEAK HR FACTOR	VOLUMES Right	Thru	Left	Total	PERCENTS Right	Thru	Left
North	7:00 AM	0.00	0	0	0	0	0	0	0
East	7:15 AM	0.91	0	257	57	314	0	82	18
South	8:00 AM	0.53	11	0	21	32	34	0	66
West	7:00 AM	0.90	120	580	0	700	17	83	0
Entire Intersection									
North	7:00 AM	0.00	0	0	0	0	0	0	0
East		0.91	0	263	49	312	0	84	16
South		0.79	6	0	16	22	27	0	73
West		0.90	120	580	0	700	17	83	0



Traffic Counting Unlimited

Site Code : 884-Roy L.
N-S Street: Hopping Brook Road
E-W Street: Rt.16-Washington Street
Weather : Sunny/Rain

Sum of the Primary and Secondary

FILE: rt16hop1

DATE: 8/13/01

Time Begin	From North RT	THRU	LT	From East RT	THRU	LT	From South RT	THRU	LT	From West RT	THRU	LT	Vehicle Total
4:00 PM	0	0	0	0	127	1	14	0	40	2	77	0	261
4:15	0	0	0	0	112	1	6	0	30	5	96	0	250
4:30	0	0	0	0	166	4	12	0	28	8	96	0	314
4:45	0	0	0	0	163	1	13	0	11	13	137	0	338
HR TOTAL	0	0	0	0	568	7	45	0	109	28	406	0	1163
5:00 PM	0	0	0	0	171	1	22	0	31	23	147	0	395
5:15	0	0	0	0	188	2	9	0	21	10	161	0	391
5:30	0	0	0	0	179	2	11	0	23	10	153	0	378
5:45	0	0	0	0	163	3	11	0	19	0	89	0	285
HR TOTAL	0	0	0	0	701	8	53	0	94	43	550	0	1449
DAY TOTAL	0	0	0	0	1269	15	98	0	203	71	956	0	2612

Traffic Counting Unlimited

Site Code : 884-Roy L.
N-S Street: Hopping Brook Road
E-W Street: Rt.16-Washington Street
Weather : Sunny/Rain

Sum of the Primary and Secondary

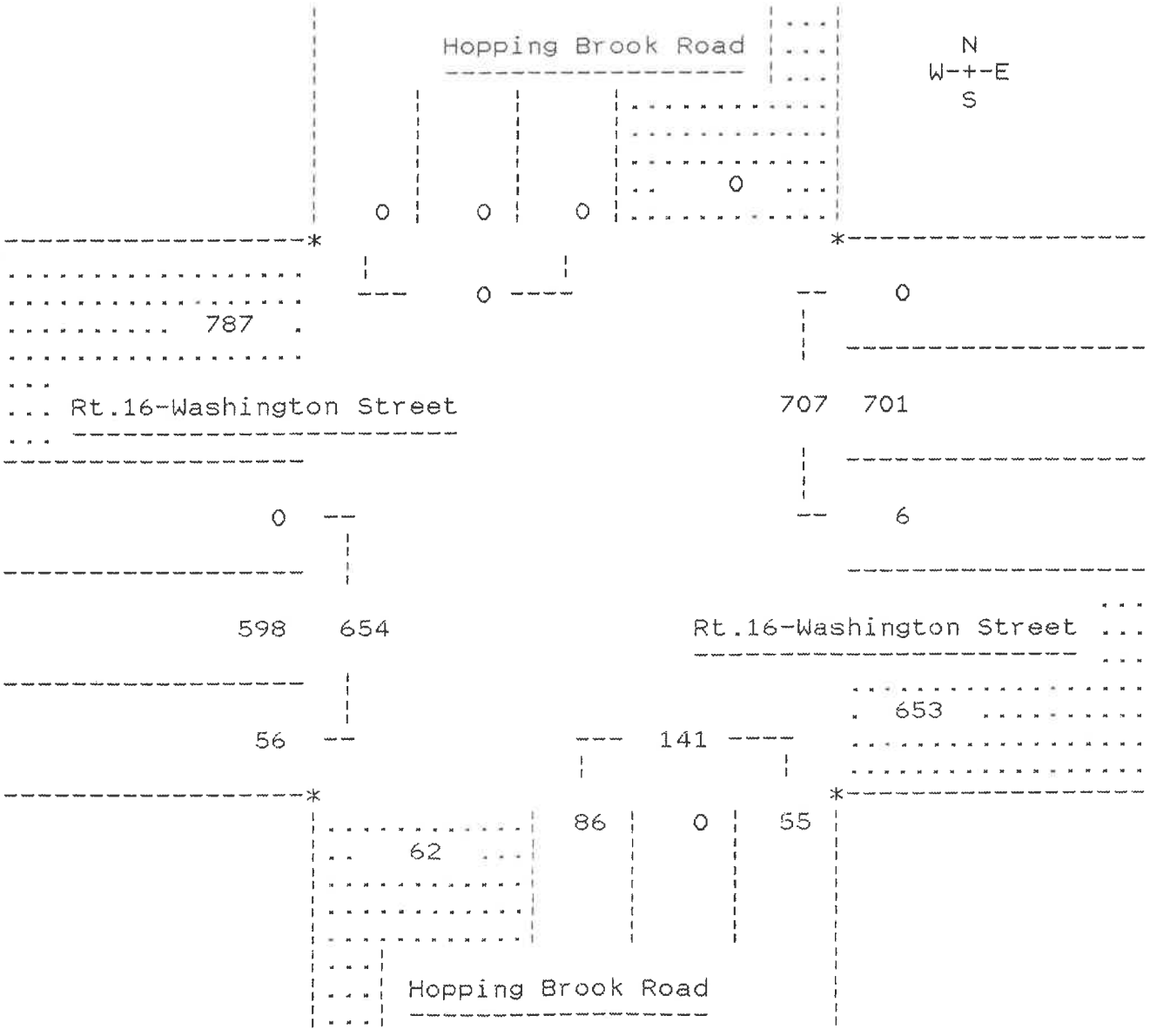
PAGE: 1
FILE: rt16hop1
DATE: 8/13/01

PEAK PERIOD ANALYSIS FOR THE PERIOD: 4:00 PM - 6:00 PM

DIRECTION FROM	START PEAK HOUR	PEAK HR FACTOR	VOLUMES Right	Thru	Left	Total	PERCENTS Right	Thru	Left
North	4:45 PM	0.00	0	0	0	0	0	0	0
East	5:00 PM	0.93	0	701	8	709	0	99	1
South	4:00 PM	0.71	45	0	109	154	29	0	71
West	4:45 PM	0.96	56	598	0	654	9	91	0

Entire Intersection

North	4:45 PM	0.00	0	0	0	0	0	0	0
East		0.93	0	701	6	707	0	99	1
South		0.67	55	0	86	141	39	0	61
West		0.96	56	598	0	654	9	91	0



Hopping Brook Road
Holliston, Massachusetts
Counted by Traffic Counting Unlimited
Bpx #734

JAMAR Technologies, Inc.
TAS for Windows
Copyright 1998

Site Code : 734
Start Date: 08/13/2001
File I.D. : C:\PROGRAM FI
Page : 1

Begin Time	Mon. 08/13 SB	Mon. 08/13 NB	Tues. SB	Tues. NB	Wed. SB	Wed. NB	Thur. SB	Thur. NB	Fri. SB	Fri. NB	Sat. SB	Sat. NB	Sun. SB	Sun. NB	Week SB	Week Avg. NB
12:00 am	*	*	0	8	0	5	*	*	*	*	*	*	*	*	0	6
01:00	*	*	0	2	1	6	*	*	*	*	*	*	*	*	0	4
02:00	*	*	1	1	0	2	*	*	*	*	*	*	*	*	0	2
03:00	*	*	2	2	1	0	*	*	*	*	*	*	*	*	2	1
04:00	*	*	3	0	4	2	*	*	*	*	*	*	*	*	4	1
05:00	*	*	26	3	23	2	*	*	*	*	*	*	*	*	24	2
06:00	*	*	141	24	121	13	*	*	*	*	*	*	*	*	131	18
07:00	*	*	166	56	189	34	*	*	*	*	*	*	*	*	178	45
08:00	*	*	197	39	184	50	*	*	*	*	*	*	*	*	190	44
09:00	*	*	114	60	60	33	*	*	*	*	*	*	*	*	87	46
10:00	*	*	68	65	55	38	*	*	*	*	*	*	*	*	62	52
11:00	65	75	56	70	50	76	*	*	*	*	*	*	*	*	57	74
12:00 pm	104	131	101	156	98	138	*	*	*	*	*	*	*	*	101	142
01:00	85	62	142	80	114	72	*	*	*	*	*	*	*	*	114	71
02:00	53	76	70	75	41	52	*	*	*	*	*	*	*	*	55	68
03:00	57	75	62	90	63	113	*	*	*	*	*	*	*	*	61	93
04:00	64	124	43	148	57	142	*	*	*	*	*	*	*	*	55	138
05:00	61	157	37	190	*	*	*	*	*	*	*	*	*	*	49	174
06:00	10	39	5	49	*	*	*	*	*	*	*	*	*	*	8	44
07:00	9	25	13	22	*	*	*	*	*	*	*	*	*	*	11	24
08:00	6	15	5	6	*	*	*	*	*	*	*	*	*	*	6	10
09:00	3	5	1	4	*	*	*	*	*	*	*	*	*	*	2	4
10:00	5	2	5	7	*	*	*	*	*	*	*	*	*	*	5	4
11:00	2	6	5	5	*	*	*	*	*	*	*	*	*	*	4	6
Totals	524	792	1263	1162	1061	778	0	0	0	0	0	0	0	0	1206	1073
	1316		2425		1839		0		0		0		0		2279	
Avg. Day	43.4%	73.8%	104.7%	108.2%	87.9%	72.5%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%		
AM Peaks	11:00	11:00	08:00	11:00	07:00	11:00									08:00	11:00
Volume	65	75	197	70	189	76									190	74
PM Peaks	12:00	05:00	01:00	05:00	01:00	04:00									01:00	05:00
Volume	104	157	142	190	114	142									114	174

ADTs

Relevant ITE Pages

TRIP GENERATION

6th Edition • Volume 2 of 3

TRIP GENERATION RATES, PLOTS, AND EQUATIONS

- Institutional (Land Uses 500-599)
- Medical (Land Uses 600-699)
- Office (Land Uses 700-799)
- Retail (Land Uses 800-899)
- Services (Land Uses 900-999)

ite
Institute of Transportation Engineers

Trip Generation, 6th Edition

An Informational Report of the
Institute of Transportation Engineers

Volume 2 of 3

The Institute of Transportation Engineers (ITE) is an international educational and scientific association of transportation and traffic engineers and other professionals who are responsible for meeting mobility and safety needs. The Institute facilitates the application of technology and scientific principles to research, planning, functional design, implementation, operation, policy development and management for any mode of transportation by promoting professional development of members, supporting and encouraging education, stimulating research, developing public awareness, and exchanging professional information; and by maintaining of a central point of reference and action.

Founded in 1930, the Institute serves as a gateway to knowledge and advancement through meetings, seminars, and publications; and through our network of approximately 15,000 members working in some 80 countries. The Institute also has more than 70 local and regional chapters and more than 90 student chapters that provide additional opportunities for information exchange, participation and networking.

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Land Use: 140
Manufacturing

Description

Manufacturing facilities are areas where the primary activity is the conversion of raw materials or parts into finished products. Size and type of activity may vary substantially from one facility to another. In addition to the actual production of goods, manufacturing facilities generally also have office, warehouse, research, and associated functions. General light industrial (land use 110), general heavy industrial (land use 120), and industrial park (land use 130) are related uses.

Additional Data

Average weekday transit trip ends
— 0.09 per employee
— 0.08 per 1,000 square feet gross floor area
— 1.25 per acre

Vehicle occupancy ranged from 1.2 to 1.3 persons per automobile on an average weekday.

The peak hour of the generator typically coincides with the peak hour of the adjacent street traffic. Facilities with employees on shift work may peak at other hours.

The sites were surveyed in the late 1960s, the early 1970s, the mid-1980s, and the 1990s throughout the United States.

Source Numbers

3, 7, 10, 15, 17, 74, 85, 88, 177, 184, 241, 357, 384, 418, 443

Manufacturing
(140)

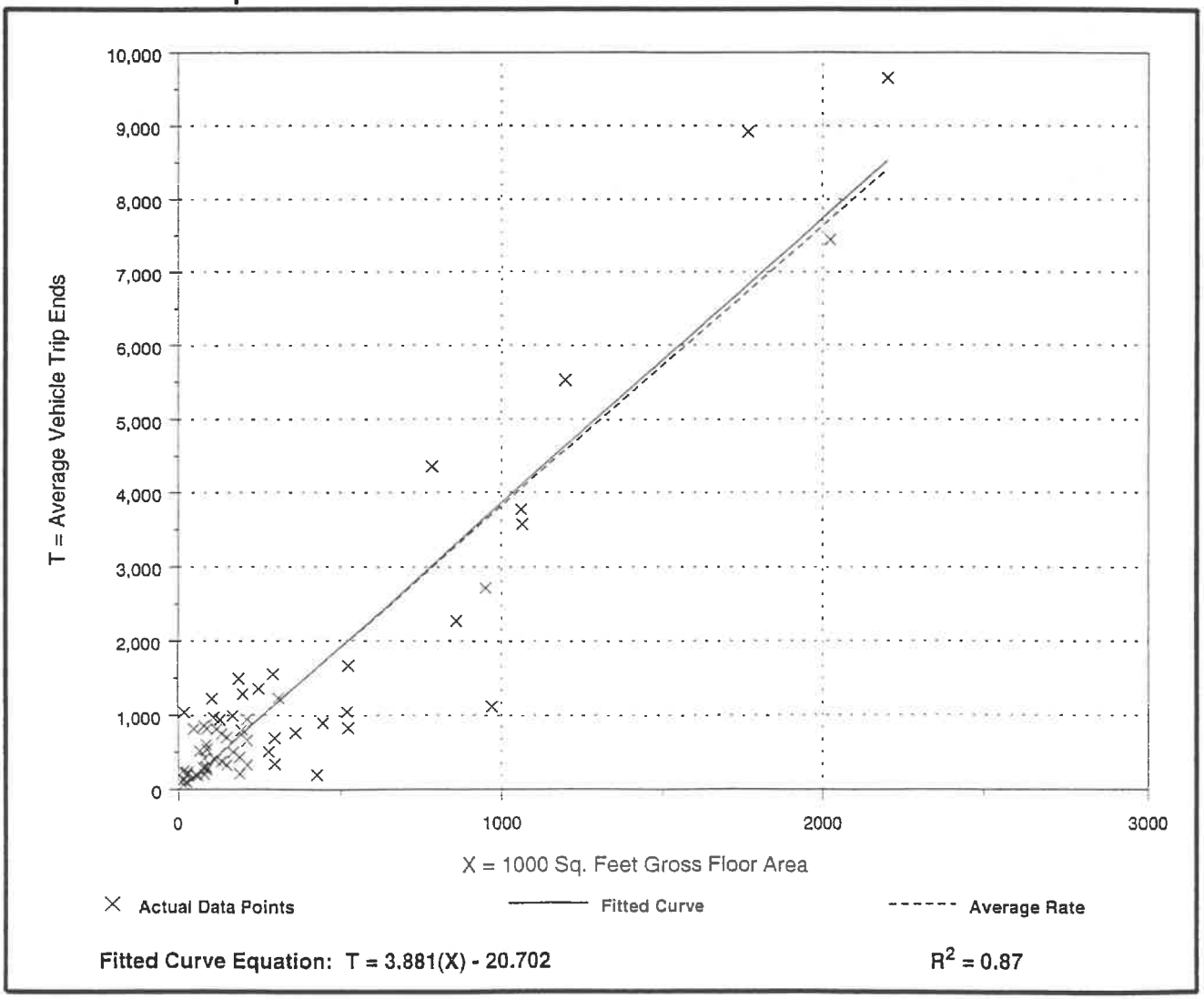
Average Vehicle Trip Ends vs: 1000 Sq. Feet Gross Floor Area
On a: Weekday

Number of Studies: 62
Average 1000 Sq. Feet GFA: 349
Directional Distribution: 50% entering, 50% exiting

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
3.82	0.50 - 52.05	3.07

Data Plot and Equation



Fitted Curve Equation: T = 3.881(X) - 20.702

$R^2 = 0.87$

Manufacturing
(140)

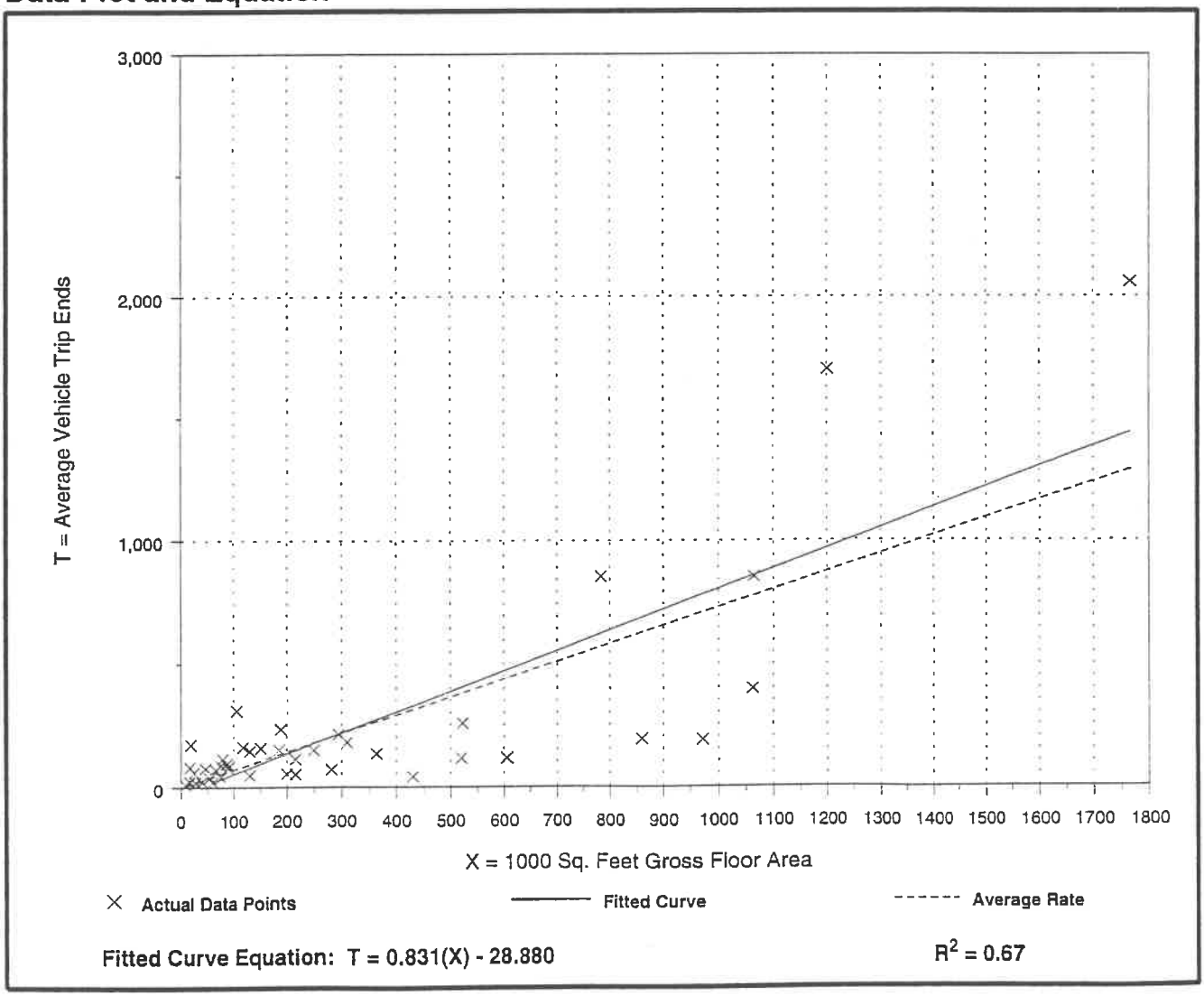
Average Vehicle Trip Ends vs: **1000 Sq. Feet Gross Floor Area**
On a: **Weekday,**
Peak Hour of Adjacent Street Traffic,
One Hour Between 7 and 9 a.m.

Number of Studies: 50
Average 1000 Sq. Feet GFA: 297
Directional Distribution: 77% entering, 23% exiting

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
0.73	0.10 - 8.75	1.04

Data Plot and Equation



Fitted Curve Equation: T = 0.831(X) - 28.880

$R^2 = 0.67$

Manufacturing
(140)

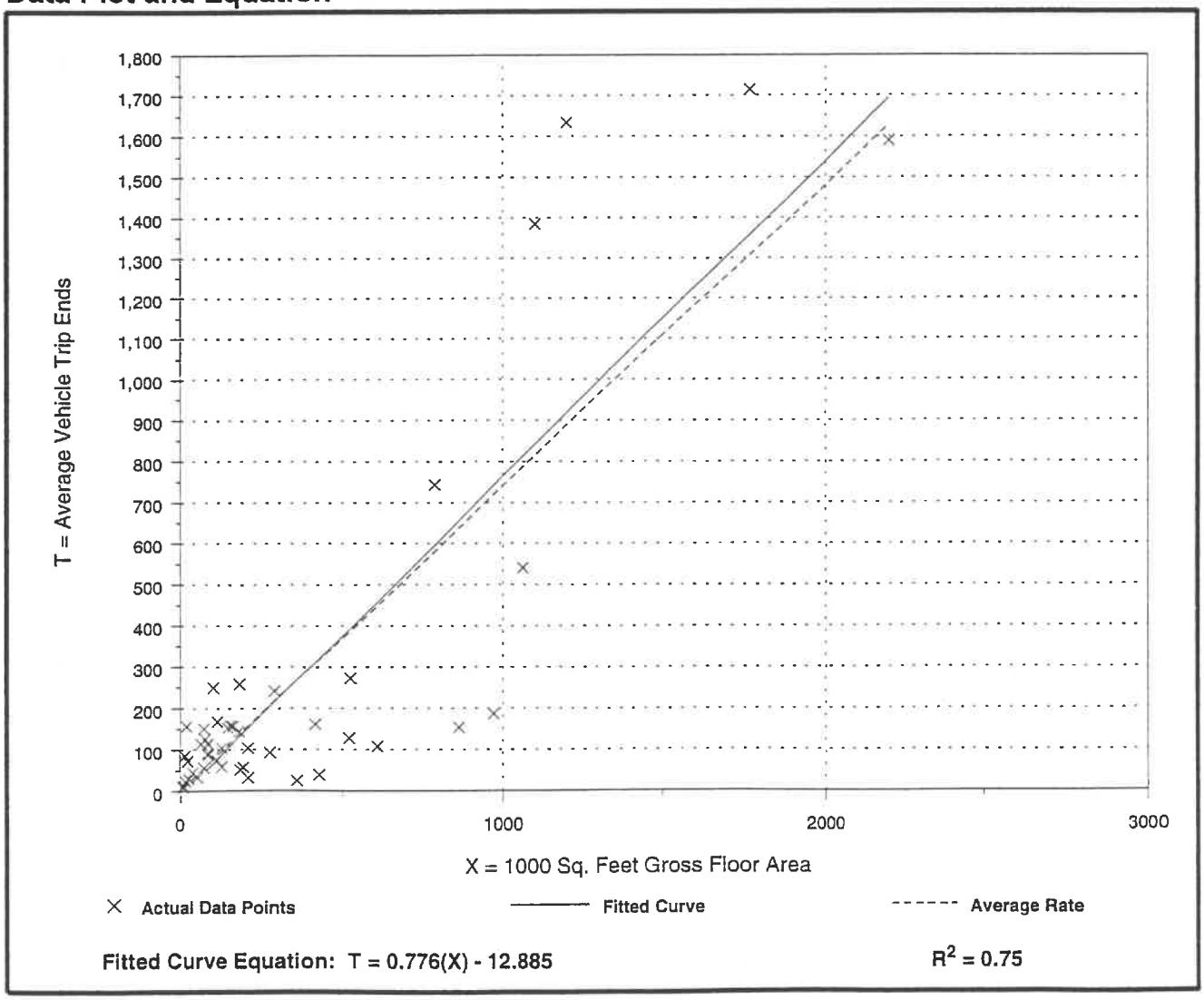
Average Vehicle Trip Ends vs: **1000 Sq. Feet Gross Floor Area**
On a: **Weekday,**
Peak Hour of Adjacent Street Traffic,
One Hour Between 4 and 6 p.m.

Number of Studies: 54
Average 1000 Sq. Feet GFA: 325
Directional Distribution: 36% entering, 64% exiting

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
0.74	0.07 - 7.85	1.01

Data Plot and Equation



Fitted Curve Equation: T = 0.776(X) - 12.885

R^2 = 0.75

Land Use: 150
Warehousing

Description

Warehouses are primarily devoted to the storage of materials; they may also include office and maintenance areas. High-cube warehouse (land use 152) is a related use.

Additional Data

No vehicle occupancy data is available specifically for warehousing, but the average was approximately 1.3 persons per automobile for all industrial uses.

The peak hour of the generator typically coincides with the peak hour of the adjacent street traffic. Facilities with employees on shift work may peak at other hours.

The sites were surveyed from the late 1960s to the mid-1990s throughout the United States and Canada.

Source Numbers

6, 7, 12, 13, 15, 17, 74, 184, 192, 390, 406, 411, 436, 443

Warehousing
(150)

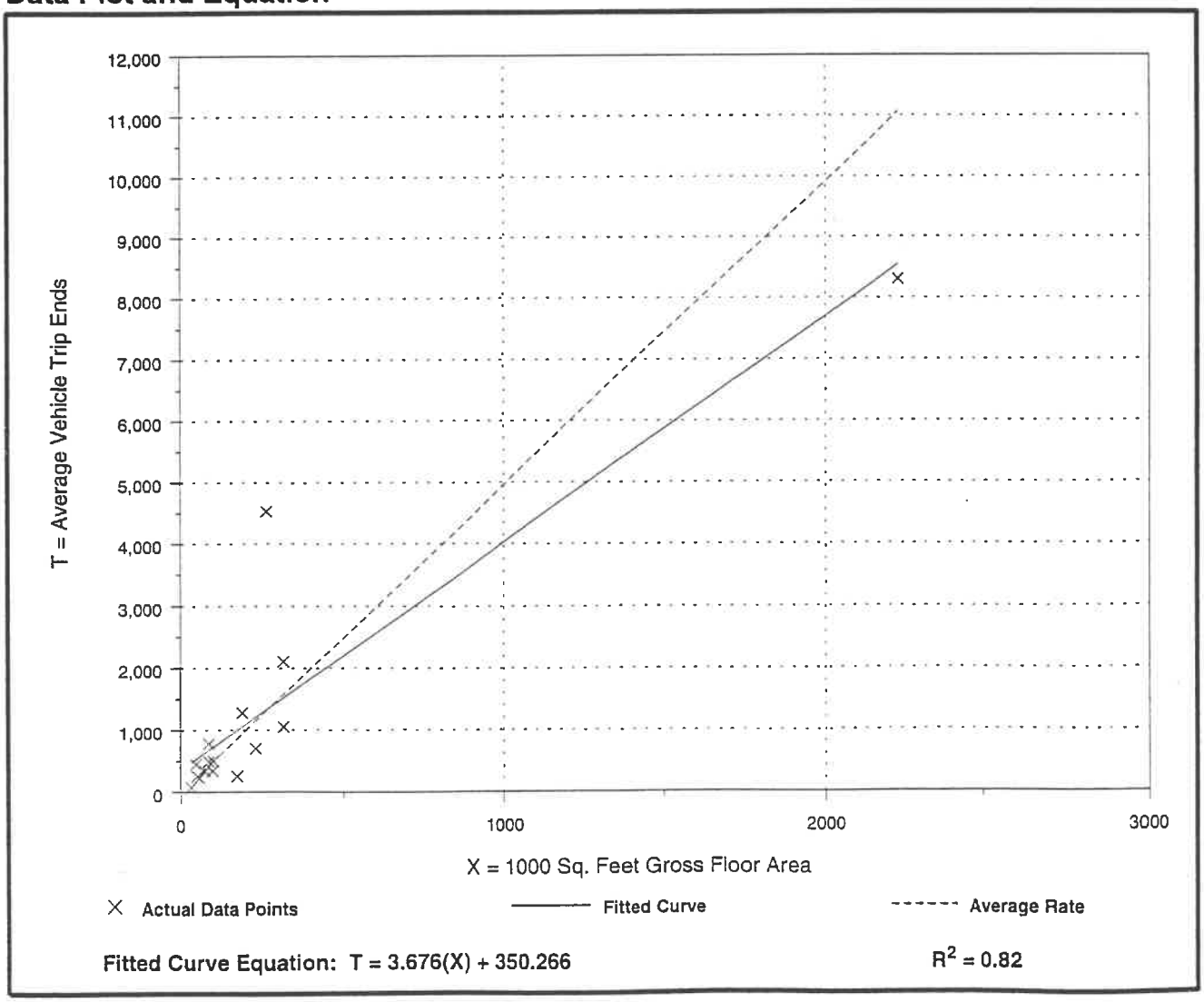
Average Vehicle Trip Ends vs: 1000 Sq. Feet Gross Floor Area
On a: Weekday

Number of Studies: 16
Average 1000 Sq. Feet GFA: 273
Directional Distribution: 50% entering, 50% exiting

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
4.96	1.51 - 17.00	4.05

Data Plot and Equation



Fitted Curve Equation: T = 3.676(X) + 350.266

R^2 = 0.82

Warehousing
(150)

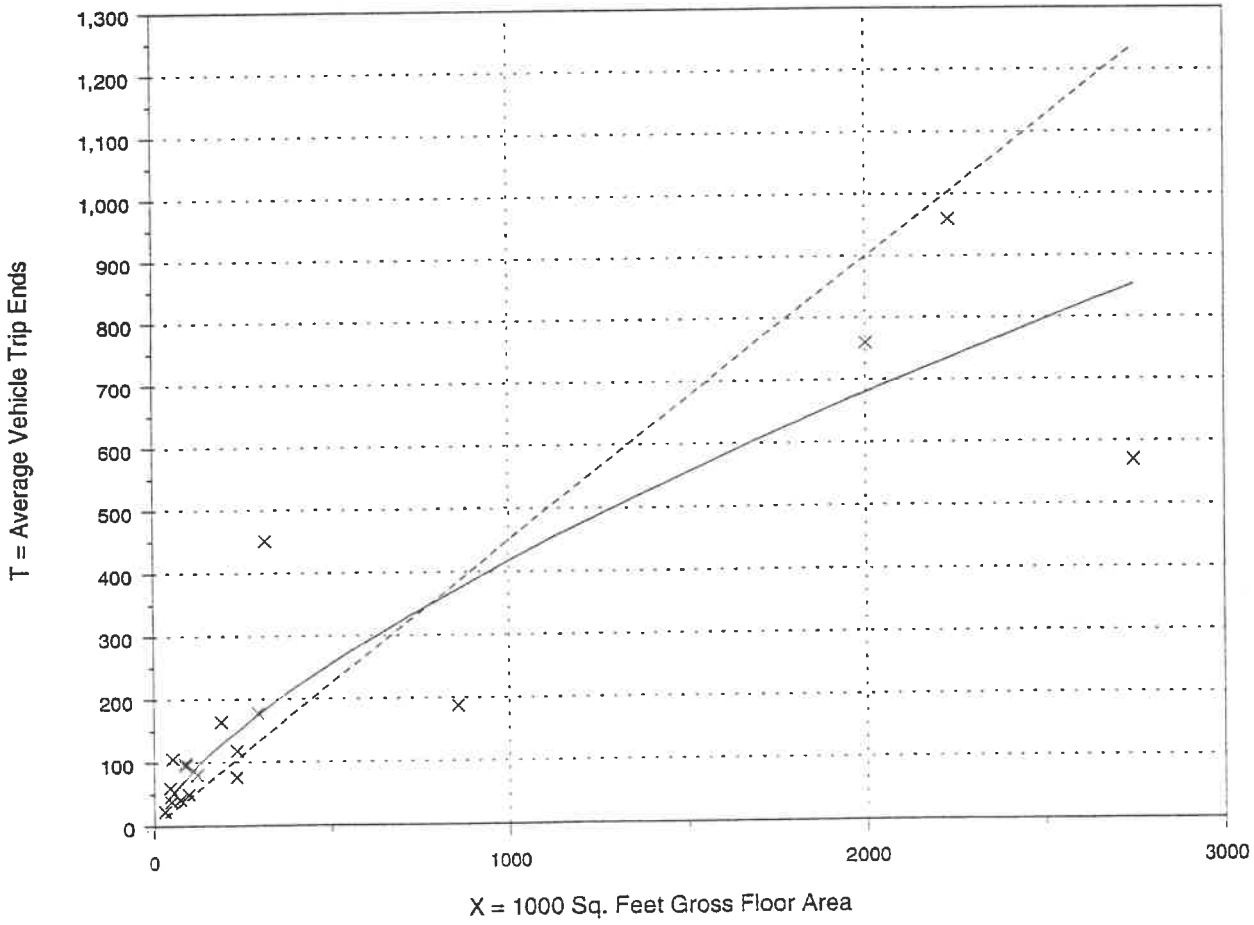
Average Vehicle Trip Ends vs: **1000 Sq. Feet Gross Floor Area**
On a: **Weekday,**
Peak Hour of Adjacent Street Traffic,
One Hour Between 7 and 9 a.m.

Number of Studies: 19
Average 1000 Sq. Feet GFA: 531
Directional Distribution: 82% entering, 18% exiting

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
0.45	0.21 - 1.93	0.74

Data Plot and Equation



Fitted Curve Equation: $Ln(T) = 0.707\ Ln(X) + 1.148$

$R^2 = 0.79$

Warehousing
(150)

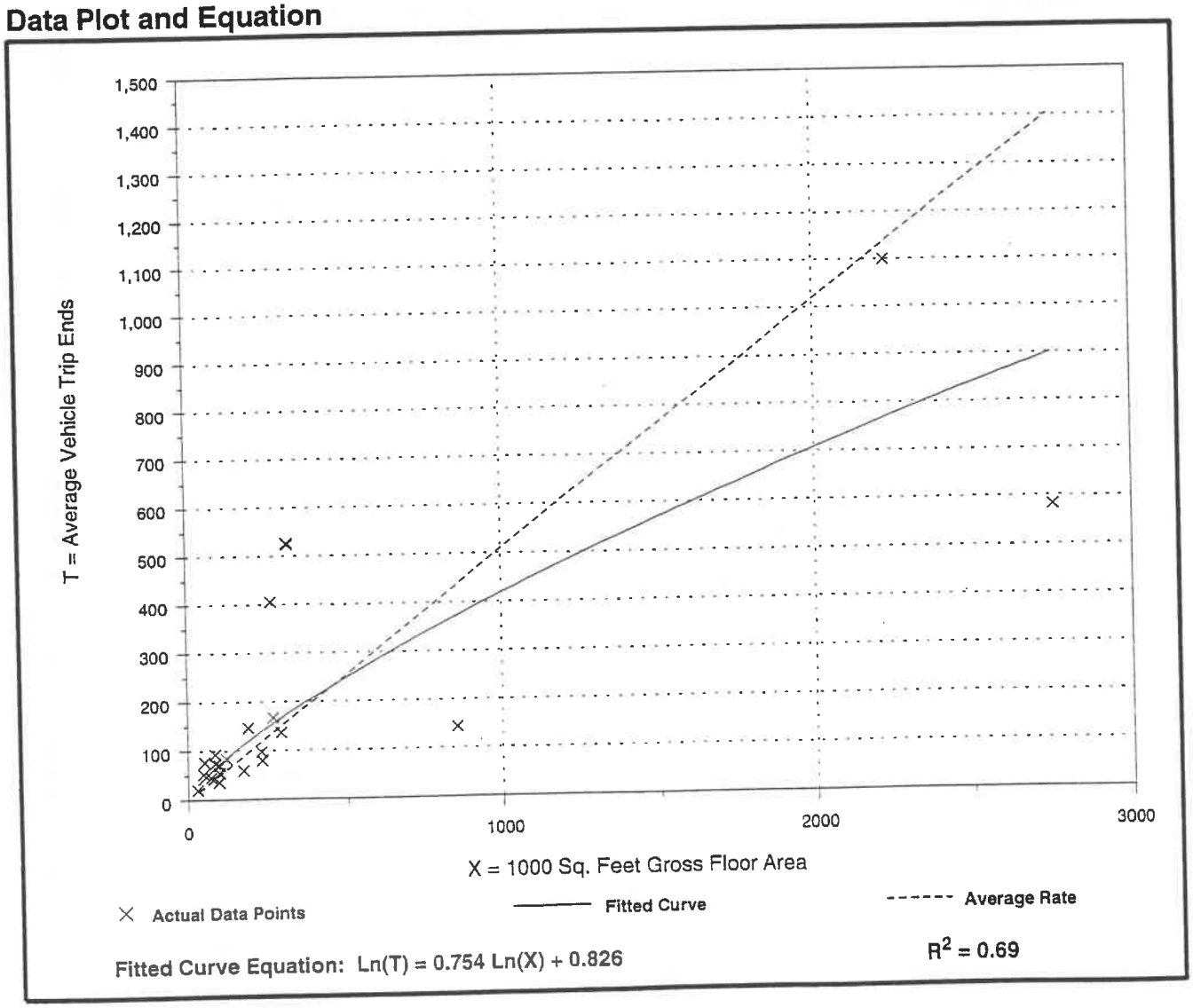
Average Vehicle Trip Ends vs: **1000 Sq. Feet Gross Floor Area**
On a: **Weekday,**
Peak Hour of Adjacent Street Traffic,
One Hour Between 4 and 6 p.m.

Number of Studies: 22
Average 1000 Sq. Feet GFA: 406
Directional Distribution: 24% entering, 76% exiting

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
0.51	0.17 - 1.66	0.83

Data Plot and Equation



Fitted Curve Equation: $Ln(T) = 0.754\ Ln(X) + 0.826$

$R^2 = 0.69$

Land Use: 710
General Office Building

Description

A general office building houses multiple tenants; it is a location where affairs of businesses, commercial or industrial organizations, or professional persons or firms are conducted. An office building or buildings may contain a mixture of tenants including professional services; insurance companies; investment brokers; and tenant services such as a bank or savings and loan institution, a restaurant or cafeteria, and service retail facilities. Nearly all of the buildings surveyed were in suburban locations. Corporate headquarters (land use 714), single tenant office building (land use 715), and office park (land use 750) are related uses.

If information is known about individual buildings, it is suggested that the general office building category be used rather than office parks when estimating trip generation for one or more office buildings in a single development. The office park category is more general, and it should be used when a breakdown of individual or different uses is not known. If the general office building category is used and if additional buildings, such as banks, restaurants, or retail stores are included in the development, then the development should be treated as a multiuse project. On the other hand, if the office park category is used, internal trip making is already reflected in the data and does not need to be considered.

When the buildings are interrelated (defined by shared parking facilities or the ability to easily walk between buildings) or house one tenant, it is suggested that the total area or employment of all the buildings be used for calculating the trip generation. When the individual buildings are isolated and not related to one another, it is suggested that the trip generation be calculated for each building separately and then summed.

Additional Data

Average weekday transit trip ends —

> Transit service was either nonexistent or negligible at the majority of the sites surveyed in this land use. Recent studies indicate increased use of transit, carpools, and other transportation demand management (TDM) strategies. Information has not been analyzed to document the impacts of TDM measures on the total site generation.

The average building occupancy varied considerably within the studies where occupancy data was provided. For buildings with occupancy rates reported, the average percent of occupied gross leasable area was 88 percent.

In some regions peaking may occur earlier or later and last somewhat longer than the traditional 7:00 A.M. to 9:00 A.M. and 4:00 P.M. to 6:00 P.M. peak period time frames.

The sites were surveyed from the 1960s to the 1990s throughout the United States.

Trip Characteristics

The trip generation for the A.M. and P.M. peak hours of the generator typically coincide with the peak hours of the adjacent street traffic; therefore, only one A.M. peak hour and one P.M. peak hour, which represent both the peak hour of the generator and the peak hour of the adjacent street traffic, are shown for general office buildings.

Source Numbers

2, 5, 20, 21, 51, 53, 54, 72, 88, 89, 92, 95, 98, 100, 159, 161, 172, 175, 178, 183, 184, 185, 189, 193, 207, 212, 217, 247, 253, 257, 260, 262, 279, 295, 297, 298, 300, 301, 302, 303, 304, 321, 322, 323, 324, 327, 404, 407, 408, 418, 419, 423

General Office Building
(710)

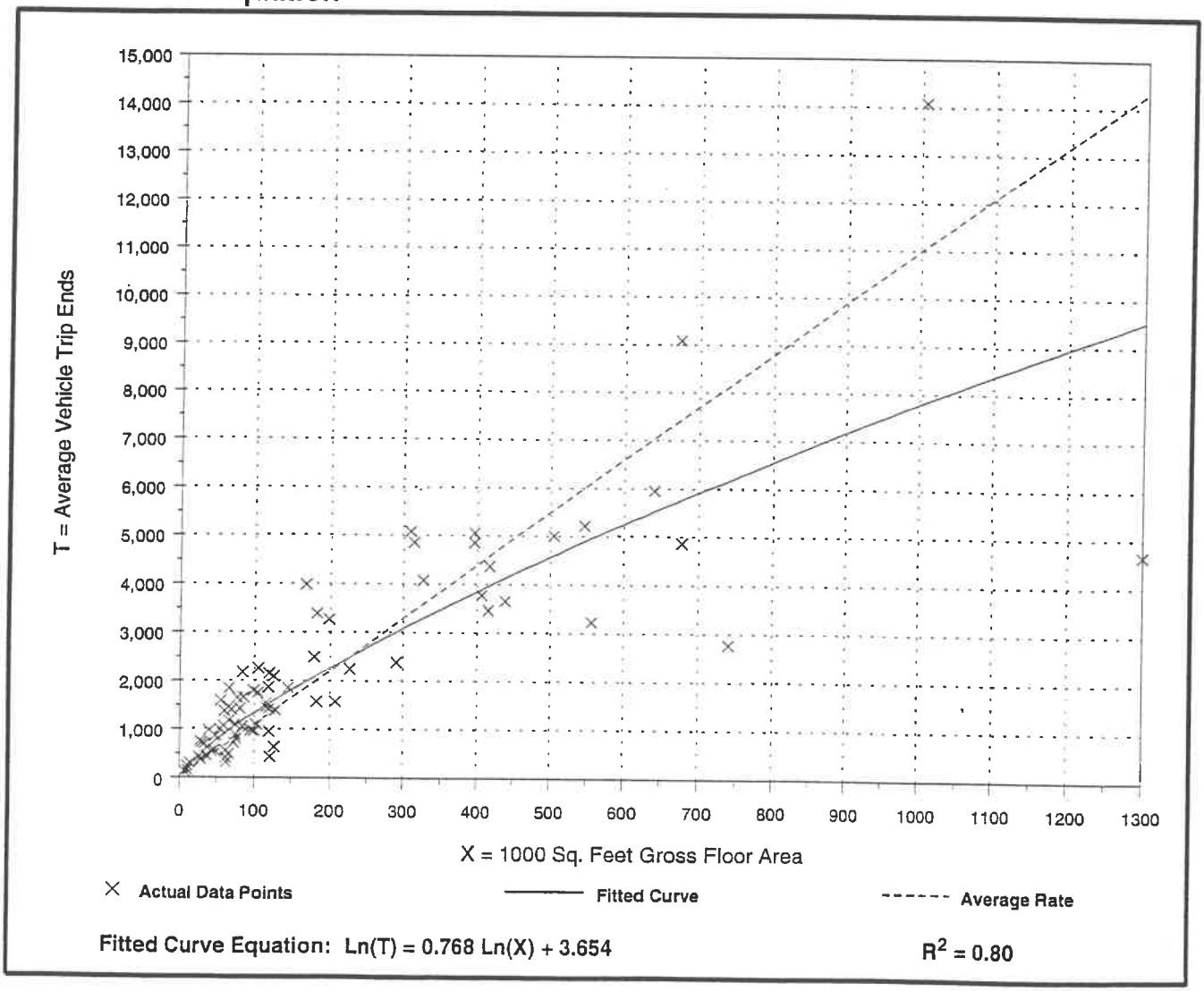
Average Vehicle Trip Ends vs: 1000 Sq. Feet Gross Floor Area
On a: Weekday

Number of Studies: 78
Average 1000 Sq. Feet GFA: 199
Directional Distribution: 50% entering, 50% exiting

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
11.01	3.58 - 28.80	6.13

Data Plot and Equation



Fitted Curve Equation: Ln(T) = 0.768 Ln(X) + 3.654

R^2 = 0.80

General Office Building
(710)

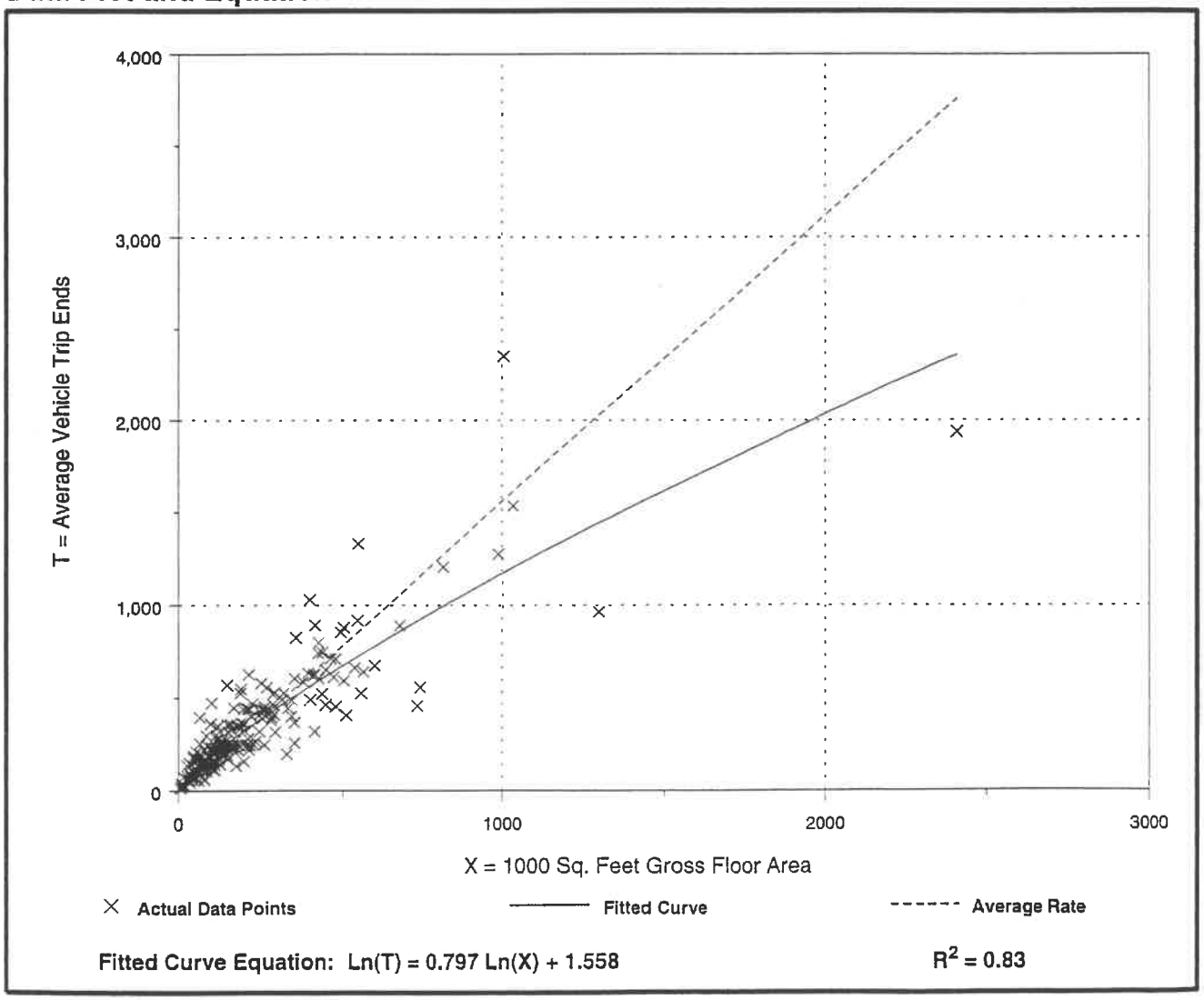
Average Vehicle Trip Ends vs: **1000 Sq. Feet Gross Floor Area**
On a: **Weekday,**
A.M. Peak Hour

Number of Studies: 216
Average 1000 Sq. Feet GFA: 223
Directional Distribution: 88% entering, 12% exiting

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
1.56	0.60 - 5.98	1.40

Data Plot and Equation



Fitted Curve Equation: $Ln(T) = 0.797\ Ln(X) + 1.558$ $R^2 = 0.83$

General Office Building
(710)

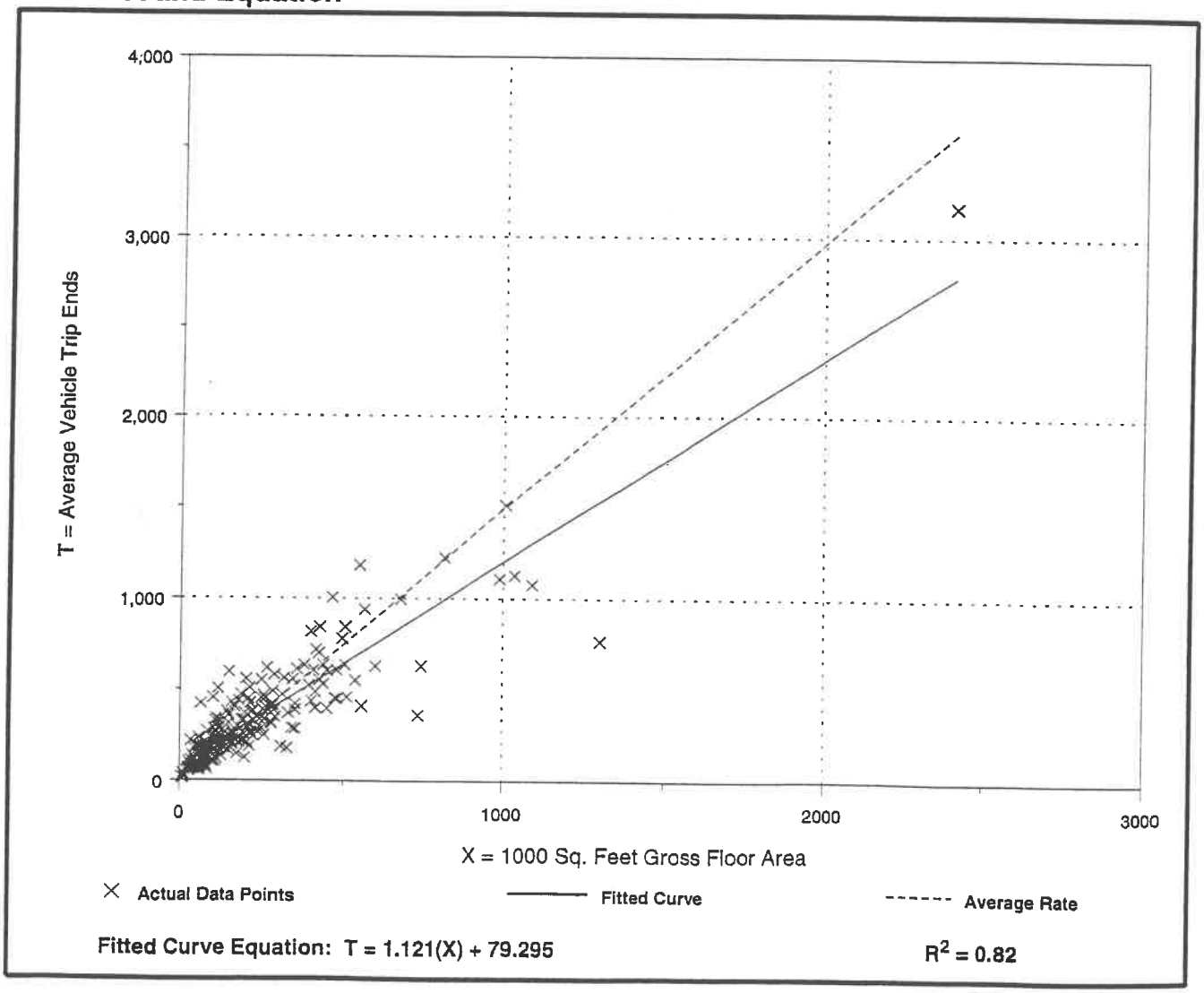
Average Vehicle Trip Ends vs: **1000 Sq. Feet Gross Floor Area**
On a: **Weekday,**
P.M. Peak Hour

Number of Studies: 234
Average 1000 Sq. Feet GFA: 216
Directional Distribution: 17% entering, 83% exiting

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
1.49	0.49 - 6.39	1.37

Data Plot and Equation



Fitted Curve Equation: T = 1.121(X) + 79.295

R^2 = 0.82

Land Use: 760
Research and Development Center

Description

Research and development centers are facilities or groups of facilities devoted almost exclusively to research and development activities. The range of specific types of businesses contained in this land use category varies significantly. Research and development centers may contain offices and light fabrication areas. General office building (land use 710), corporate headquarters building (land use 714), single tenant office building (land use 715), office park (land use 750), and business park (land use 770) are related uses.

Additional Data

Truck trips accounted for 1.84 percent of the weekday traffic at the research and development centers surveyed (range of 0.4 percent to 4.0 percent).

The average vehicle occupancy for the thirteen studies where information was submitted is approximately 1.19 persons per automobile. The range of vehicle occupancy rates is 1.10 to 1.33 persons per automobile.

The sites were surveyed from the 1960s to the 1990s throughout the United States, with many conducted in the Washington, D.C.; San Francisco; and San Diego metropolitan areas.

Trip Characteristics

The trip generation for the A.M. and P.M. peak hours of the generator typically coincide with the peak hours of the adjacent street traffic; therefore, only one A.M. peak hour and one P.M. peak hour, which represent both the peak hour of the generator and the peak hour of the adjacent street traffic, are shown for research and development centers.

Source Numbers

9, 105, 213, 218, 253, 332, 384, 423

Research and Development Center
(760)

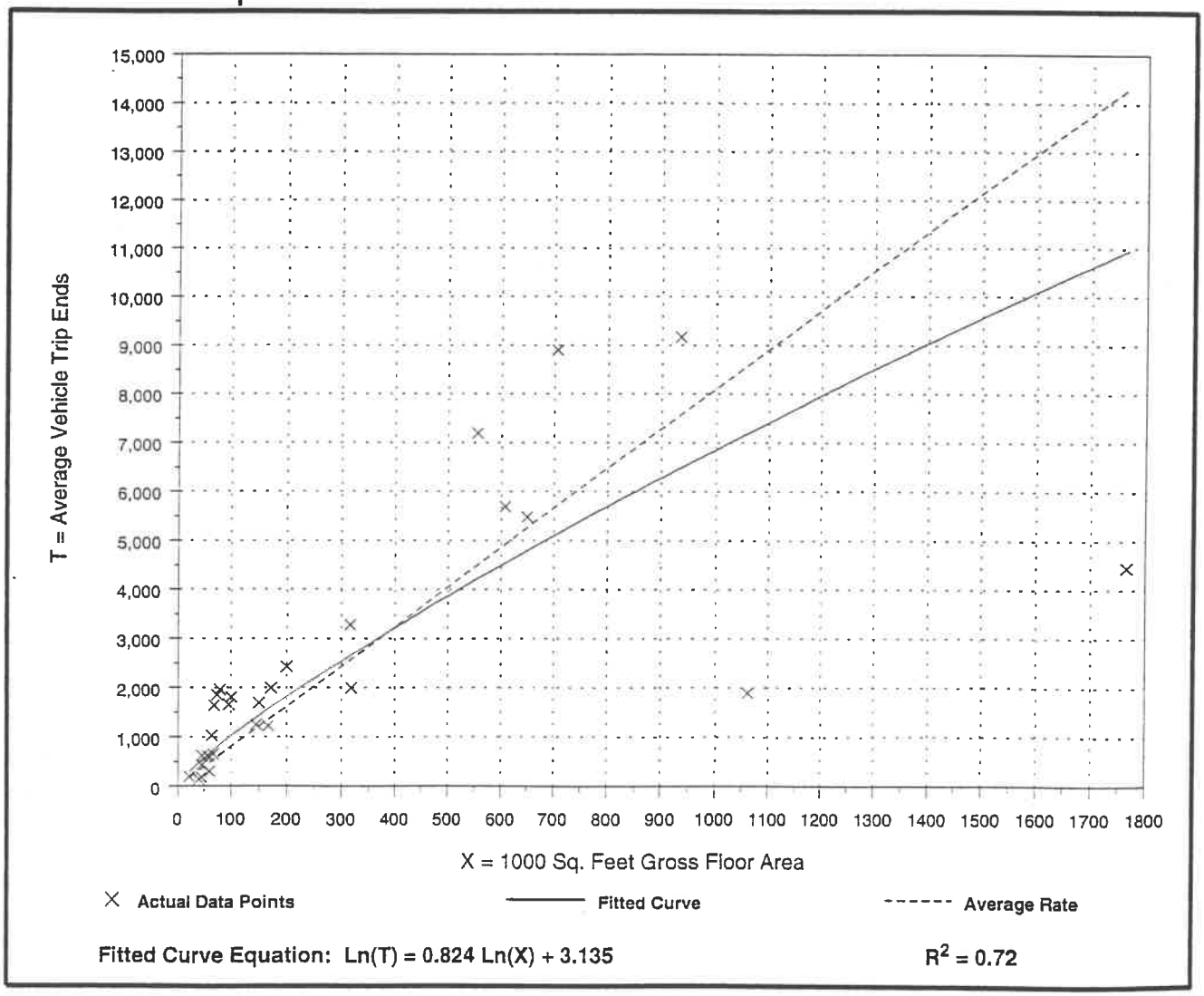
Average Vehicle Trip Ends vs: 1000 Sq. Feet Gross Floor Area
On a: Weekday

Number of Studies: 28
Average 1000 Sq. Feet GFA: 308
Directional Distribution: 50% entering, 50% exiting

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
8.11	1.78 - 24.95	5.85

Data Plot and Equation



Fitted Curve Equation: Ln(T) = 0.824 Ln(X) + 3.135

R^2 = 0.72

Research and Development Center
(760)

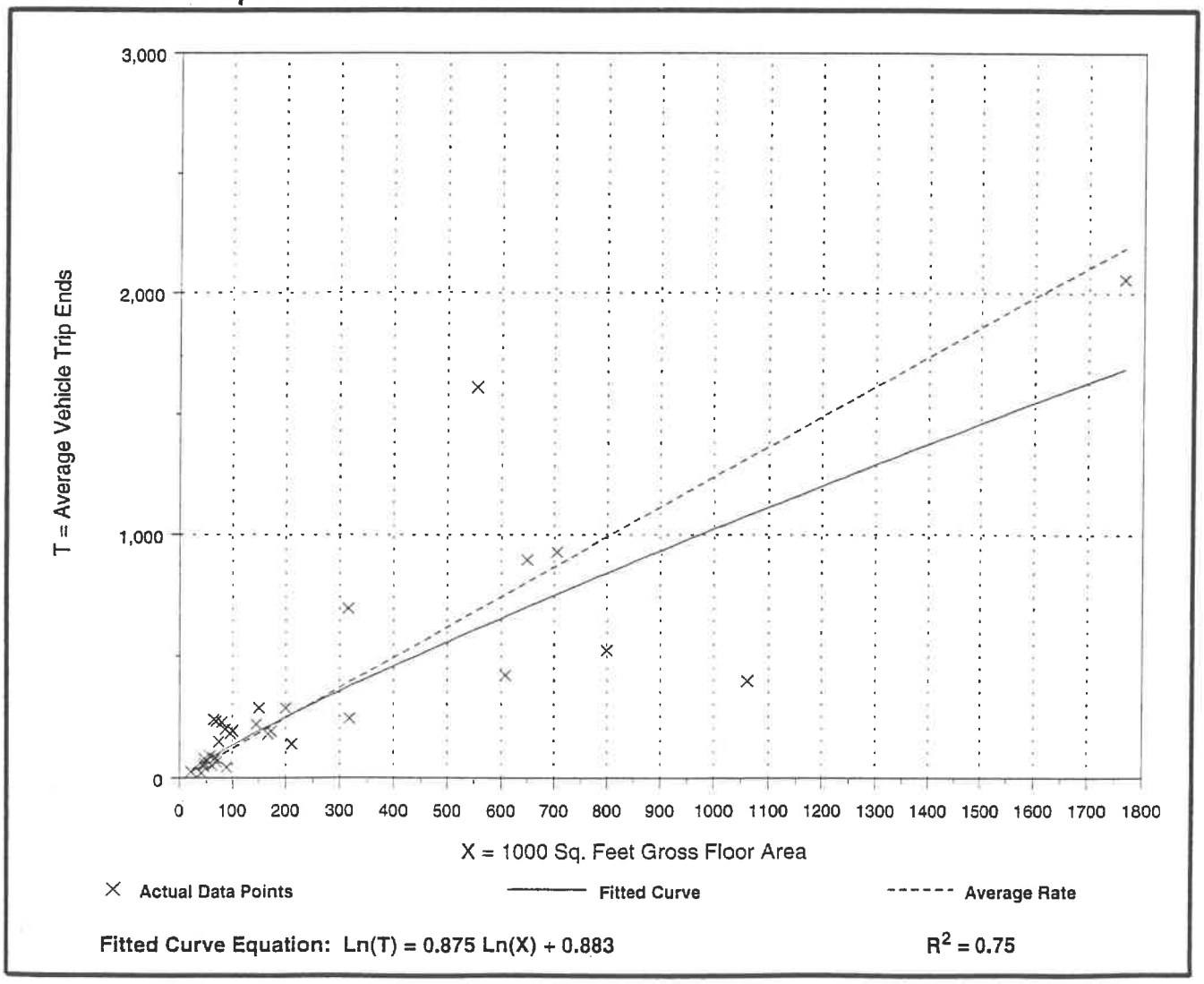
Average Vehicle Trip Ends vs: 1000 Sq. Feet Gross Floor Area
On a: Weekday,
A.M. Peak Hour

Number of Studies: 32
Average 1000 Sq. Feet GFA: 279
Directional Distribution: 83% entering, 17% exiting

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
1.24	0.37 - 3.73	1.32

Data Plot and Equation



Fitted Curve Equation: Ln(T) = 0.875 Ln(X) + 0.883 $R^2 = 0.75$

Research and Development Center
(760)

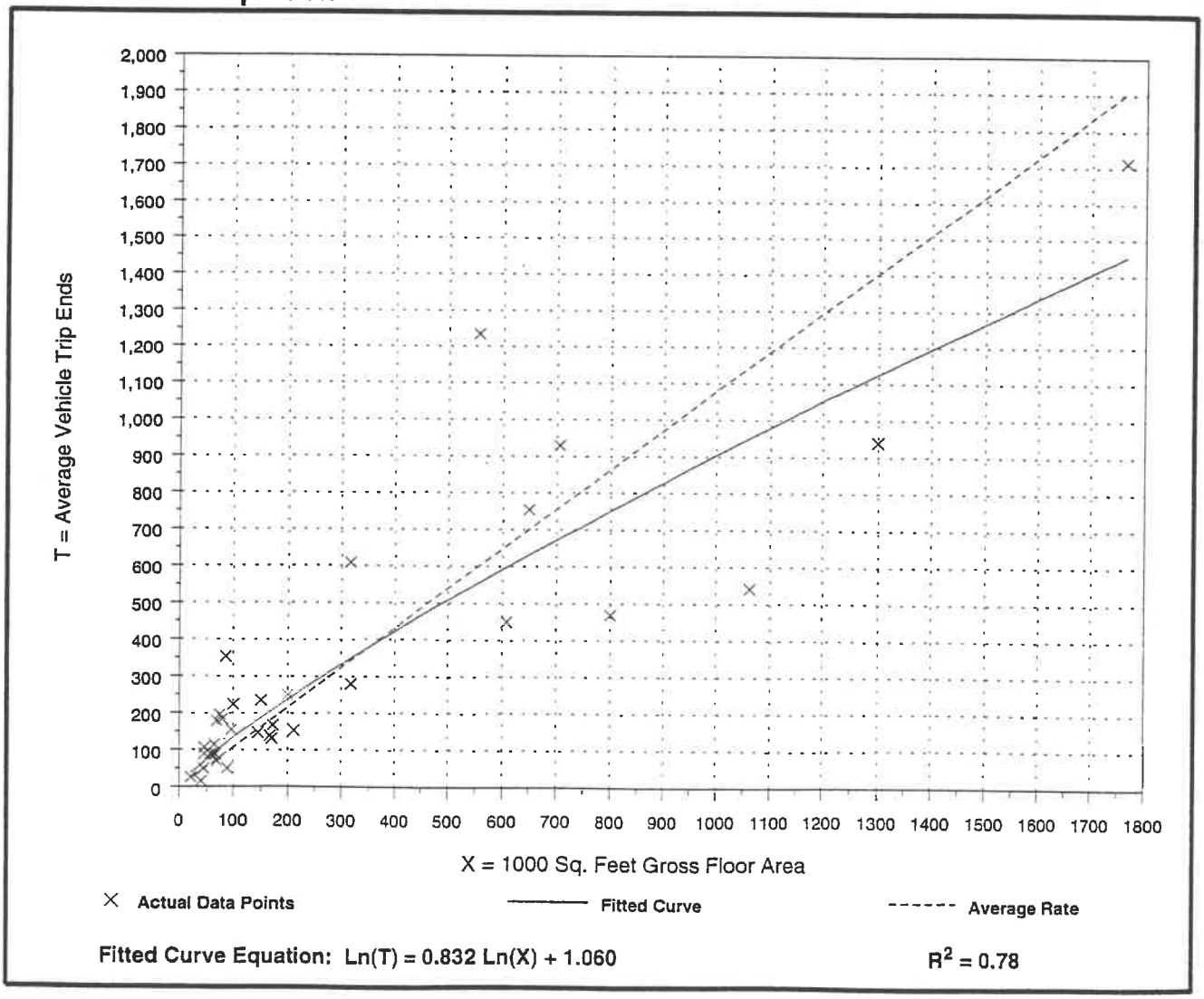
Average Vehicle Trip Ends vs: **1000 Sq. Feet Gross Floor Area**
On a: **Weekday,**
P.M. Peak Hour

Number of Studies: 34
Average 1000 Sq. Feet GFA: 306
Directional Distribution: 15% entering, 85% exiting

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
1.08	0.40 - 4.13	1.19

Data Plot and Equation



Fitted Curve Equation: $Ln(T) = 0.832\ Ln(X) + 1.060$

$R^2 = 0.78$

Level of Service Description

LOS

The average control delay per vehicle is estimated for each lane group and aggregated for each approach and for the intersection as a whole. LOS is directly related to the control delay value. The criteria are listed in Exhibit 16-2.

EXHIBIT 16-2. LOS CRITERIA FOR SIGNALIZED INTERSECTIONS

LOS	Control Delay per Vehicle (s/veh)
A	≤ 10
B	> 10–20
C	> 20–35
D	> 35–55
E	> 55–80
F	> 80

EXHIBIT 17-2. LEVEL-OF-SERVICE CRITERIA FOR TWSC INTERSECTIONS

Level of Service	Average Control Delay (s/veh)
A	0–10
B	> 10–15
C	> 15–25
D	> 25–35
E	> 35–50
F	> 50

Capacity Calculations

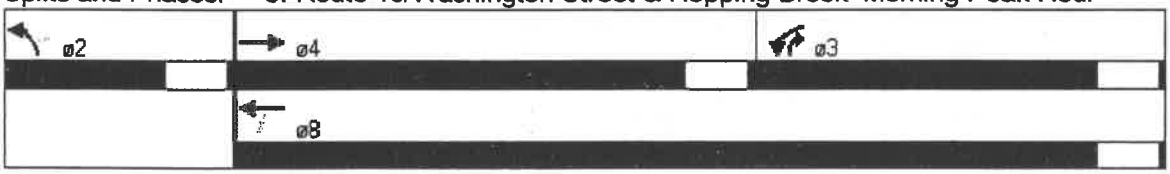
Lane Group	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↑	↱	↰	↑	↰	↱
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Storage Length (ft)		300	300		0	0
Storage Lanes		1	1		1	1
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0
Leading Detector (ft)	50	50	50	50	50	50
Trailing Detector (ft)	0	0	0	0	0	0
Turning Speed (mph)		9	15		15	9
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	1.00
Frt		0.850				0.850
Flt Protected			0.950		0.950	
Satd. Flow (prot)	1863	1583	1770	1863	1770	1583
Flt Permitted			0.138		0.950	
Satd. Flow (perm)	1863	1583	257	1863	1770	1583
Right Turn on Red		Yes				Yes
Satd. Flow (RTOR)		586				76
Headway Factor	1.00	1.00	1.00	1.00	1.00	1.00
Link Speed (mph)	30			30	30	
Link Distance (ft)	2268			2404	1552	
Travel Time (s)	51.5			54.6	35.3	
Volume (vph)	667	1459	602	302	186	70
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	725	1586	654	328	202	76
Lane Group Flow (vph)	725	1586	654	328	202	76
Turn Type		Free	pm+pt			pm+ov
Protected Phases	4		3	8	2	3
Permitted Phases		Free	8			2
Detector Phases	4		3	8	2	3
Minimum Initial (s)	4.0		4.0	4.0	4.0	4.0
Minimum Split (s)	20.0		8.0	20.0	10.0	8.0
Total Split (s)	29.0	0.0	23.0	52.0	13.0	23.0
Total Split (%)	45%	0%	35%	80%	20%	35%
Yellow Time (s)	3.5		3.5	3.5	3.5	3.5
All-Red Time (s)	0.5		0.5	0.5	0.5	0.5
Lead/Lag	Lead		Lag			Lag
Lead-Lag Optimize?	Yes		Yes			Yes
Recall Mode	None		None	None	Min	None
Act Effct Green (s)	25.0	65.0	48.0	48.0	9.0	32.0
Actuated g/C Ratio	0.38	1.00	0.74	0.74	0.14	0.49
v/c Ratio	1.01	1.00	1.03	0.24	0.82	0.09
Uniform Delay, d1	20.0	0.0	18.6	2.7	27.2	0.0
Delay	50.2	20.9	56.2	2.8	45.1	2.7
LOS	D	C	E	A	D	A
Approach Delay	30.1			38.3	33.5	
Approach LOS	C			D	C	
Queue Length 50th (ft)	~286	~3	~235	30	79	0
Queue Length 95th (ft)	#502	#241	#269	52	#183	18
Internal Link Dist (ft)	2188			2324	1472	
50th Up Block Time (%)						

Lane Group	EBT	EBR	WBL	WBT	NBL	NBR
95th Up Block Time (%)						
Turn Bay Length (ft)		300	300			
50th Bay Block Time %	7%					
95th Bay Block Time %	41%		7%			
Queuing Penalty (veh)	378		12			

Intersection Summary

Area Type: Other
Cycle Length: 65
Actuated Cycle Length: 65
Natural Cycle: 65
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 1.03
Intersection Signal Delay: 32.6 Intersection LOS: C
Intersection Capacity Utilization 95.6% ICU Level of Service E
~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 5: Route 16/Washington Street & Hopping Brook Morning Peak Hour



Lane Group	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↑	↱	↰	↑	↰	↱
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Storage Length (ft)		300	300		0	0
Storage Lanes		1	1		1	1
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0
Turning Speed (mph)		9	15		15	9
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	1.00
Frt		0.850				0.850
Flt Protected			0.950		0.950	
Satd. Flow (prot)	1863	1583	1770	1863	1770	1583
Flt Permitted			0.072		0.950	
Satd. Flow (perm)	1863	1583	134	1863	1770	1583
Right Turn on Red		Yes				Yes
Satd. Flow (RTOR)		335				110
Headway Factor	1.00	1.00	1.00	1.00	1.00	1.00
Link Speed (mph)	30			30	30	
Link Distance (ft)	2270			1858	1536	
Travel Time (s)	51.6			42.2	34.9	
Volume (vph)	688	640	69	806	961	618
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	748	696	75	876	1045	672
Lane Group Flow (vph)	748	696	75	876	1045	672
Turn Type		Free	pm+pt			pm+ov
Protected Phases	4		3	8	2	3
Permitted Phases		Free	8			2
Minimum Split (s)	20.0		8.0	20.0	20.0	8.0
Total Split (s)	60.0	0.0	8.0	68.0	62.0	8.0
Total Split (%)	46%	0%	6%	52%	48%	6%
Yellow Time (s)	3.5		3.5	3.5	3.5	3.5
All-Red Time (s)	0.5		0.5	0.5	0.5	0.5
Lead/Lag	Lead		Lag			Lag
Lead-Lag Optimize?	Yes		Yes			Yes
Act Effct Green (s)	56.0	130.0	64.0	64.0	58.0	66.0
Actuated g/C Ratio	0.43	1.00	0.49	0.49	0.45	0.51
v/c Ratio	0.93	0.44	0.65	0.96	1.32	0.78
Uniform Delay, d1	35.2	0.0	36.4	31.6	36.0	21.3
Delay	46.1	0.0	47.8	45.0	153.8	22.3
LOS	D	A	D	D	F	C
Approach Delay	23.9			45.2	102.4	
Approach LOS	C			D	F	
Queue Length 50th (ft)	590	0	33	689	~1138	385
Queue Length 95th (ft)	#850	0	#79	#981	#1397	562
Internal Link Dist (ft)	2190			1778	1456	
50th Up Block Time (%)						
95th Up Block Time (%)						
Turn Bay Length (ft)		300	300			
50th Bay Block Time %	30%			31%		
95th Bay Block Time %	41%			39%		
Queuing Penalty (veh)	246			26		

Intersection Summary

Area Type: Other
Cycle Length: 130
Actuated Cycle Length: 130
Offset: 0 (0%), Referenced to phase 2:NBL and 6:, Start of Green
Natural Cycle: 130
Control Type: Pretimed
Maximum v/c Ratio: 1.32
Intersection Signal Delay: 61.6 Intersection LOS: E
Intersection Capacity Utilization 111.4% ICU Level of Service G
~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 7: Route 16/Washington Street & Hopping Brook Evening Peak Hour