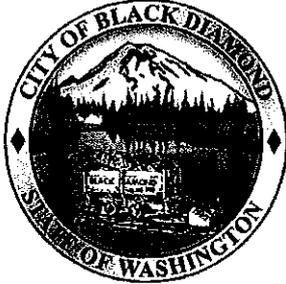


25a.

Traffic Monitoring Report: Response to Comments,  
Transpo Group  
March 28, 2014

TRAFFIC



# REVISION/CORRECTION SUBMITTAL FORM

COMMUNITY DEVELOP.

MAR 31 2014

RECEIVED

**Submittal Requirements:**

All revisions / correction submittals **MUST** contain the following:

1. A completed City of Black Diamond Revision/Correction submittal form
2. Two (2) sets of revised and/or corrected drawings/sheets (wet stamped by architect, if applicable).
3. Revised structural calculations, if applicable (must be stamped by engineer)
4. A written letter to the City that shows an itemized summary of your submittal (must include sheet and detail numbers)
5. All changes **MUST BE CLOUDED** or **HIGHLIGHTED** on each plan set

Date: 3/31/14

Permit #: PLN13-0027, PLN11-0008  
PLN11-0010

Property Address: SEE THE PROJECT NARRATIVES FOR PHASE 2 PLATS A, B, & C  
 Project Name: THE VILLAGES & LAWSON HILLS MPDS - PHASE 2  
 Contact Person: COLIN LUND  
 Phone: (425) 498-2100  
 Email: CLUND@YARROWBAYHOLDINGS.COM

**TYPE OF SUBMITTAL:**

- ( ) **REVISION:** A change the applicant has made to a plan that is either:
1. An approved plan already issued by the City or
  2. A project under current plan review
- (X) **CORRECTION:** An applicant response to a correction letter written by the City to the applicant

Permit Issued? ( ) Yes (X) No \*A plan check fee for revision is \$84 per hour with a minimum of \$42 for ½ hour

**Please describe revision/correction submittal:**

THE VILLAGES AND LAWSON HILLS MPDS - PHASE 2 TRAFFIC MONITORING REPORT, RESPONSE TO COMMENTS  
DATED MARCH 28, 2014

**Sheets Affected:** \_\_\_\_\_ If more than two (2) sheets will be changed, please submit two (2) new full sets of plans. Revisions on issued permits only require submittal of the affected sheets.

**For City Use Only:**

REQ'D APPROVAL	CHECKED BY	ROUTE TO	DATE	INITIAL	COMMENTS	FEES
( )	1. BUILDING	_____	_____	_____	_____	_____
( )	2. PLANNING	_____	_____	_____	_____	_____
( )	3. FIRE	_____	_____	_____	_____	_____
( )	4. PW	_____	_____	_____	_____	_____
( )	5	_____	_____	_____	_____	_____

TOTAL \$

## TECHNICAL MEMORANDUM

<b>Date:</b>	March 28, 2014	<b>TG:</b>	05387.03
<b>To:</b>	Colin Lund – YarrowBay Holdings		
<b>From:</b>	Kevin L. Jones, P.E., PTOE – Transpo Group		
<b>Subject:</b>	The Villages and Lawson Hills MPDs - Phase 2 Traffic Monitoring Report, Response to Comments		

This memo provides responses to the seven comments described in the Technical Memorandum from Parametrix's John Perlic to the City of Black Diamond's Andy Williamson dated February 27, 2014 regarding Parametrix's review of *The Villages and Lawson Hills MPDs – Phase 2 Traffic Monitoring Report* dated December 2013. Each comment is reiterated in italics below followed by our written response.

1. *Provide information showing that November can be considered similar in traffic levels as February.*

To clarify, the traffic counts collected as part of *The Villages MPD – Phase 1A Traffic Impact Study* (Traffic Monitoring Report) were collected the week of December 6, 2010 and the traffic counts collected as part of *The Villages and Lawson Hills MPDs – Phase 2 Traffic Monitoring Report* were collected the week of November 12, 2013. And while these two sets of counts were not collected during the same calendar month, these sets are separated by only three weeks or so and consequently, we did not believe it was necessary to apply a seasonal adjustment factor because both sets were collected during the same season (late autumn).

2. *Attach existing count data in the appendix.*

Attachment 1 includes copies of existing (November 2013) weekday PM peak hour traffic count data at study intersections.

3. *Provide trip generation and distributions for Sugarloaf Mountain West.*

Based on the number of new single-family dwelling units (93) and average PM peak hour trip generation rate published in the latest edition of *Trip Generation* for "Single-Family Detached Housing" (one trip per dwelling unit), it is estimated that Sugarloaf Mountain West will generate 93 weekday PM peak hour trips. It was assumed that the development would be approximately 60 percent occupied by 2015 and fully occupied by 2016. All project-generated trips will travel to/from the west and increase eastbound and westbound through traffic at the study intersection of SE Kent-Kangley Road/Landsburg Road SE. Based on the trip distribution estimates presented in the traffic impact analysis for Sugarloaf Mountain West, very few if any project trips will be oriented to/from the south and southwest and therefore, we did not assign project traffic to any of the other study intersections.

4. *Provide information on the NCHRP report 599 methodology for adjusting PHFs.*

Pertinent excerpts from the National Cooperative Highway Research Program (NCHRP) Report 599 ("Default Values for Highway Capacity and Level of Service Analyses") are included in Attachment 2. Based on over 2,500 unique observations, the majority of which were made in the northwestern United States during the weekday PM peak period, peak hour factors (PHFs) were found to generally increase as traffic volumes increase. Median intersection PHFs as a function of total intersection traffic volume are summarized in Table 19 on page 50.

In evaluating future traffic operations, we applied the intersection's existing PHF unless, in view of the research in NCHRP Report 599, existing traffic volumes were anticipated to increase enough to support increasing the existing PHF. For example, the existing PHF at SR 169/Jones Lake Road is 0.89 with approximately 840 vehicles entering the intersection during the weekday PM peak hour. Future with-project PM peak hour traffic volumes at this intersection are estimated at approximately 1,250 vehicles. Given the anticipated increase of 410 vehicles and the research summarized in Table 19 of NCHRP Report 599, we applied a PHF of 0.91 in evaluating future PM peak hour traffic operations at this intersection. This PHF represents the median PHF for intersections with more than 1,000 hourly vehicles and up to 1,500 hourly vehicles.

5. *Provide a description of the ERU methodology, in particular how the Elementary School trips are converted to ERUs.*

Equivalent residential units (ERUs) were calculated based on the number of net new weekday PM peak hour trips generated by the MPDs. The ERU calculation for all land uses, including the elementary school, is based on the average number of trips generated by a detached single-family dwelling unit, which is approximately one PM peak hour trip per *Trip Generation*. Therefore, each net new weekday PM peak hour trip generated by the Phase 2 land uses is equivalent to approximately one ERU. And with respect to the elementary school, it is estimated to generate 47 net new PM peak hour trips (see Table 5), the same amount of traffic generated by 47 single-family dwelling units. Thus, this school is anticipated to generate weekday PM peak hour traffic representative of 47 ERUs.

6. *Provide additional information describing how the internal trip reductions were calculated. The exhibits in Appendix C Internal Capture Calculations needs a legend or description on how to read the diagram, so that the diagrams can be reviewed.*

Internal trip reductions were estimated following the "Multi-Use Development" methodology outlined in Chapter 7 of the *Trip Generation Handbook* and included in Attachment 3. The internal capture rates from Tables 7.1 and 7.2 of the *Handbook* were used for the residential, retail and office land uses of The Villages MPD. The *Handbook* does not provide an internal capture rate for education land uses so instead, a rate of 30 percent was assumed for the elementary school consistent with the assumption in *The Villages Transportation Technical Report (TTR)* (Parametrix, December 2009), *Lawson Hills TTR* (Parametrix, December 2009) and *The Villages MPD – Phase 1A Traffic Impact Study* (Transpo Group, February 2011).

The internal capture rates were applied following the process illustrated in Figures 7.2, 7.3, 7.4 and 7.5 of the *Handbook*. Based on the prescribed methodology, the number of internal trips generated by The Villages Phase 1A alone would be no different than the number of internal trips generated by the combination of Phases 1A and 2 (e.g., an overall increase in the number of trips internal to the MPD would not be expected with the development of Phase 2). For that reason, we did not estimate the internal trip making of Phase 2 by subtracting the number of internal trips generated by Phase 1A from the number of internal trips generated by Phases 1A and 2 because some of the residential trips generated by Phase 2 would be linked to the non-residential trips generated by Phase 1A. Instead, it was assumed that the number of internal trips between the two phases of development would be offset by a reduction in trips internal to Phase 1A. This "offsetting" was applied for each year of Phase 2 development (2013 through 2020) based on the proportion of gross residential trips between Phases 1A and 2.

7. *Provide information on how the 4th and 8th hour volumes used in the warrant analyses were determined.*

Traffic volumes during the fourth and eighth highest hours of the day were estimated using information in NCHRP Report 365 ("Travel Estimation Techniques for Urban Planning"). Pertinent

excerpts from this report, including Table 41 on page 83, are included in Attachment 4. The percentage of daily vehicle trips is presented by hour and for all trip purposes, shows that the weekday PM peak hour represents approximately 9 percent of daily vehicle trips and the fourth and eighth highest hours represent approximately 7 and 6 percent, respectively. Using these percentages, we estimated future traffic volumes during the fourth and eighth highest hours by multiplying future PM peak hour traffic volumes by approximately 80 percent (7.13 percent / 8.95 percent) and 68 percent (6.12 percent / 8.95 percent), respectively. The resulting traffic volumes were used to evaluate the Four-Hour and Eight-Hour Vehicular Volume Warrants.

Attachments 1-4





Prepared for: **Transpo Group**  
**Traffic Count Consultants, Inc.**

Phone: (253) 926-6009 FAX: (253) 922-7211 E-Mail: Team@TC2inc.com

WB/DBE

Intersection: 216th Ave SE & SE 288th St

Date of Count: Thurs 11/14/2013

Location: Black Diamond, Washington

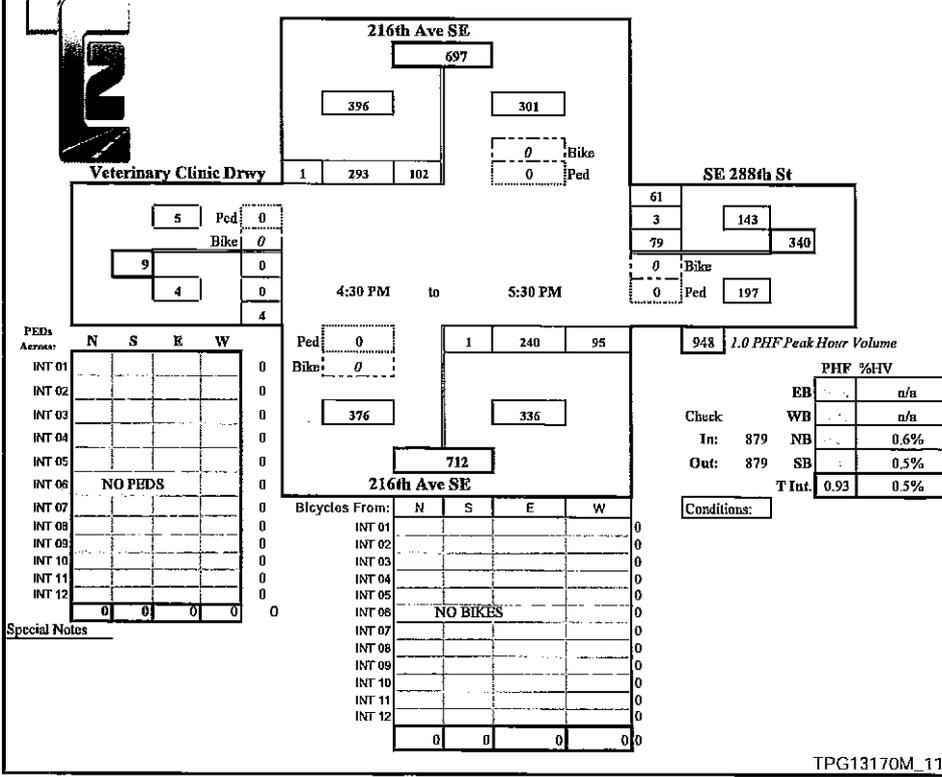
Checked By: Jess

Time Interval Ending at	From North on (SB) 216th Ave SE				From South on (NB) 216th Ave SE				From East on (WB) SE 288th St				From West on (EB) Veterinary Clinic Drwy				Interval Total
	T	L	S	R	T	L	S	R	T	L	S	R	T	L	S	R	
4:15 P	2	20	73	1	1	2	56	16	3	24	0	11	0	0	0	4	207
4:30 P	1	22	54	0	1	0	57	20	0	23	1	12	0	1	1	0	191
4:45 P	1	29	66	0	1	0	75	20	0	16	1	13	0	0	0	1	221
5:00 P	0	24	84	1	0	0	47	24	0	22	0	22	0	0	0	0	224
5:15 P	0	16	54	0	0	1	60	25	0	21	2	16	0	0	0	2	197
5:30 P	1	33	89	0	1	0	58	26	0	20	0	10	0	0	0	1	237
5:45 P	0	25	65	0	1	0	52	17	0	23	0	14	0	2	0	0	198
6:00 P	0	19	60	0	0	0	56	23	0	18	0	10	0	2	0	0	188
6:15 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:30 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:45 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:00 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Total Survey	5	188	545	2	5	3	461	171	3	167	4	108	0	5	1	8	1663
--------------	---	-----	-----	---	---	---	-----	-----	---	-----	---	-----	---	---	---	---	------

Peak Hour: 4:30 PM to 5:30 PM

Total	2	102	293	1	2	1	240	95	0	79	3	61	0	0	0	4	879
Approach	396				336				143				4				879
%HV	0.5%				0.6%				n/a				n/a				0.5%
PHF																	0.93





Prepared for: **Transpo Group**  
**Traffic Count Consultants, Inc.**

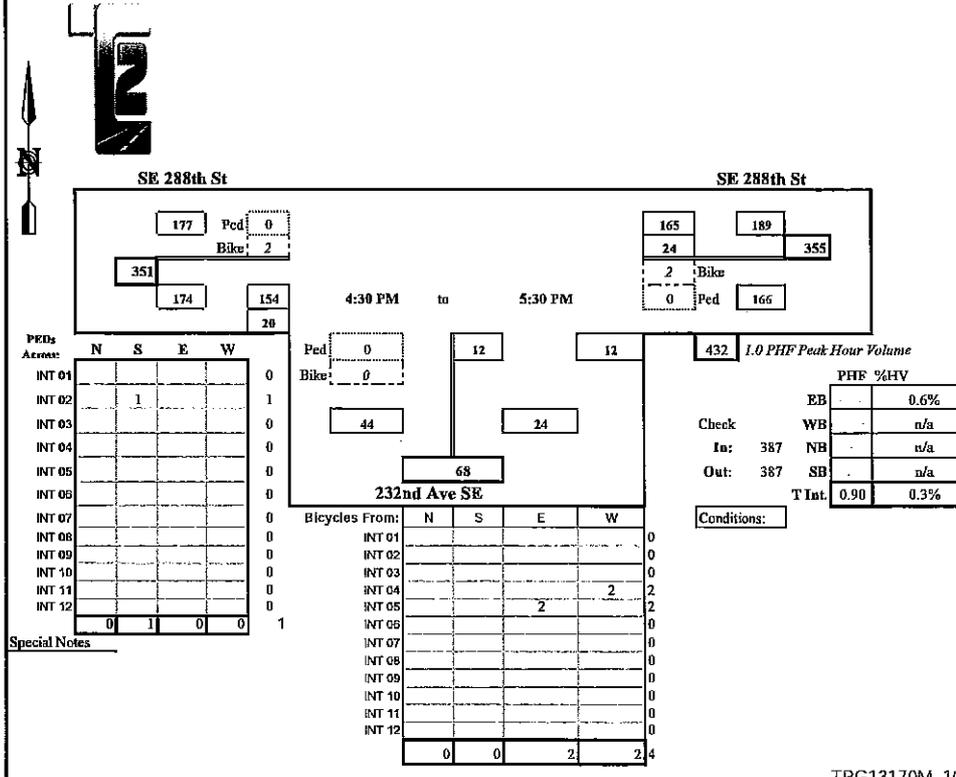
Phone: (253) 926-6009 FAX: (253) 922-7211 E-Mail: Team@TC2inc.com

WBE/DBE

Intersection: 232nd Ave SE & SE 288th St  
 Location: Black Diamond, Washington

Date of Count: Thurs 11/14/2013  
 Checked By: Jess

Time Interval Ending at	From North on (SB)				From South on (NB)				From East on (WB)				From West on (EB)				Interval Total			
	T	L	S	R	T	L	S	R	T	L	S	R	T	L	S	R				
4:15 P	0	0	0	0	1	3	0	3	2	5	40	0	1	0	26	4	81			
4:30 P	0	0	0	0	1	2	0	4	1	5	39	0	0	0	30	5	85			
4:45 P	0	0	0	0	0	1	0	2	0	6	43	0	1	0	44	2	98			
5:00 P	0	0	0	0	0	3	0	3	0	7	40	0	0	0	38	5	96			
5:15 P	0	0	0	0	0	5	0	4	0	5	38	0	0	0	30	3	85			
5:30 P	0	0	0	0	0	3	0	3	0	6	44	0	0	0	42	10	108			
5:45 P	0	0	0	0	0	1	0	3	0	3	39	0	1	0	34	4	84			
6:00 P	0	0	0	0	0	5	0	2	0	2	26	0	0	0	27	6	68			
6:15 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
6:30 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
6:45 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
7:00 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
<b>Total</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>2</b>	<b>23</b>	<b>0</b>	<b>24</b>	<b>3</b>	<b>39</b>	<b>309</b>	<b>0</b>	<b>3</b>	<b>0</b>	<b>271</b>	<b>39</b>	<b>705</b>			
<b>Survey</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>12</b>	<b>0</b>	<b>12</b>	<b>0</b>	<b>24</b>	<b>165</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>154</b>	<b>20</b>	<b>387</b>			
Peak Hour: 4:30 PM to 5:30 PM																				
<b>Total</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>12</b>	<b>0</b>	<b>12</b>	<b>0</b>	<b>24</b>	<b>165</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>154</b>	<b>20</b>	<b>387</b>			
<b>Approach</b>	0				24				189				174				387			
<b>%HV</b>	n/a				n/a				n/a				0.6%				0.3%			
<b>PHF</b>	0.90																			







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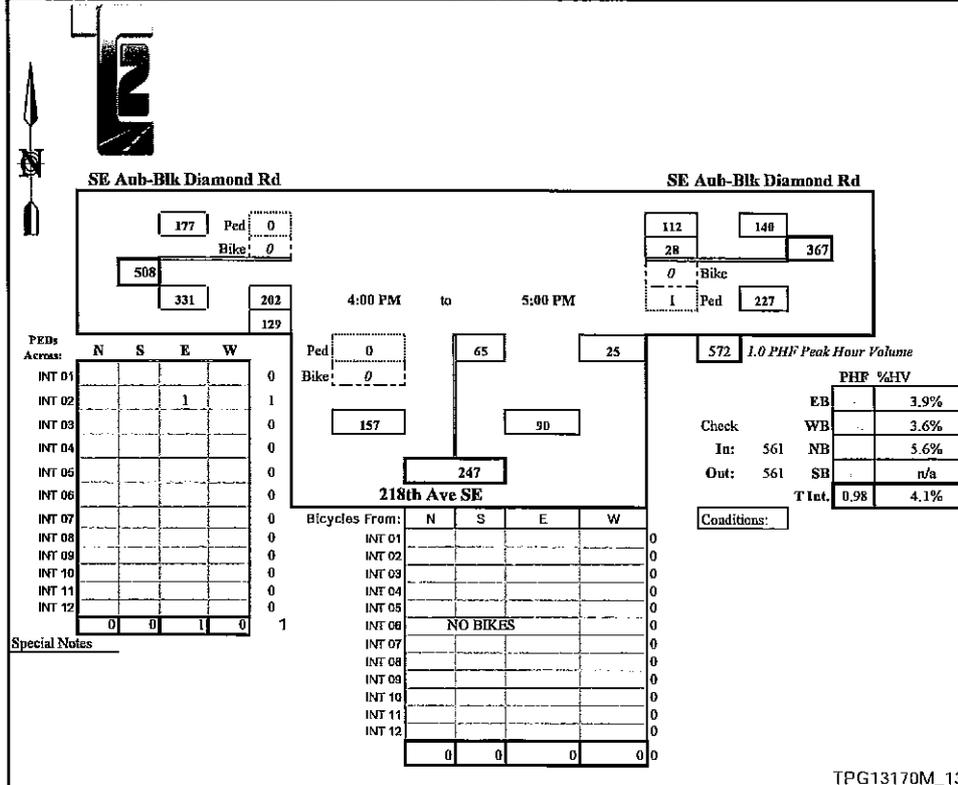
WBE/DBE

Intersection: 218th Ave SE & SE Anburn-Black Diamond Rd  
 Location: Black Diamond, Washington

Date of Count: Thurs 11/14/2013  
 Checked By: Jess

Time Interval Ending at	From North on (SB)				From South on (NB)				From East on (WB)				From West on (EB)				Interval Total
	T	L	S	R	T	L	S	R	T	L	S	R	T	L	S	R	
4:15 P	0	0	0	0	1	13	0	6	1	11	28	0	2	0	42	33	133
4:30 P	0	0	0	0	2	18	0	2	0	7	23	0	2	0	59	34	143
4:45 P	0	0	0	0	0	37	0	8	2	7	33	0	3	0	46	31	142
5:00 P	0	0	0	0	2	17	0	9	2	3	28	0	6	0	55	31	143
5:15 P	0	0	0	0	2	15	0	4	0	4	22	0	3	0	46	35	126
5:30 P	0	0	0	0	2	20	0	10	1	12	16	0	2	0	45	37	140
5:45 P	0	0	0	0	0	15	0	11	1	4	27	0	3	0	47	29	133
6:00 P	0	0	0	0	0	7	0	4	0	9	12	0	6	0	51	31	114
6:15 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:30 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:45 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:00 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Total Survey	0	0	0	0	9	122	0	54	7	57	189	0	27	0	391	261	1074
Peak Hour: 4:00 PM to 5:00 PM																	
Total	0	0	0	0	5	65	0	25	5	28	112	0	13	0	202	129	561
Approach	0				90				140				331				561
%HV	n/a				5.6%				3.6%				3.9%				4.1%
PHF																	0.98







Prepared for: **Transpo Group**  
**Traffic Count Consultants, Inc.**

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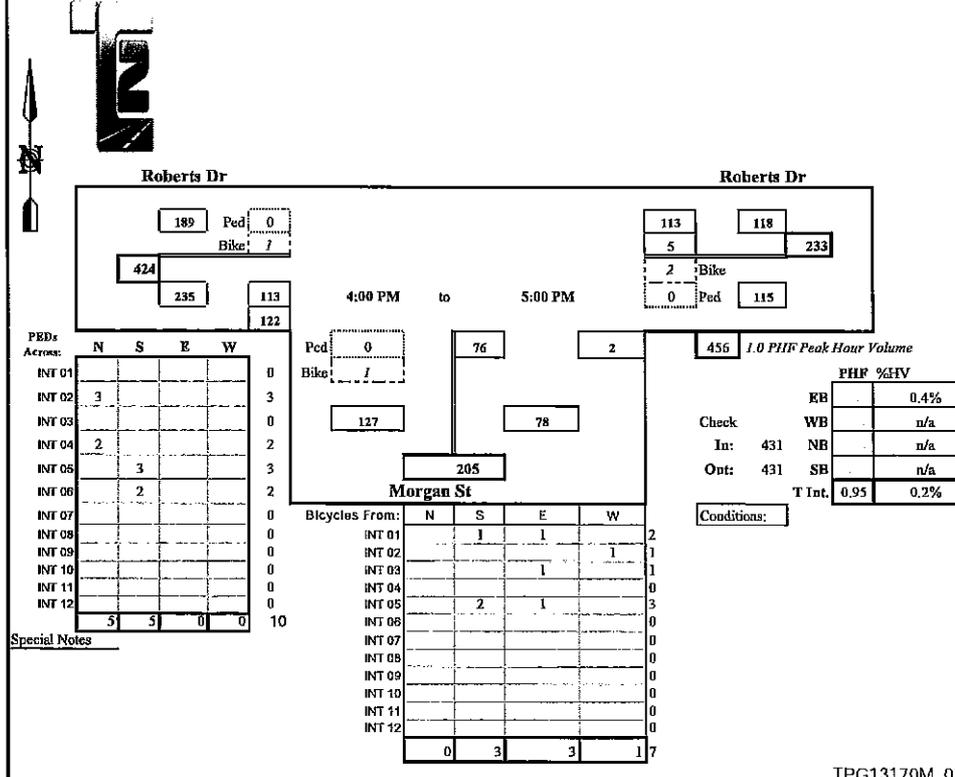
WBE/DBB

Intersection: Morgan St & Roberts Dr  
 Location: Black Diamond, Washington

Date of Count: Wed 11/13/2013  
 Checked By: Jess

Time Interval	From North on (SB)				From South on (NB)				From East on (WB)				From West on (EB)				Interval Total
	T	L	S	R	T	L	S	R	T	L	S	R	T	L	S	R	
4:15 P	0	0	0	0	0	19	0	1	0	3	21	0	0	0	33	37	114
4:30 P	0	0	0	0	0	22	0	0	0	0	33	0	0	0	24	31	110
4:45 P	0	0	0	0	0	15	0	1	0	1	25	0	0	0	27	34	103
5:00 P	0	0	0	0	0	20	0	0	0	1	34	0	1	0	29	20	104
5:15 P	0	0	0	0	0	13	0	1	0	2	45	0	0	0	25	22	108
5:30 P	0	0	0	0	0	18	0	0	0	3	17	0	1	0	17	29	84
5:45 P	0	0	0	0	0	14	0	2	0	2	25	0	0	0	31	39	113
6:00 P	0	0	0	0	0	13	0	0	0	2	32	0	1	0	26	30	103
6:15 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:30 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:45 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:00 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

<b>Total Survey</b>	0	0	0	0	0	134	0	5	0	14	232	0	3	0	212	242	839
Peak Hour: 4:00 PM to 5:00 PM																	
<b>Total</b>	0	0	0	0	0	76	0	2	0	5	113	0	1	0	113	122	431
<b>Approach</b>	0				78				118				235				431
<b>%HV</b>	n/a				n/a				n/a				0.4%				0.2%
<b>PHF</b>	0.95																





Prepared for: **Transpo Group**  
**Traffic Count Consultants, Inc.**

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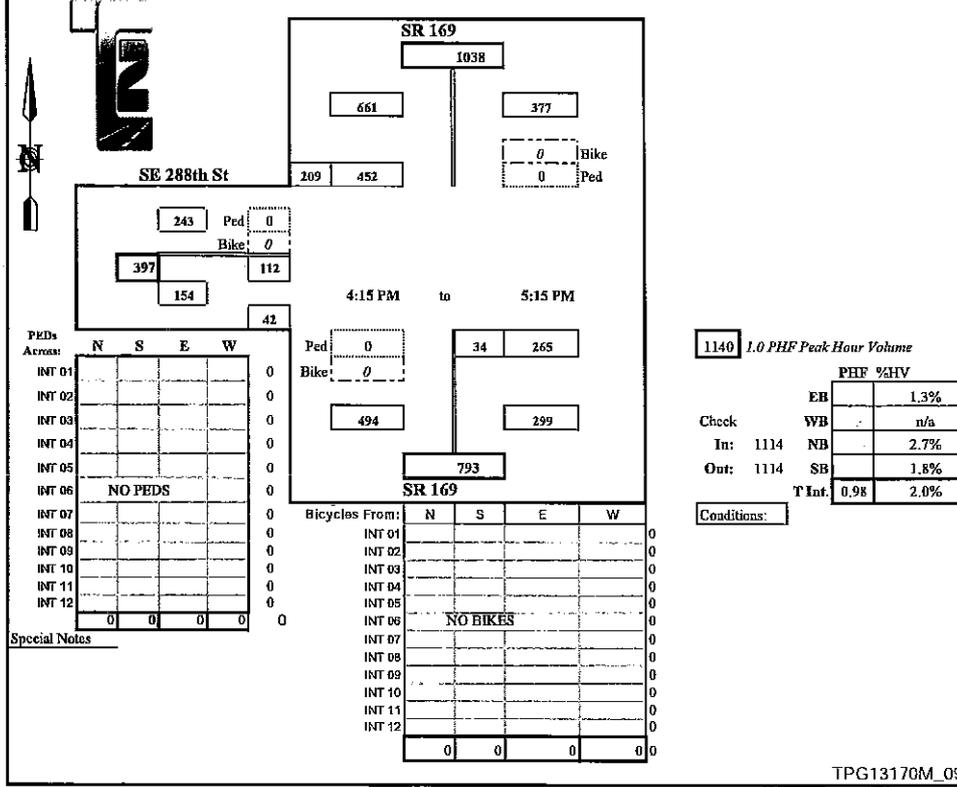
WB/DBE

Intersection: SR 169 & SE 288th St  
 Location: Black Diamond, Washington

Date of Count: Thurs 11/14/2013  
 Checked By: Jess

Time Interval Ending at	From North on (SB) SR 169				From South on (NB) SR 169				From East on (WB) 0				From West on (EB) SE 288th St				Interval Total
	T	L	S	R	T	L	S	R	T	L	S	R	T	L	S	R	
4:15 P	5	0	76	38	2	5	47	0	0	0	0	0	1	19	0	6	191
4:30 P	7	0	126	64	3	5	58	0	0	0	0	0	1	29	0	3	285
4:45 P	2	0	106	48	3	7	77	0	0	0	0	0	1	27	0	17	282
5:00 P	0	0	100	49	1	11	63	0	0	0	0	0	0	33	0	10	266
5:15 P	3	0	120	48	1	11	67	0	0	0	0	0	0	23	0	12	281
5:30 P	3	0	98	60	0	7	60	0	0	0	0	0	0	40	0	11	276
5:45 P	3	0	122	49	1	4	57	0	0	0	0	0	0	33	0	9	274
6:00 P	2	0	100	40	0	7	50	0	0	0	0	0	1	22	0	11	230
6:15 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:30 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:45 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:00 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Total Survey	25	0	848	396	11	57	479	0	0	0	0	0	0	4	226	0	79	2085
Peak Hour: 4:15 PM to 5:15 PM																		
Total	12	0	452	209	8	34	265	0	0	0	0	0	0	2	112	0	42	1114
Approach	661				299				0				154				1114	
%HV	1.8%				2.7%				n/a				1.3%				2.0%	
PHF																	0.98	





Prepared for: **Transpo Group**  
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WBE/DBE

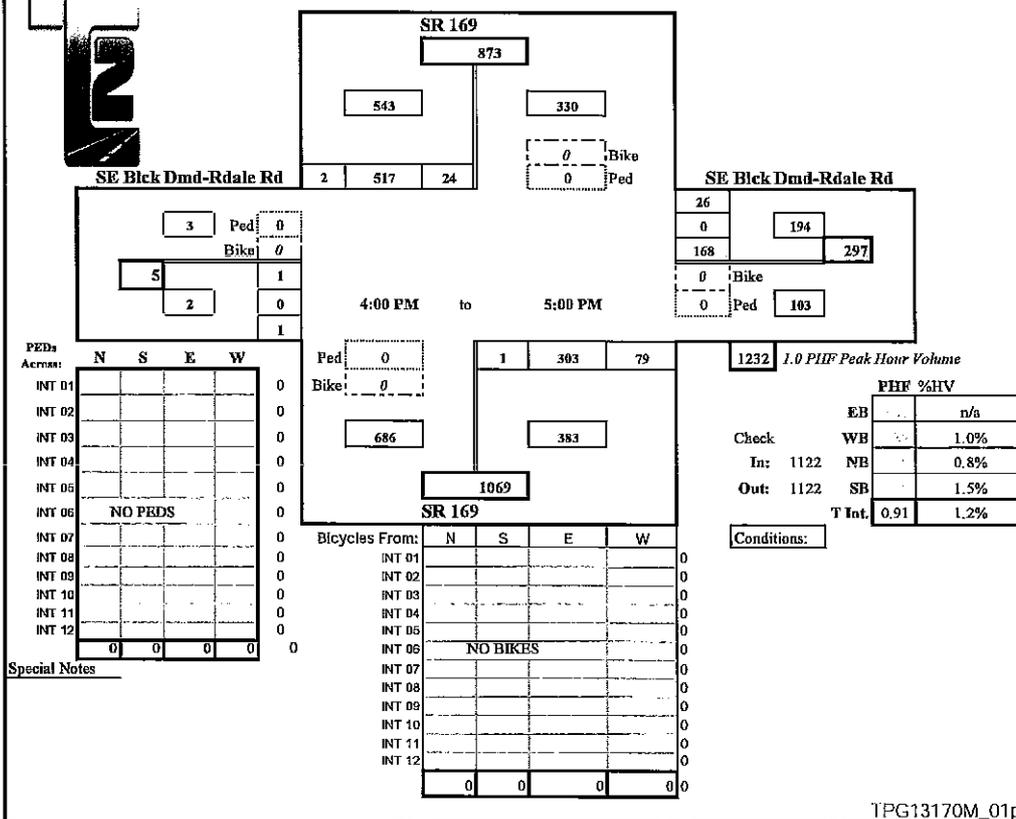
Intersection: SR 169 & SE Black Diamond-Ravensdale Rd  
 Location: Black Diamond, Washington

Date of Count: Wed 11/13/2013  
 Checked By: Jess

Time Interval	From North on (SB) SR 169				From South on (NB) SR 169				From East on (WB) SE Blck Dmd-Rdale Rd				From West on (EB) SE Blck Dmd-Rdale Rd				Interval Total
	T	L	S	R	T	L	S	R	T	L	S	R	T	L	S	R	
4:15 P	3	8	142	1	1	0	77	21	1	37	0	2	0	0	0	0	288
4:30 P	1	4	138	0	1	1	96	14	0	49	0	6	0	0	0	0	308
4:45 P	1	5	113	1	0	0	63	21	0	33	0	8	0	1	0	1	246
5:00 P	3	7	124	0	1	0	67	23	1	49	0	10	0	0	0	0	280
5:15 P	1	13	124	0	0	0	62	18	1	48	0	8	0	2	0	1	276
5:30 P	1	5	129	1	1	0	62	18	0	36	0	8	0	0	0	0	259
5:45 P	3	14	105	0	1	0	74	12	1	45	0	9	0	0	0	0	259
6:00 P	1	5	117	0	1	0	56	12	0	47	0	9	0	0	0	0	246
6:15 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:30 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:45 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:00 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Total Survey	14	61	992	3	6	1	557	139	4	344	0	60	0	3	0	2	2162
Peak Hour: 4:00 PM to 5:00 PM																	

Total	8	24	517	2	3	1	303	79	2	168	0	26	0	1	0	1	1122
Approach	543				383				194				2				1122
%HV	1.5%				0.8%				1.0%				n/a				1.2%
PHF																	0.91





Prepared for: **Transpo Group**  
**Traffic Count Consultants, Inc.**

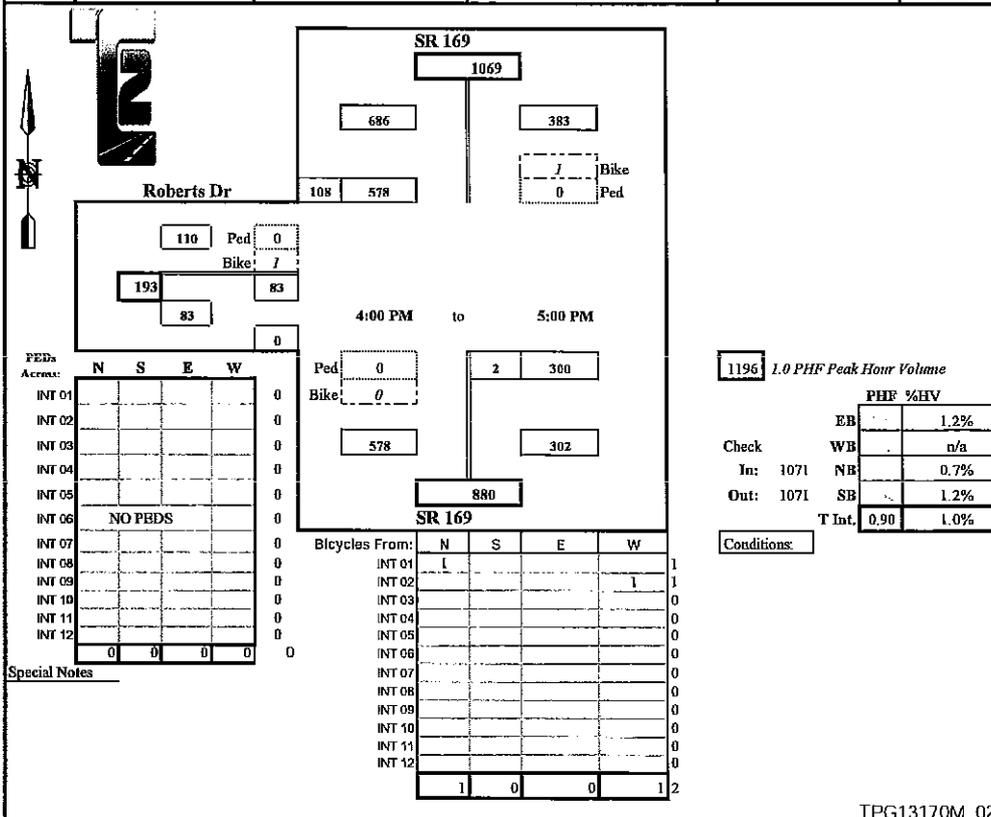
Phone: (253) 926-6009 FAX: (253) 922-7211 E-Mail: Team@TC2inc.com

WBE/DBE

Intersection: SR 169 & Roberts Dr  
 Location: Black Diamond, Washington

Date of Count: Wed 11/13/2013  
 Checked By: Jess

Time Interval Ending at	From North on (SB) SR 169				From South on (NB) SR 169				From East on (WB) 0				From West on (EB) Roberts Dr				Interval Total
	T	L	S	R	T	L	S	R	T	L	S	R	T	L	S	R	
4:15 P	4	0	133	27	1	0	75	0	0	0	0	0	1	23	0	0	278
4:30 P	0	0	157	30	1	1	89	0	0	0	0	0	0	22	0	0	299
4:45 P	1	0	127	20	0	0	69	0	0	0	0	0	15	0	0	231	
5:00 P	3	0	141	31	0	1	67	0	0	0	0	0	23	0	0	263	
5:15 P	2	0	134	38	0	0	59	0	0	0	0	0	22	0	0	253	
5:30 P	1	0	144	21	1	0	71	0	0	0	0	0	9	0	0	245	
5:45 P	3	0	122	28	1	0	60	0	0	0	0	0	27	0	0	237	
6:00 P	1	0	135	29	1	0	44	0	0	0	0	1	23	0	0	231	
6:15 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
6:30 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
6:45 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
7:00 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<b>Total Survey</b>	<b>15</b>	<b>0</b>	<b>1113</b>	<b>224</b>	<b>5</b>	<b>2</b>	<b>534</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>2</b>	<b>164</b>	<b>0</b>	<b>0</b>	<b>2037</b>
Peak Hour: 4:00 PM to 5:00 PM																	
<b>Total</b>	<b>8</b>	<b>0</b>	<b>578</b>	<b>108</b>	<b>2</b>	<b>2</b>	<b>300</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>83</b>	<b>0</b>	<b>0</b>	<b>1071</b>
<b>Approach</b>	686				302				0				83				1071
<b>%HV</b>	1.2%				0.7%				n/a				1.2%				1.0%
<b>PHF</b>	0.90																





Prepared for: **Transpo Group**  
**Traffic Count Consultants, Inc.**

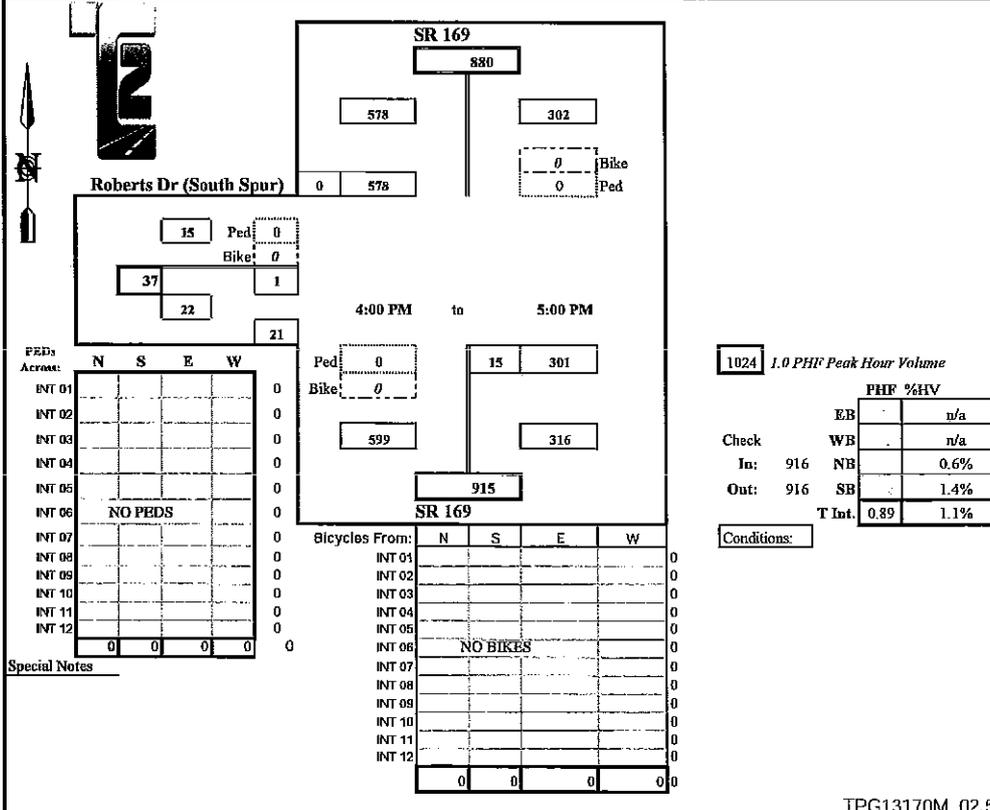
Phone: (253) 926-6009 FAX: (253) 922-7211 E-Mail: Team@TC2inc.com

WBE/DBE

Intersection: SR 169 & Roberts Dr (South Spur)  
 Location: Black Diamond, Washington

Date of Count: Wed 11/13/2013  
 Checked By: Jess

Time Interval Ending at	From North on (SB) SR 169				From South on (NB) SR 169				From East on (WB) 0				From West on (EB) Roberts Dr (South Spur)				Interval Total
	T	L	S	R	T	L	S	R	T	L	S	R	T	L	S	R	
4:15 P	4	0	153	0	1	5	75	0	0	0	0	0	0	0	0	5	238
4:30 P	0	0	157	0	1	3	90	0	0	0	0	0	0	0	0	6	256
4:45 P	1	0	127	0	0	3	69	0	0	0	0	0	0	0	7	206	
5:00 P	3	0	141	0	0	4	67	0	0	0	0	0	0	1	0	3	216
5:15 P	2	0	134	0	0	4	59	0	0	0	0	0	0	0	0	6	203
5:30 P	1	0	144	0	1	1	71	0	0	0	0	0	0	0	0	7	223
5:45 P	3	0	122	0	1	3	59	0	0	0	0	0	0	1	0	4	189
6:00 P	1	0	135	0	1	4	44	0	0	0	0	0	0	0	0	0	183
6:15 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:30 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:45 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:00 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>Total Survey</b>	15	0	1113	0	5	27	534	0	0	0	0	0	0	2	0	38	1714
Peak Hour: 4:00 PM to 5:00 PM																	
<b>Total</b>	8	0	578	0	2	15	301	0	0	0	0	0	0	1	0	21	916
<b>Approach</b>	578				316				0				22				916
<b>%HV</b>	1.4%				0.6%				n/a				n/a				1.1%
<b>PHF</b>	0.89																





Prepared for: **Transpo Group**  
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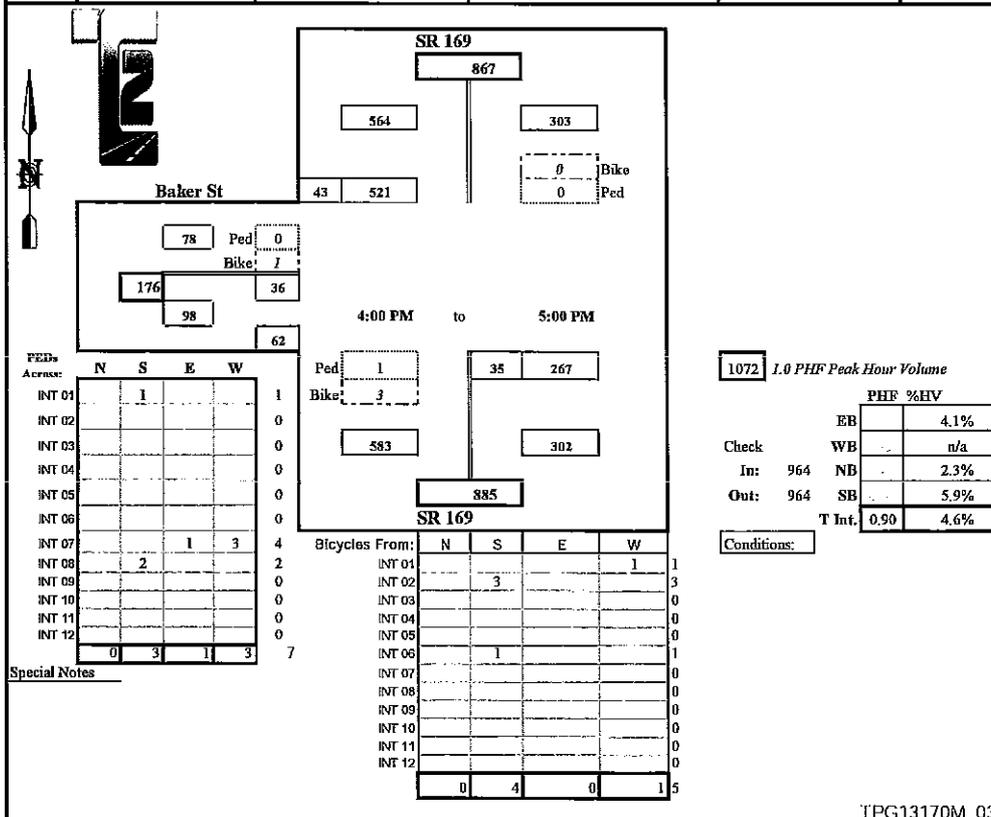
Phone: (253) 926-8009 FAX: (253) 922-7211 E-Mail: Team@TC2inc.com

WBE/DBE

Intersection: SR 169 & Baker St  
 Location: Black Diamond, Washington

Date of Count: Wed 11/13/2013  
 Checked By: Jess

Time Interval Ending at	From North on (SB) SR 169				From South on (NB) SR 169				From East on (WB) 0				From West on (EB) Baker St				Interval Total
	T	L	S	R	T	L	S	R	T	L	S	R	T	L	S	R	
4:15 P	10	0	139	12	4	9	79	0	0	0	0	0	0	12	0	17	268
4:30 P	10	0	133	15	2	6	69	0	0	0	0	0	2	9	0	22	254
4:45 P	7	0	114	9	0	9	63	0	0	0	0	0	6	0	10	211	
5:00 P	6	0	135	7	1	11	56	0	0	0	0	0	2	9	0	13	231
5:15 P	10	0	124	10	0	5	55	0	0	0	0	0	5	0	15	214	
5:30 P	8	0	129	6	2	13	60	0	0	0	0	0	1	4	0	14	226
5:45 P	7	0	113	10	1	4	50	0	0	0	0	0	1	10	0	22	209
6:00 P	4	0	115	13	1	4	42	0	0	0	0	0	4	0	13	191	
6:15 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:30 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:45 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:00 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>Total Survey</b>	62	0	1002	82	11	61	474	0	0	0	0	0	6	59	0	126	1804
Peak Hour: 4:00 PM to 5:00 PM																	
<b>Total</b>	33	0	521	43	7	35	267	0	0	0	0	0	4	36	0	62	964
<b>Approach</b>	564				302				0				98				964
<b>%HV</b>	5.9%				2.3%				n/a				4.1%				4.6%
<b>PHF</b>	0.90																





Prepared for: **Transpo Group**  
**Traffic Count Consultants, Inc.**

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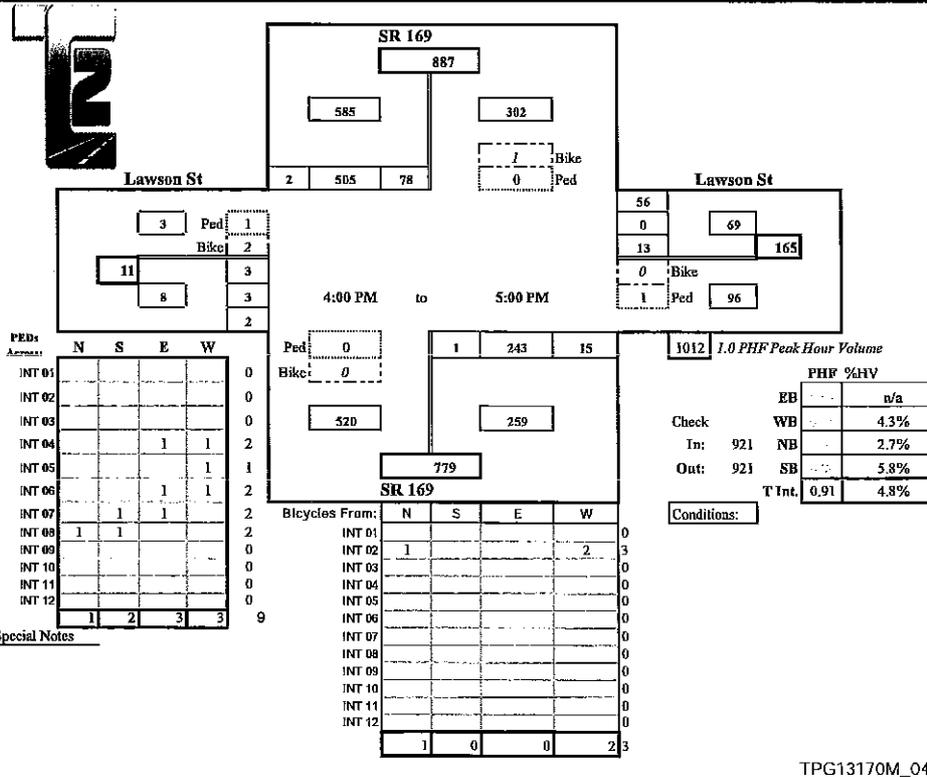
WBR/DBE

Intersection: SR 169 & Lawson St  
 Location: Black Diamond, Washington

Date of Count: Wed 11/13/2013  
 Checked By: Jess

Time Interval Ending at	From North on (SB) SR 169				From South on (NB) SR 169				From East on (WB) Lawson St				From West on (EB) Lawson St				Interval Total
	T	L	S	R	T	L	S	R	T	L	S	R	T	L	S	R	
4:15 P	11	24	130	1	4	0	70	8	2	3	0	15	0	1	1	0	253
4:30 P	11	21	132	1	2	0	63	3	0	4	0	12	0	1	0	1	238
4:45 P	5	15	113	0	0	0	57	2	0	2	0	15	0	1	0	0	205
5:00 P	7	18	130	0	1	1	53	2	1	4	0	14	0	0	2	1	225
5:15 P	10	22	122	1	0	0	50	6	0	6	2	12	0	0	1	0	222
5:30 P	7	28	116	1	3	1	58	5	0	7	0	13	0	0	0	0	229
5:45 P	6	29	110	0	1	0	46	4	1	4	2	11	0	0	0	0	206
6:00 P	3	14	112	0	3	0	34	2	1	4	1	12	0	0	0	0	179
6:15 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:30 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:45 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:00 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Total Survcy	60	171	965	4	14	2	431	32	5	34	5	104	0	3	4	2	1737
Peak Hour: 4:00 PM to 5:00 PM																	
Total	34	78	505	2	7	1	243	15	3	13	0	56	0	3	3	2	921
Approach	585			259			69			8			921				
%HV	5.6%			2.7%			4.3%			n/a			4.8%				
PHF													0.91				





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**Traffic Count Consultants, Inc.**

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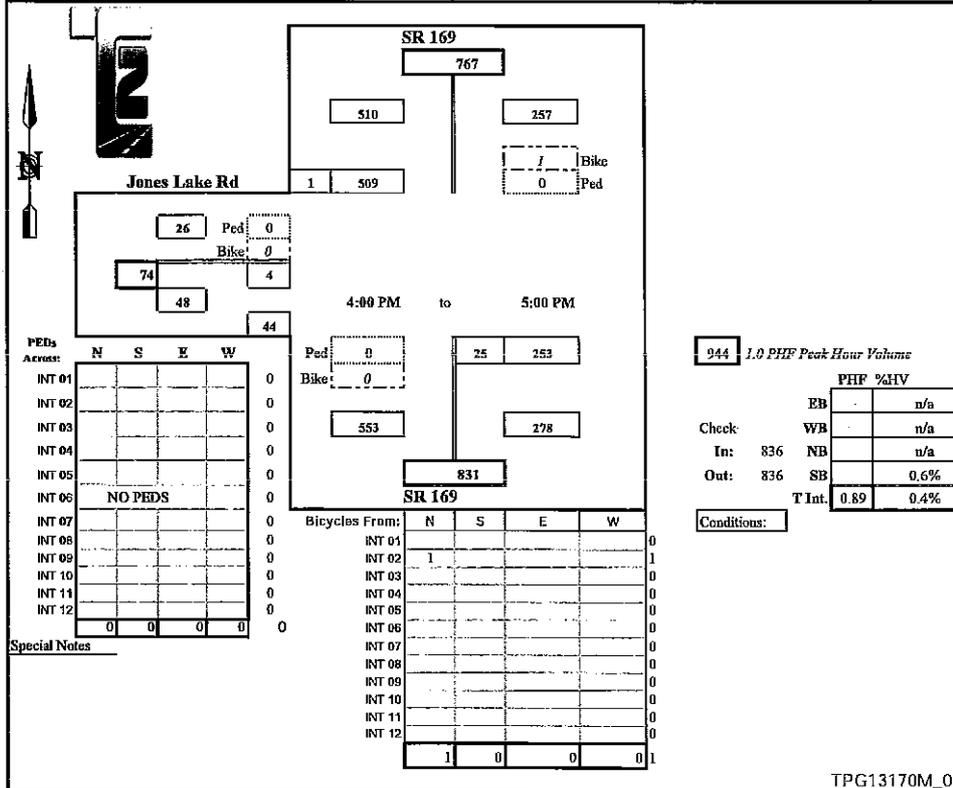
WBEDBE

Intersection: SR 169 & Jones Lake Rd  
 Location: Black Diamond, Washington

Date of Count: Wed 11/13/2013  
 Checked By: Jess

Time Interval	From North on (SB) SR 169				From South on (NB) SR 169				From East on (WB) 0				From West on (EB) Jones Lake Rd				Interval Total
	T	L	S	R	T	L	S	R	T	L	S	R	T	L	S	R	
4:15 P	1	0	133	0	0	9	79	0	0	0	0	0	0	2	0	13	236
4:30 P	1	0	132	1	0	6	63	0	0	0	0	0	1	0	13	216	
4:45 P	0	0	114	0	0	2	60	0	0	0	0	0	1	0	15	192	
5:00 P	1	0	130	0	0	8	51	0	0	0	0	0	0	0	3	192	
5:15 P	1	0	126	0	0	8	58	0	0	0	0	0	1	0	6	199	
5:30 P	0	0	118	1	0	9	74	0	0	0	0	0	0	0	18	220	
5:45 P	2	0	110	0	0	10	44	0	0	0	0	0	1	1	15	180	
6:00 P	0	0	118	0	0	2	32	0	0	0	0	0	0	0	13	165	
6:15 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
6:30 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
6:45 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
7:00 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Total Survey	6	0	981	2	0	54	461	0	0	0	0	0	1	6	0	96	1600
Peak Hour: 4:00 PM to 5:00 PM																	
Total	3	0	509	1	0	25	253	0	0	0	0	0	0	4	0	44	836
Approach	510				278				0				48				836
%HV	0.6%				n/a				n/a				n/a				0.4%
PHF	0.89																





Prepared for: **Transpo Group**  
**Traffic Count Consultants, Inc.**

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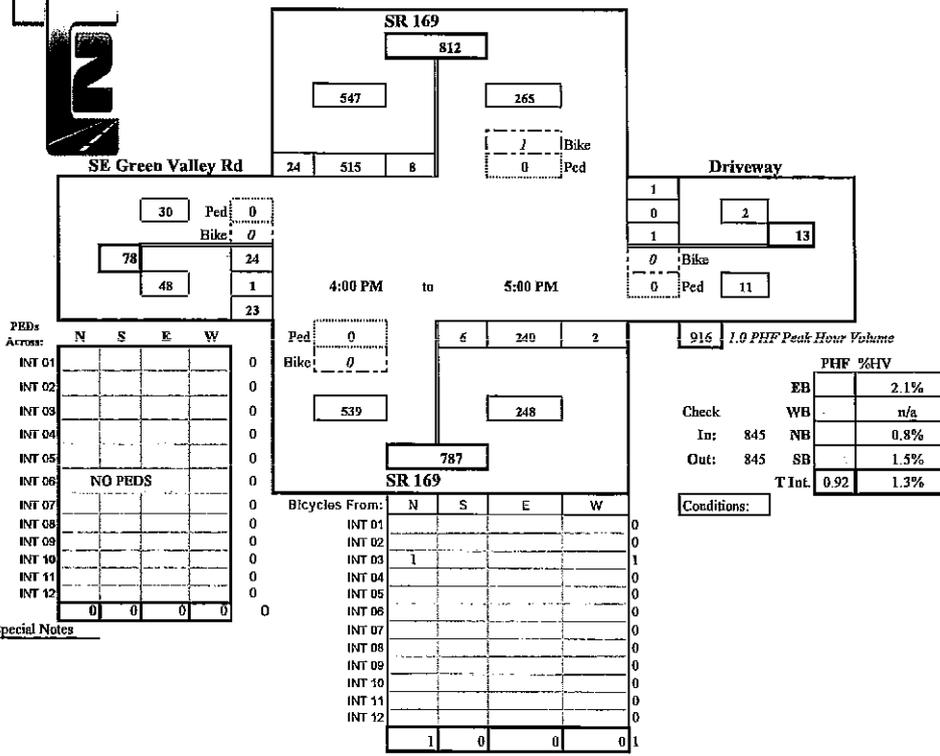
WB/DBB

Intersection: SR 169 & SE Green Valley Rd  
 Location: Black Diamond, Washington

Date of Count: Wed 11/13/2013  
 Checked By: Jess

Time Interval	From North on (SB) SR 169				From South on (NB) SR 169				From East on (WB) Driveway				From West on (EB) SE Green Valley Rd				Interval Total
	T	L	S	R	T	L	S	R	T	L	S	R	T	L	S	R	
4:15 P	5	1	136	9	0	1	63	1	0	0	0	0	1	8	0	4	223
4:30 P	2	5	138	3	1	1	65	1	0	0	0	0	0	9	1	6	229
4:45 P	0	0	113	6	0	4	57	0	0	0	0	0	0	5	0	7	192
5:00 P	1	2	128	6	1	0	55	0	0	1	0	1	0	2	0	6	201
5:15 P	2	0	129	1	0	3	63	2	0	0	0	0	0	3	0	2	203
5:30 P	0	1	125	9	0	1	72	0	0	1	0	1	0	5	1	4	220
5:45 P	4	2	116	4	0	2	40	2	0	0	0	1	0	7	0	1	175
6:00 P	0	4	120	2	2	1	28	4	0	0	0	0	0	4	0	1	164
6:15 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:30 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:45 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:00 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Total Survey	14	15	1005	40	4	13	443	10	0	2	0	3	1	43	2	31	1607
Peak Hour: 4:00 PM to 5:00 PM																	
Total	8	8	515	24	2	6	240	2	0	1	0	1	1	24	1	23	845
Approach	547				248				2				48				845
%HV	1.5%				0.8%				n/a				2.1%				1.3%
PHF	0.92																





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**Traffic Count Consultants, Inc.**

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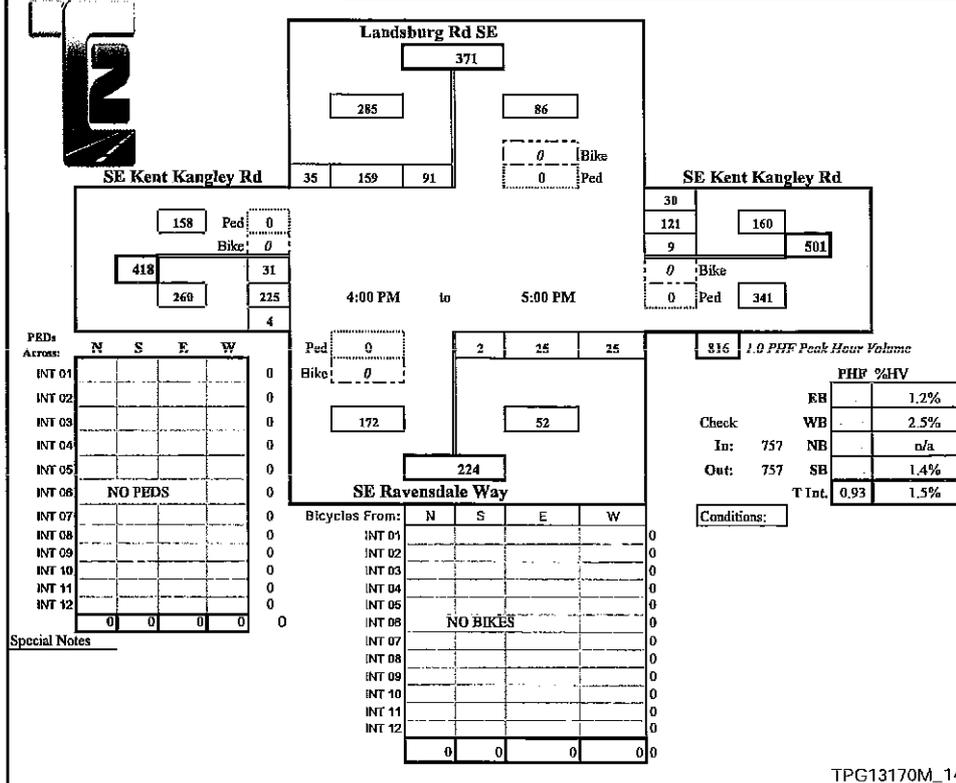
WBE/DBB

Intersection: Landsburg Rd SE/SE Ravensdale Way & SE Kent Kangley Rd  
 Location: Black Diamond, Washington

Date of Count: Thurs 11/14/2013  
 Checked By: Jess

Time Interval	From North on (SB) Landsburg Rd SE				From South on (NB) SE Ravensdale Way				From East on (WB) SE Kent Kangley Rd				From West on (EB) SE Kent Kangley Rd				Interval Total
	T	L	S	R	T	L	S	R	T	L	S	R	T	L	S	R	
4:15 P	2	24	43	10	0	1	7	8	0	2	31	11	2	6	45	0	188
4:30 P	1	28	36	5	0	0	5	3	2	3	40	6	0	9	69	0	204
4:45 P	1	19	46	5	0	0	8	10	1	2	27	6	0	6	48	1	178
5:00 P	0	20	34	15	0	1	5	4	1	2	23	7	1	10	63	3	187
5:15 P	4	26	43	8	0	2	3	3	0	6	24	3	0	7	49	0	174
5:30 P	0	12	39	17	0	0	8	5	1	1	24	7	0	9	58	1	181
5:45 P	1	30	34	7	0	0	6	0	0	3	26	5	0	7	45	0	163
6:00 P	0	18	44	10	0	0	7	3	0	1	29	4	2	12	28	0	156
6:15 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:30 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:45 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:00 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Total Survey	9	177	319	77	0	4	49	36	5	20	224	49	5	66	405	5	1431
Peak Hour: 4:00 PM to 5:00 PM																	
Total	4	91	159	35	0	2	25	25	4	9	121	30	3	31	225	4	757
Approach	285				52				160				260				757
%HV	1.4%				n/a				2.5%				1.2%				1.5%
PHF																	0.93





Prepared for: **Transpo Group**  
**Traffic Count Consultants, Inc.**

Phone: (253) 926-6009 FAX: (253) 922-7211 E-Mail: Team@TC2inc.com

WBB/DBE

Intersection: SE Green Valley Rd & SE Auburn-Black Diamond Rd  
 Location: Black Diamond, Washington

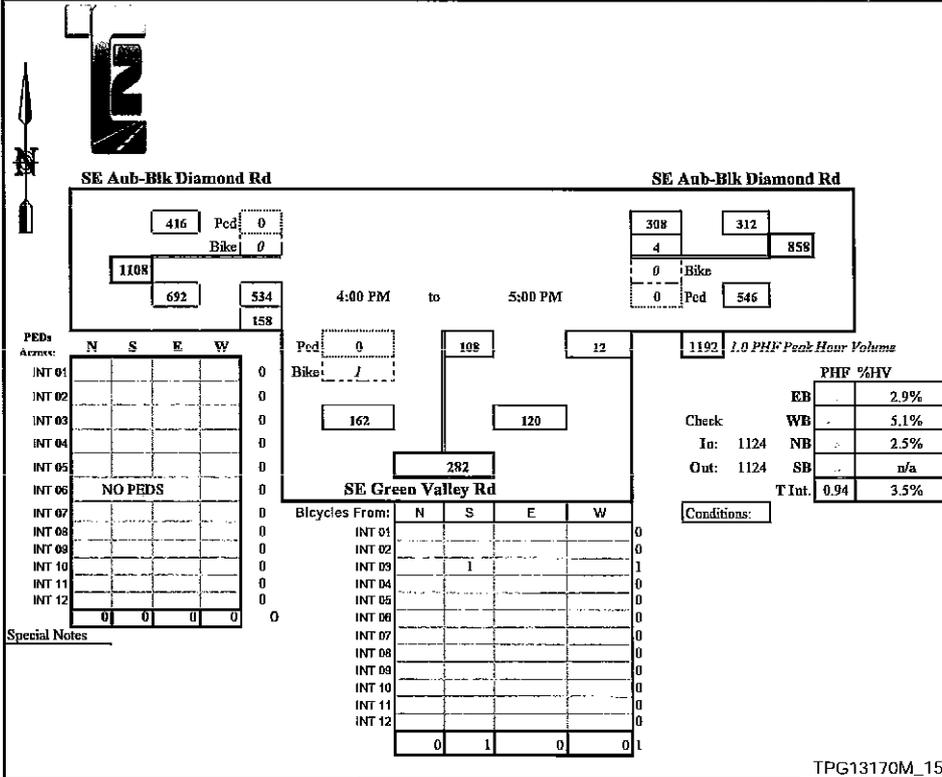
Date of Count: Thurs 11/14/2013  
 Checked By: Jess

Time Interval	From North on (SB)				From South on (NB)				From East on (WB)				From West on (EB)				Interval Total
	T	L	S	R	T	L	S	R	T	L	S	R	T	L	S	R	
4:15 P	0	0	0	0	0	29	0	3	3	0	78	0	4	0	129	36	275
4:30 P	0	0	0	0	1	32	0	3	6	2	84	0	7	0	137	40	298
4:45 P	0	0	0	0	0	23	0	1	4	1	68	0	6	0	147	35	275
5:00 P	0	0	0	0	2	24	0	3	5	3	78	0	3	0	121	47	276
5:15 P	0	0	0	0	0	17	0	2	0	0	67	0	4	0	148	41	275
5:30 P	0	0	0	0	5	15	0	1	1	0	69	0	3	0	138	47	270
5:45 P	0	0	0	0	0	10	0	1	0	0	53	0	4	0	154	41	259
6:00 P	0	0	0	0	1	12	0	1	3	0	53	0	4	0	128	38	232
6:15 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:30 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:45 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:00 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Total Survey	0	0	0	0	9	162	0	17	20	4	550	0	35	0	1102	325	2160
--------------	---	---	---	---	---	-----	---	----	----	---	-----	---	----	---	------	-----	------

Peak Hour: 4:00 PM to 5:00 PM

Total	0	0	0	0	3	108	0	12	16	4	308	0	20	0	534	158	1124
Approach	0				120				312				692				1124
%HV	n/a				2.5%				5.1%				2.9%				3.5%
PHF																	0.94





**NCHRP REPORT 599**

**Default Values for  
Highway Capacity and  
Level of Service Analyses**

**Transpo Group**

John D. Zegeer

Mark Vandehey

Miranda Blogg

Khang Nguyen

Michael Ereti

KITTELSON & ASSOCIATES, INC.

Fort Lauderdale, FL

*Subject Areas*

Planning and Administration

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Research sponsored by the American Association of State Highway and Transportation Officials  
in cooperation with the Federal Highway Administration

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WASHINGTON, D.C.

2008

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# CONTENTS

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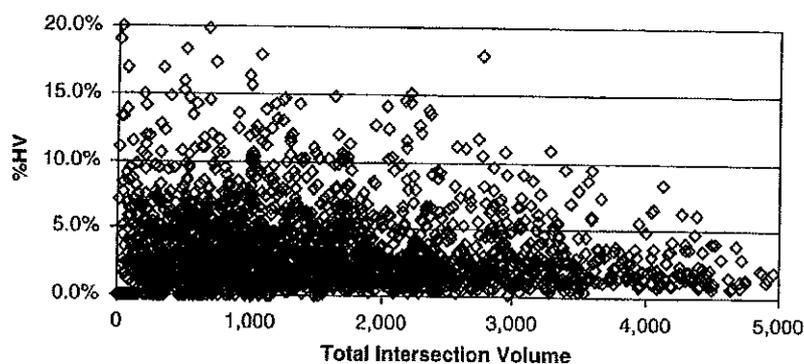


Figure 11. %HV as a function of total intersection volume.

### Recommended Default Values

The recommended %HV is 3%, which is slightly higher than the current HCM default of 2%. The user should be aware of the relationship with volume, period, and city size, as indicated in the analysis above. As volume decreases, the %HV tends to increase. The %HV is typically lower during the a.m. peak period than during the p.m. peak period, and the %HV increases with decreasing city size.

### PHFs for Interrupted Flow Facilities

The HCM defines PHF as “a measure of traffic demand fluctuation within the peak hour.” This can be computed by dividing the peak hourly volume by the peak 15-min flow rate within that peak hour. Because the existing definition in the HCM is general in nature, there are a number of different methods available to calculate PHFs at an intersection. Three popular methods are described as follows:

- Use the total entering volume to determine the peak 15-min interval and the peak hour. Subsequently, compute an overall intersection PHF. This approach yields the correct total volume during the peak 15-min time period, but may underestimate or overestimate the demands for the individual approaches and/or movements.
- Use the total approach volume to determine the peak 15-min interval and the peak hour. Subsequently, compute individual approach PHFs. Thus, a four-leg intersection would have four PHFs and a T-junction would have three PHFs. This approach, while used in practice (and perhaps encouraged by the HCM methodology), is fundamentally flawed in that it assumes that the individual approaches peak during the same time period, which rarely occurs. The result is a high likelihood of overestimating the total volume during the peak 15-min time period.
- Use the movement volume to determine the peak 15-min interval and the peak hour. Subsequently, compute individual movement PHFs. Thus, a four-leg intersection with left-through-right movements would have 12 PHFs. This approach is also fundamentally flawed in that it assumes that the individual movements peak during the same time period, which is extremely rare. The result is a very high likelihood of overestimating the total volume during the peak 15-min time period.

There are other variations of these methods. The total intersection volume method (the first method described above) is the only method that yields the correct total intersection flow rate. Calculating the approach or movement PHF assumes that each of the approaches or individual movements peak during the same time period, which is unlikely to occur.

## Data Sources

Seven sources of useable PHF data were obtained. The seven sources are the Delaware DOT; Wisconsin DOT, the City of Kennewick, Washington; the City of Los Angeles; VRPA Technologies, Inc.; Tucson, Arizona; and Quality Counts, Inc. All data for PHF estimation were based on actual traffic counts collected in 15-min intervals—mostly in 2005 and 2006. Further, most data are typical weekday counts (i.e., Tuesday, Wednesday, or Thursday) that were conducted during one or more of the peak periods.

- Delaware DOT and Wisconsin DOT data were provided in MS Excel and PDF formats and included a number of intersections in various counties. All intersections have 12-hr count data (6 a.m. to 6 p.m.) in 15-min intervals and comprise of a state highway intersecting another state highway or local street.
- The City of Kennewick, Washington, provided data in PDF format for over 100 intersections within the city limits. While the majority of the intersections were signalized intersections, there were also ten two-way stop-controlled and seven all-way stop-controlled intersections. Count data were available for 2 hr each for the a.m., p.m., and/or midday periods in 15-min intervals.
- The largest data set was provided by the Quality Counts (QC) database. The data were provided in both PDF and MS Excel formats. The data comprised over 2,000 intersection counts at signalized and unsignalized intersections in Arizona, Idaho, California, Florida, Maryland, Oregon, Utah, and Washington. Each observation represented counts conducted during the a.m., p.m., or midday periods. The counts are typically in 5-min or 15-min intervals.
- The Pima Association of Governments (PAG) in Tucson, Arizona, provided data in MS Excel format at 16 major signalized intersections. All data were collected in spring 2006. Each intersection data set included 2 hr of 15-min counts for the a.m., midday, and p.m. peak periods.
- VRPA Technologies, Inc., provided data at eight intersections in Fresno, California; 10 intersections in Riverside, California; and 15 intersections in San Diego, California. The data were provided in MS Excel format and included both a.m. and p.m. peak counts in 15-min intervals.

## Data Summary and Analysis

Figure 12 illustrates the frequency of the intersection PHF for signalized, two-way stop-controlled and all-way stop-controlled intersection types. The PHF mean, median, and mode of the data were found to be 0.89, 0.93, and 0.93 to 0.94, respectively. Removing the few outliers with PHF values of less than 0.70 resulted in a mean PHF of 0.90.

For planning purposes, the PHF for the major street volume was also calculated. As shown in Figure 13, the intersection PHF and major street PHF are heavily correlated. This could be helpful

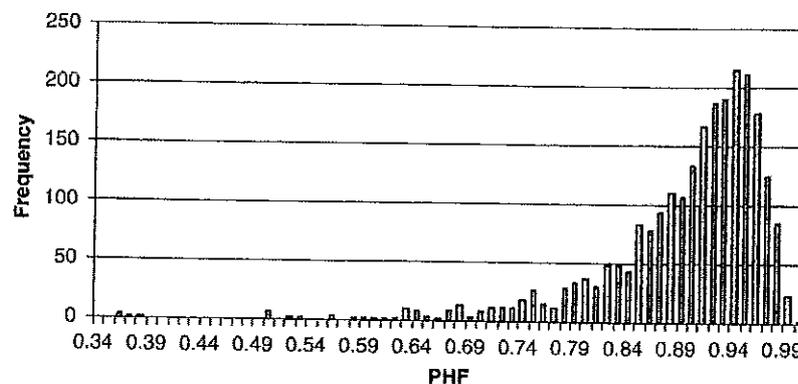
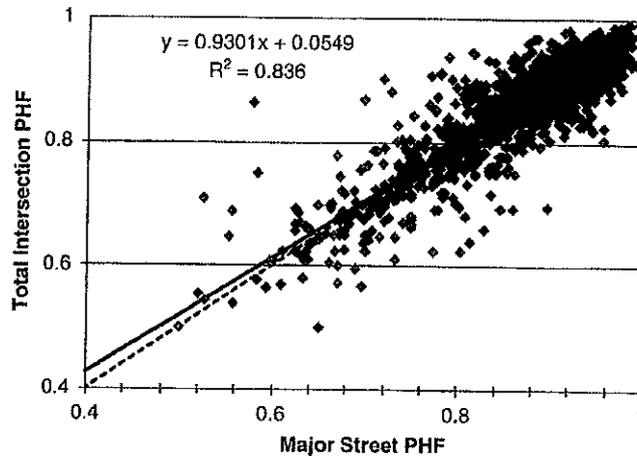


Figure 12. Frequency of intersection PHF.



**Figure 13. Intersection PHF as a function of major street PHF.**

in situations where the user only had PHF data for the major street (based on tube count data for example).

Table 19 provides a summary of the number of observations, mean intersection PHF, and median PHF as a function of a number of discrete independent variables, including region, city size, intersection control, peak period (time of day) and volume. As indicated in the table, 78% of the data is represented in the northwest region. There are few observations in the northeast and midwest. Fifty-four percent of the data is located in cities with greater than 1.5 million people. Approximately 60% of the PHF data occurs in the p.m. peak period.

As indicated in Table 19, with the exception of the total intersection volume and time of day, most of the variables do not indicate any trend in the mean or median.

Figure 14 illustrates the intersection PHF as a function of total intersection volume. At lower total volumes, there is more variation in the PHF. This variation results in larger mean PHF at lower volumes. The median also indicates a similar trend. The median was found to be 0.93. Based on the results of the analysis, the current HCM default value of 0.92 appears to be reasonable when the total entering volume is greater than 1,000 vehicles. A more-conservative PHF (below 0.90) is likely to occur when the total entering volume is less than 1,000 vehicles.

Figure 15 illustrates the weighted frequency of the PHF for the a.m. and p.m. peak periods. The a.m. peak period has a greater spread and a lower peak PHF than the p.m. peak period. The a.m. and p.m. peak periods have different types of trips which result in different peaking characteristics. The a.m. peak period primarily consists of commuter trips, while the p.m. peak period contains different types of trips including tourist, shopping, and school trips. Hence, the p.m. peak period traffic is more evenly spread over the hour, resulting in higher PHF.

## Recommended Default Values

Intersection PHF (rather than approach or movement PHF) has been used to determine the recommended PHF default value. The total intersection volume method is the only method that yields the correct total intersection volume. Approach or movement PHF assumes each of the approaches or individual movements peak during the same time period, which is unlikely to occur.

Based on the results of this analysis, the current HCM default value of 0.92 appears to be reasonable. The user should be aware of the relationship of PHF with volume and time of day. A

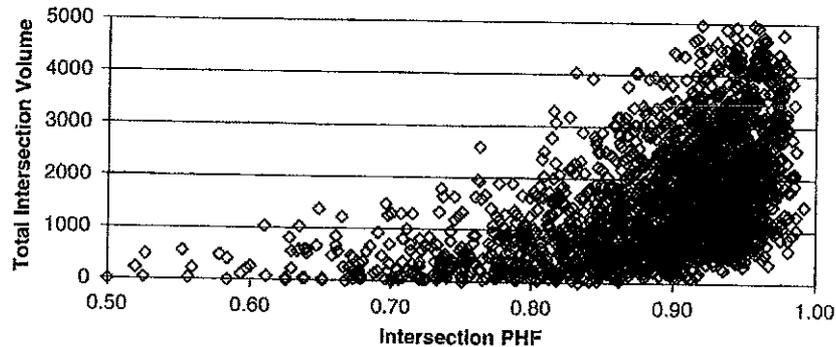
**Table 19. PHF by region, city, intersection type, time period and volume.**

Description	Number of Observations	Mean PHF	Median PHF
<b>REGION</b>			
Southwest	246	0.92	0.93
Southeast	226	0.91	0.92
Northwest	1949	0.88	0.90
Midwest	54	0.92	0.93
Northeast	28	0.89	0.90
<b>CITY SIZE</b>			
>1.5M	1340	0.89	0.91
250K-1.5M	334	0.90	0.92
50K-250K	269	0.89	0.90
<50K	550	0.88	0.90
<b>INTERSECTION CONTROL</b>			
AWSC	89	0.88	0.90
Signalized	1794	0.89	0.91
TWSC	618	0.87	0.89
<b>TIME PERIOD</b>			
AM	726	0.85	0.87
MID	232	0.92	0.94
PM	1362	0.90	0.92
TOTAL	2320		
<b>TOTAL INTERSECTION VOLUME</b>			
0-500	401	0.79	0.82
501-1000	498	0.87	0.89
1001-1500	452	0.90	0.91
1501-2000	338	0.91	0.92
2001-2500	259	0.92	0.93
>2500	559	0.93	0.94

AWSC: all-way stop-controlled  
 TWSC: two-way stop-controlled

more-conservative PHF (below 0.90) is likely to occur when the total entering volume is less than 1,000 vehicles. Similarly the a.m. peak period PHF is likely to be lower than the p.m. peak period PHF.

In most cases, the major street PHF correlates with the intersection PHF. As such, the major street PHF can be used directly as an estimate of the intersection PHF, when the side street volumes are not readily available for planning applications.



**Figure 14. Intersection PHF as a function of total intersection volume.**

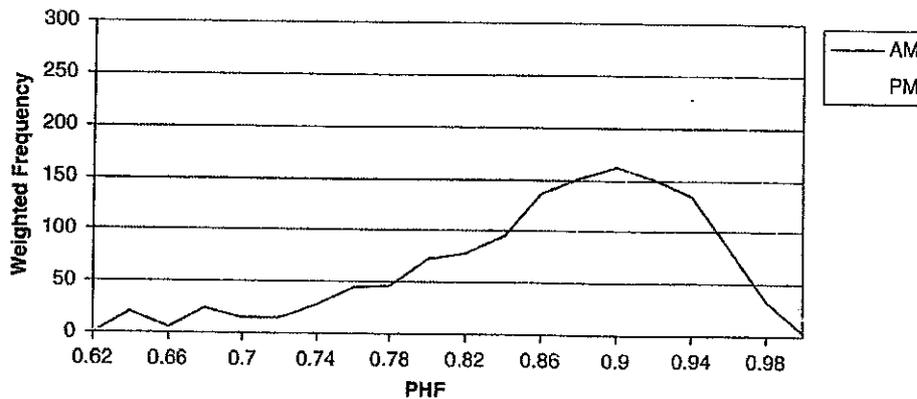


Figure 15. Intersection PHF as a function of time period.

### Base Saturation Flow Rates for Signalized Intersections

The HCM defines saturation flow rate as “the equivalent hourly rate at which previously queued vehicles can traverse an intersection approach under prevailing conditions, assuming that the green signal is available at all times and no lost times are experienced.” The saturation flow rate can be estimated or measured in the field using procedures in the HCM. This research focuses on field data collected in accordance with HCM guidelines.

#### Data Sources

Government agencies do not typically collect saturation flow rate data as they do for PHF and %HV. A few agencies do collect the data, but because the collection methods do not strictly adhere to the HCM guidelines, their data cannot be used. The sources available for this analysis included NCHRP Project 3-72 research; FDOT research; field measurements in Tucson, Arizona; five communities in Oregon (Woodburn, Salem, Milwaukie, Tigard, and Albany); and published papers reporting findings in Maryland, Indiana, Texas, and Nevada. The following is a brief description of each source:

- The NCHRP Project 3-72 research collected saturation flow rates at 15 intersections in various parts of the county to study the effect of lane width on saturation flow rate.
- The FDOT research collected saturation flow rates at 33 intersection approaches in Florida to estimate the statewide base saturation flow rate. The research found relationships between saturation flow rate and area population, posted speed limit, number of lanes, and traffic pressure, in addition to other factors reported in HCM 2000. The research established an equation to estimate the base saturation rate for Florida.
- The Tucson, Arizona, data included data collected at eight intersection approaches in Tucson, Arizona.
- The Oregon data included data collected at seven intersection approaches in small to medium-size communities.
- Research findings on saturation flow rates have been reported for local conditions in Maryland, Indiana, Texas, and Nevada. Since cycle by cycle data are not available from this published research, direct comparisons with the above data sources are not appropriate; however, average saturation flow rates and the number of headway observations reported were considered useable data.

As indicated in Table 20, because the total number of saturation flow rate observations is low, dividing the data into bins to evaluate either regional differences or population size differences is inappropriate. No data were available from the Northeast region.





# Trip Generation Handbook

Second Edition

An ITE Recommended Practice

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June 2004

Institute of Transportation Engineers

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# Multi-Use Development

## 7.1 Background

A basic premise behind the data presented in *Trip Generation* is that data were collected at single-use, free-standing sites. However, the development of mixed-use or multi-use sites is increasingly popular. While the trip generation rates for individual uses on such sites may be the same or similar to what they are for free-standing sites, there is potential for interaction among those uses within the multi-use site, particularly where the trip can be made by walking. As a result, the total generation of vehicle trips entering and exiting the multi-use site may be reduced from simply a sum of the individual, discrete trips generated by each land use.

A common example of this internal trip-making occurs at a multi-use development containing offices and a shopping/service area. Some of the trips made by office workers to shops, restaurants, or banks may occur on site. These types of trips are defined as internal to (i.e., "captured" within) the multi-use site.

## 7.2 What Is a Multi-Use Development?

For purposes of this handbook, a *multi-use development is typically a single real-estate project that consists of two or more ITE land use classifications between which trips can be made without using the off-site road system*. Because of the nature of these land uses, the

trip-making characteristics are interrelated, and some trips are made among the on-site uses. This capture of trips internal to the site has the net effect of reducing vehicle trip generation between the overall development site and the external street system (compared to the total number of trips generated by comparable, stand-alone sites).

Multi-use developments are commonly found *ranging in size from 100,000 sq. ft. to 2 million sq. ft.*

The data presented in this chapter correspond to multi-use developments in this size range. The recommended procedures for estimating trip generation at multi-use developments are likely applicable at even larger sites, but the analyst is encouraged to collect additional data.

A key characteristic of a multi-use development is that trips among the various land uses can be made on site and these *internal trips are not made on the major street system*. In some multi-use developments, these internal trips can be made either by walking or by vehicles using internal roadways without using external streets.

An *internal capture rate* can generally be defined as a percentage reduction that can be applied to the trip generation estimates for individual land uses to account for trips internal to the site. It is important to note that these reductions are applied externally to the site (i.e., at entrances, adjacent intersections

---

### Multi-Use Development

- ◆ Typically planned as a single real-estate project,
- ◆ Typically between 100,000 and 2 million sq. ft. in size,
- ◆ Contains two or more land uses,
- ◆ Some trips are between on-site land uses, and
- ◆ Trips between land uses do not travel on major street system.

### Not a(n)

- ◆ Central business district,
  - ◆ Suburban activity center, or
  - ◆ Existing ITE land use classification with potential for a mix of land uses, such as
    - Shopping center,
    - Office park with retail,
    - Office building with retail, or
    - Hotel with limited retail and restaurant space.
- 

and adjacent roadways). The trip reduction for internally captured trips is separate from the reduction for *pass-by trips*. These are two distinct phenomena and both could be applicable for a proposed development. The internal trips, if present, should be subtracted out *before* pass-by trip reductions are applied (refer to Chapter 5 for a complete discussion of pass-by trip estimation).

### 7.3 What Is Not a Multi-Use Development?

In literal terms, a multi-use development could mean any combination of different land use types within a defined, congruous area. But that definition would encompass a wide range of potential applications, many of which are not intended to be the focus of this chapter.

A traditional downtown or central business district (CBD) is not considered a multi-use development for purposes of this handbook. Downtown areas typically have a mixture of diverse employment, retail, residential, commercial, recreation and hotel uses. Extensive pedestrian interaction occurs because of the scale of the downtown area, ease of access and proximity of the various uses. Automobile occupancy, particularly during peak commuting hours, is usually higher in the CBD than in outlying areas. Some downtowns have excellent transit service. For these reasons, trip generation characteristics in a downtown environment are different from those found in outlying or suburban areas. The focus of the data presented throughout *Trip Generation* is on sites in suburban settings with limited or no transit service and free parking. *Accordingly, trip generation characteristics in this chapter, and specifically in the case of capture rates at multi-use developments, are directly applicable only to sites outside the traditional downtown.* The potential effects of transit service and on-site parking fees are discussed in Appendix B.

A shopping center could also be considered a multi-use development. However, because data have been collected directly for them, shopping centers are considered in *Trip Generation* as a single land use. The associated trip generation rates and equations given in *Trip Generation* reflect the "multi-use" nature of the development because of the way shopping center data have been collected. *Accordingly, internal capture rates are not applicable and should not be used to forecast trips for shopping centers if using statistics and data for Land Use Code 820.* However, if the shopping center is planned to have out-parcel development of a significantly different land use classification or a very large percentage of overall GLA, the site could be considered a multi-use development for the purpose of estimating site trip generation.

Likewise, a subdivision or planned unit development containing general office buildings and support services such as banks, restaurants and service stations arranged in a park- or campus-like atmosphere should be considered as an **office park** (Land Use Code 750), not as a multi-use development. Similarly, office buildings with support retail or restaurant facilities contained inside the building should be treated as **general office buildings** (Land Use Code 710) because the trip generation rates and equations already reflect such support uses. A hotel with an on-site restaurant and small retail falls within Land Use Code 310 and should not be treated as a multi-use development.

### 7.4 Methodology for Estimating Trip Generation at Multi-Use Sites

Internally captured trips can be a significant component in the travel patterns at multi-use developments. However, more studies are needed to thoroughly quantify this phenomenon. Section 7.5 presents a recommended procedure for estimating internal capture rates (and a worksheet for organizing and documenting the analysis assumptions used in the estimation of the internal capture rates) for multi-use development sites.

The internal trip-making characteristics of multi-use development sites are directly related to the mix of on-site land uses (which are typically a combination of residential, office, shopping/retail, restaurant, entertainment and hotel/motel). When combined within a single mixed-use development, these land uses tend to interact and thus attract a portion of each other's trip generation.

The recommended methodology for estimating internal capture rates and trip generation at multi-use sites is based on two fundamental assumptions. First, the proportions of trips between interacting land use types (which will be satisfied internally by pairs of land uses) are assumed to be relatively stable. Second, if sufficient data were available, these internal capture percentages could be predicted with adequate confidence. The need for additional data collection at multi-use developments is described in Section 7.7.

As should be expected, the observed internal capture rates for multi-use developments vary by time of day, the site's mix of land uses and size of the development.

Several premises frame the recommended methodology. An example to illustrate its application is presented in the highlighted text to the side. Key to the success of this methodology in replicating internal capture patterns at multi-use sites is its iterative, balancing steps that constrain internal trip-making levels to what are realistic given the mix of land uses.

---

### ***Illustration of Methodology Overview***

**Assume a multi-use development with a mix of office, retail and residential uses. Assume that the office building generates 500 exiting trips during the evening peak hour (based on factors presented in *Trip Generation*).**

**Based on surveys at other multi-use developments (for illustration purposes), it is estimated that the 500 peak hour trips could go to the following destinations: 5 trips to another office building within the development, 115 trips to a retail site within the development, 10 trips to residential units on-site and 370 to external sites (as illustrated in Figure 7.1a).**

***What if there are no on-site residential units?*** The number of trips from the office to an internal residential destination changes to zero and the number of trips to external destinations becomes 380 (i.e., the total trips from the office building remains constant at 500).

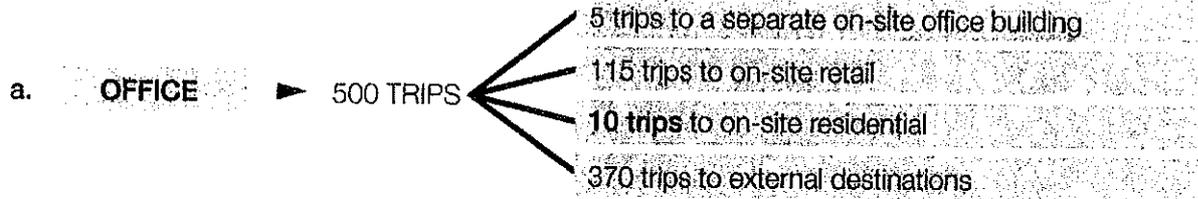
***What if there are a large number of on-site residences?*** Assume the residential uses generate 1,000 entering trips during the evening peak hour. As illustrated in Figure 7.1b, the trips are assumed to originate as follows: 20 trips from an on-site office building, 310 trips from on-site retail, no trips from another on-site residential component and 670 trips from external origins.

With the larger number of residences, as many as 20 trips could come from on-site office buildings. But the actual on-site office buildings generate only 10 trips to the on-site residential land use. So, 10 trips would be expected from on-site office to on-site residential in Figure 7.1c. The key assumption is that the ***"balanced" number of internal trips will match the controlling (i.e., lower) value.***

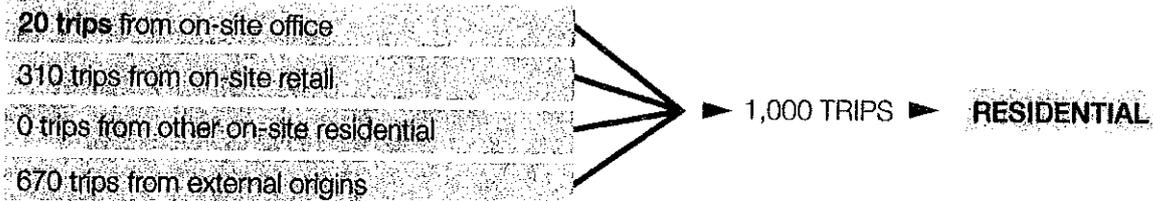
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**Figure 7.1 Illustration of Internal Trip Balancing for a Multi-Use Development**

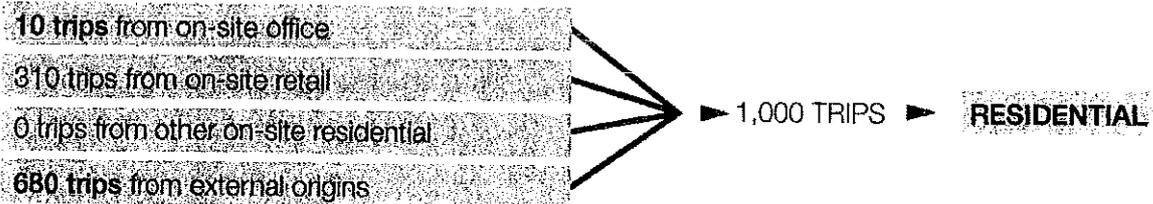
**DISTRIBUTION OF POTENTIAL DESTINATIONS OF TRIPS FROM OFFICE USE**



**b. DISTRIBUTION OF POTENTIAL ORIGINS OF TRIPS TO RESIDENTIAL USE**



**c. BALANCED<sup>1</sup> DISTRIBUTION OF ORIGINS OF TRIPS TO RESIDENTIAL USE**



<sup>1</sup> Only the office-to-residential values have been "balanced." Similarly, all other land use pairs would need to be balanced.

**Premise 1:** The distribution of trip purposes among motorists entering or exiting a development site is relatively stable. The distribution of destination land uses is likewise assumed to be relatively stable. For example, the destinations of trips from an office building are distributed among the many potential destinations (e.g., retail, residential, other office) in roughly the same pattern whether the office is stand-alone or in a multi-use development.

**Premise 2:** The converse of Premise 1 is also true, that the distribution of origins for trips to a particular land use is relatively stable.

**Premise 3:** The number of trips from a land use within a multi-use development to another land use within the same multi-use development (i.e., an internal trip) is a function of the size of the "receiving" land use and the number of trips it attracts, as well as the size of

the "originating" land use and the number of trips it sends. *The number of trips between a particular pair of internal land uses is limited to the smaller of these two values.*

## 7.5 Procedure for Estimating Multi-Use Trip Generation

The recommended procedure for trip estimation, although complex, simplifies the actual trip-making dynamics within a multi-use development. For example, the procedure does not take into account a number of key variables that are likely to affect the internal capture rate, such as proximity of on-site land uses (and pedestrian connections between them) and location of the multi-use site within the urban/suburban area (and the proximity of competing or complementary land uses). **The analyst is encouraged to exercise caution in applying the data presented herein because of the limited sample size and scope.**

**Additional data should be collected where possible (refer to Section 7.7 for guidance). The analyst is also encouraged to make logical assumptions in his/her use of this procedure. In summary, use good professional judgment.**

---

### WORDS OF ADVICE

- ◆ Collect additional data if possible
  - ◆ Exercise caution
  - ◆ Be logical
  - ◆ Use good professional judgment
- 

The step-by-step procedure, as described below, can be used for any number of land uses within the multi-use site. Sample forms are provided for three and four land uses, however, the analyst can modify the sample worksheet to correspond to the desired number of land uses. The layout of the worksheet will become more complex as additional land uses are included.

Blank worksheets for estimating multi-use development trip generation are provided at the end of this chapter. The following step-by-step procedures illustrate how the worksheet should be completed.

## Step 1. Document Characteristics of Multi-Use Development

Enter the following information onto the worksheet:

- ◆ Name of development;
- ◆ Description of each land use in the development and its ITE land use code; and
- ◆ Size of each land use, corresponding to the most appropriate independent variable used in *Trip Generation* (e.g., gross leasable area, gross floor area, dwelling units).

If the site has two or more buildings containing the same land use, combine the sizes of the multiple buildings if they are situated within reasonable and convenient walking distance of each other. If the buildings are not close to each other, treat them as separate land uses on the worksheet (for example, as Office A and Office B).

If the site has multiple residential components (single-family, apartment, etc.), compute the trip generation for each residential type separately (later in Step 3), but record as only a single land use on the worksheet.

## Step 2. Select Time Period for Analysis

Enter the time period for which the analysis is being conducted onto the worksheet (for help in selecting the appropriate time period for analysis, refer to Chapter 2 of this handbook).

Internal capture rates vary by time of day. A separate worksheet should be completed for each distinct time period. It should be noted that typical internal capture rates are presented later in this chapter for the weekday midday, weekday evening peak and weekday daily.

Internal capture rates may also vary by day of the week. The typical internal capture rates used in a later step are based on data collected on a Tuesday, Wednesday, or Thursday (unless specifically noted otherwise). Analyses for a Friday or Saturday may need modified rates.

## Step 3. Compute Baseline Trip Generation for Individual Land Uses

Compute the number of trips generated for the desired time period for each land use based on the given independent variable.

◆ Refer to notes in Step 1 if there are multiple buildings of the same land use within the site.

◆ Compute number of trips generated by direction (enter/exit).

◆ Use the *Trip Generation* rate, *Trip Generation* equation, or local data for each land use. Refer to Chapter 3 for guidance on how to select the appropriate rate or equation for each land use. Do not adjust for pass-by or diverted linked trips at this time.

Record trip generation values in worksheet. For each land use, record the baseline trip generation in the column under the "total" heading.

---

### SAMPLE PROBLEM

**Step 1.** For our example problem, we are analyzing a multi-use site comprised of a 200,000-sq. ft. shopping center; a 120,000-sq. ft. office building; and 200 low-rise apartments. On the worksheet in Figure 7.2, the three land use types and their corresponding ITE land use codes and sizes are recorded.

**Step 2.** We will assume the analysis time period is the evening peak hour of adjacent street traffic (as indicated in the worksheet in Figure 7.2).

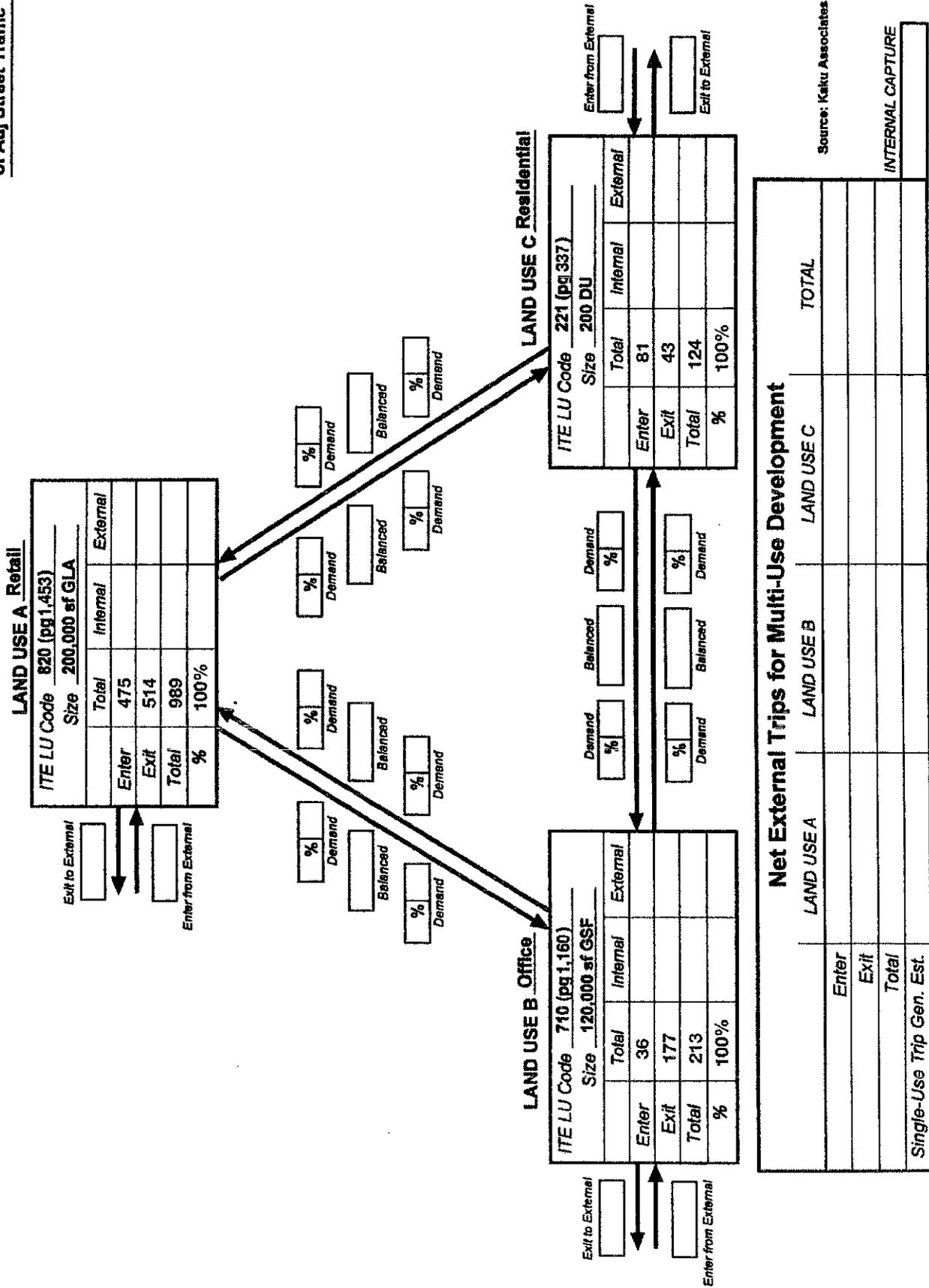
**Step 3.** For Land Use Code 820, use the equation from page 1,453 of *Trip Generation, Seventh Edition*, to compute trips; for Land Use Code 710, use the equation from page 1,160; for Land Use Code 221, use the equation from page 337. The results are listed in the worksheet in Figure 7.2.

---

Analyst \_\_\_\_\_  
Date \_\_\_\_\_

Name of Dvlpmt \_\_\_\_\_  
Time Period **PM Peak Hour**  
of Adj Street Traffic

Figure 7.2 Steps 1-3 for Multi-Use Trip Generation Calculation Sample Problem



## Step 4. Estimate Anticipated Internal Capture Rate Between Each Pair of Land Uses

Tables 7.1 and 7.2 present unconstrained internal capture rates that have been estimated on the basis of a series of studies conducted in Florida. These are the only data available to ITE prior to publication that are detailed enough for credible use. Readers are encouraged to collect and submit additional data to ITE using procedures described in Section 7.7. As the best available applicable data, it is recommended that these internal capture rates be used unless local data are collected.

---

### SAMPLE PROBLEM (continued)

**Step 4. The sample worksheet in Figure 7.3 shows the recorded "internal capture" rates for each pair of land uses.**

---

Estimate the interaction between each pair of land uses for the selected time period.

◆ Use Tables 7.1 and 7.2 (or local data) as the basis for the estimate. (Note: there are no data provided for the weekday morning peak period or for the Saturday midday peak period.)

◆ Table 7.1 presents estimated unconstrained internal capture

rates for trip origins within a multi-use development. For example, during the weekday midday peak period, of all the vehicle-trips exiting an on-site office use, 2 percent of the trips could be destined for another on-site office use and 20 percent destined for on-site retail use.

◆ Table 7.2 presents estimated unconstrained internal capture rates for trip destinations within a multi-use development. For example, during the weekday midday peak period, of all the vehicle-trips entering an on-site retail use, 4 percent of the trips could originate at an on-site office use and 5 percent at an on-site residential use.

Record the estimated capture rates on the worksheet (in the boxes marked "demand").

◆ For each land use pairing, record four values; for example, for the pairing of retail and office uses, the following four values should be recorded:

- Percent of trips from on-site office destined to an internal retail destination
- Percent of trips to on-site retail originating from an internal office use
- Percent of trips from on-site retail destined to an internal office destination
- Percent of trips to on-site office originating from an internal retail use

◆ Each value represents the unconstrained demand (or maximum potential trip interaction between the two land uses), by direction.

Because of the limited database on trip characteristics at multi-use sites, the analyst is cautioned to review the particular characteristics of the multi-use development under analysis before using the factors presented in Tables 7.1 and 7.2. Specifically, the analyst must *assess whether each set of internal trip capture rates makes sense considering the particular individual land uses within the multi-use development.*

---

**If local data on internal capture rates by land use pair can be obtained, the local data should be given preference.**

---

The data in Table 7.1 are limited to trip interaction among the three land uses for which sufficient data were available. *If an on-site land use does not match a land use category in Table 7.1, either (1) collect local data to establish an internal capture rate, according to procedures described in Section 7.7 of this chapter; or (2) assume no internal capture.* (Note: although this assumption of no internal capture may be unrealistic, in the absence of any data it is better to overestimate off-site vehicle-trips.)

**Table 7.1 Unconstrained Internal Capture Rates for Trip Origins within a Multi-Use Development**

		WEEKDAY		
		MIDDAY PEAK HOUR	p.m. PEAK HOUR OF ADJACENT STREET TRAFFIC	DAILY
from OFFICE	to Office	2%	1%	2%
	to Retail	20%	23%	22%
	to Residential	0%	2%	2%
from RETAIL	to Office	3%	3%	3%
	to Retail	29%	20%	30%
	to Residential	7%	12%	11%
from RESIDENTIAL	to Office	N/A	N/A	N/A
	to Retail	34%	53%	38%
	to Residential	N/A	N/A	N/A

Caution: The estimated typical internal capture rates presented in this table rely directly on data collected at a limited number of multi-use sites in Florida. While ITE recognizes the limitations of these data, they represent the only known credible data on multi-use internal capture rates and are provided as illustrative of typical rates. ***If local data on internal capture rates by paired land uses can be obtained, the local data may be given preference.***

N/A—Not Available; logic indicates there is some interaction between these two land uses; however, the limited data sample on which this table is based did not record any interaction.

**Table 7.2 Unconstrained Internal Capture Rates for Trip Destinations Within a Multi-Use Development**

		WEEKDAY		
		MIDDAY PEAK HOUR	p.m. PEAK HOUR OF ADJACENT STREET TRAFFIC	DAILY
to OFFICE	from Office	6%	6%	2%
	from Retail	38%	31%	15%
	from Residential	0%	0%	N/A
to RETAIL	from Office	4%	2%	4%
	from Retail	31%	20%	28%
	from Residential	5%	9%	9%
to RESIDENTIAL	from Office	0%	2%	3%
	from Retail	37%	31%	33%
	from Residential	N/A	N/A	N/A

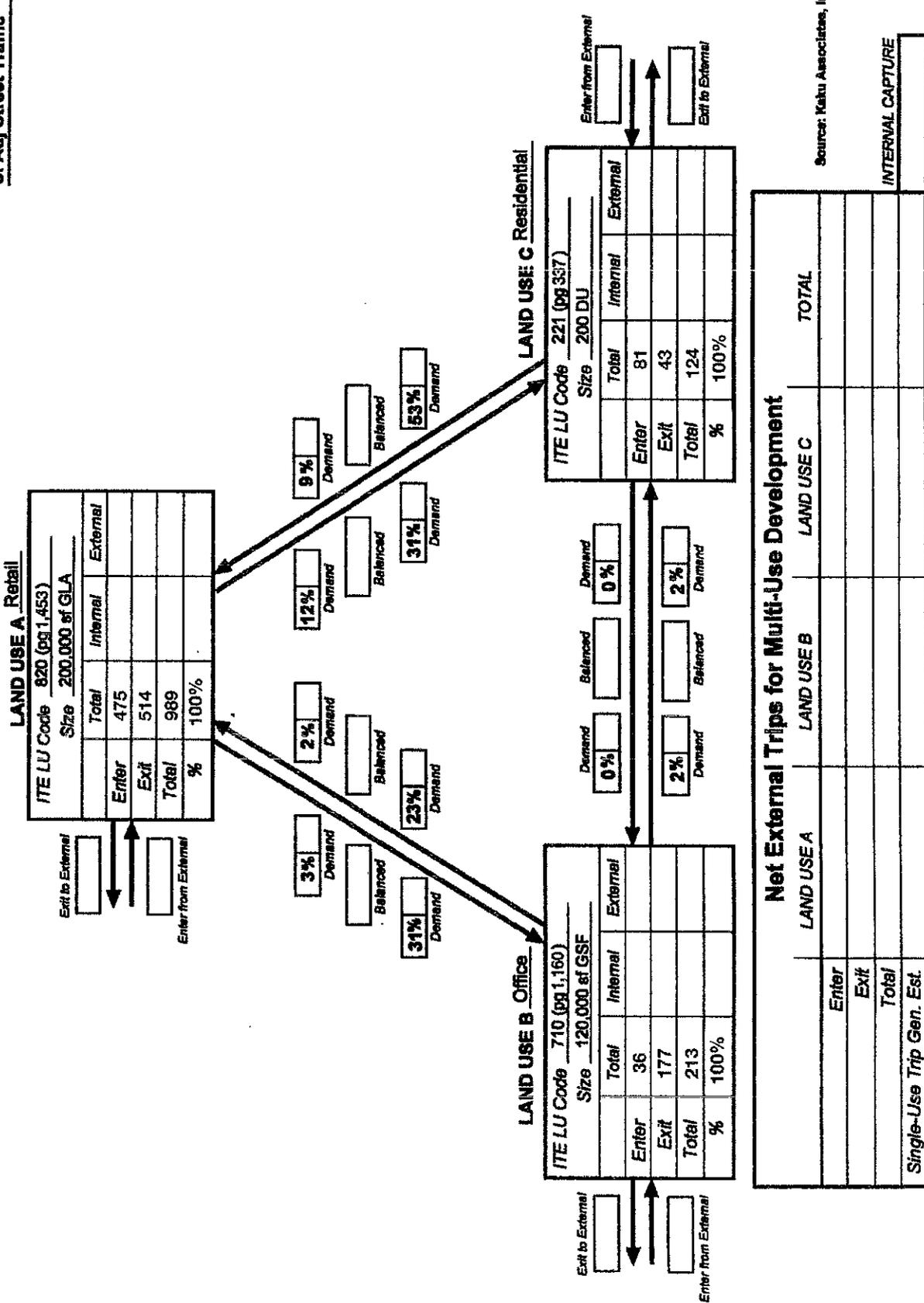
Caution: The estimated typical internal capture rates presented in this table rely directly on data collected at a limited number of multi-use sites in Florida. While ITE recognizes the limitations of these data, they represent the only known credible data on multi-use internal capture rates and are provided as illustrative of typical rates. ***If local data on internal capture rates by paired land uses can be obtained, the local data may be given preference.***

N/A—Not Available; logic indicates there is some interaction between these two land uses; however, the limited data sample on which this table is based did not record any interaction.

Analyst \_\_\_\_\_  
Date \_\_\_\_\_

Name of Div/pt \_\_\_\_\_  
Time Period PM Peak Hour  
of Adj Street Traffic of Adj Street Traffic

Figure 7.3 Step 4 for Multi-Use Trip Generation Calculation Sample Problem



### Step 5. Estimate "Unconstrained Demand" Volume by Direction

Multiply the internal capture percentages by the appropriate directional trip generation value in the worksheet.

- ◆ For each pair of land uses, compute a directional value from the percentages that were entered. (Note: these values will be balanced later in Step 6.)

Record the "unconstrained demand" volumes by direction on the worksheet in the boxes marked "demand" next to the percentages.

---

#### SAMPLE PROBLEM

(continued)

Step 5. The "unconstrained demand" volumes are computed by multiplying the directional trip generation value by the "unconstrained demand" percentage, as shown in the sample worksheet in Figure 7.4. For example,

- ◆ Trips from retail to office:  
 $514 \text{ outbound trips} \times 3\% = 15 \text{ trips}$
  - ◆ Trips to office from retail:  $36 \text{ inbound trips} \times 31\% = 11 \text{ trips}$
  - ◆ Trips from office to retail:  
 $177 \text{ outbound trips} \times 23\% = 41 \text{ trips}$
  - ◆ Trips to retail from office  
 $475 \text{ inbound trips} \times 2\% = 10 \text{ trips}$
- 

### Step 6. Estimate "Balanced Demand" Volume by Direction

Compare the two values in each direction for each land use pairing and select the lower (i.e., controlling) value.

Record the value as the "balanced demand" (the lower of the directional internal volumes) between each pair of land uses.

- ◆ Record the lower value for each land use for each direction
- ◆ Record in the worksheet boxes marked "balanced."

---

Step 6. Select the controlling value (i.e., the lower value) for each pair of land uses for each direction. For example, in the Figure 7.4 worksheet,

- ◆ For trips from retail to office, the retail could generate 15 internal trips but the office could only receive 11 internal trips; the controlling value is 11 internal trips.
  - ◆ For trips from office to retail, the office could generate 41 internal trips but the retail could only receive 10 internal trips; the controlling value is 10 internal trips.
- 

### Step 7. Estimate Total Internal Trips to/from Multi-Use Development Land Uses

For each land use, first sum the internal trips to each other land use. Then for each land use, sum the internal trips from each other land use. Record these total internal trip values in the worksheet in the summary table for each land use.

Compute and record the internal percentages for each land use in the summary table for each land use. Review values and verify that they are reasonable.

---

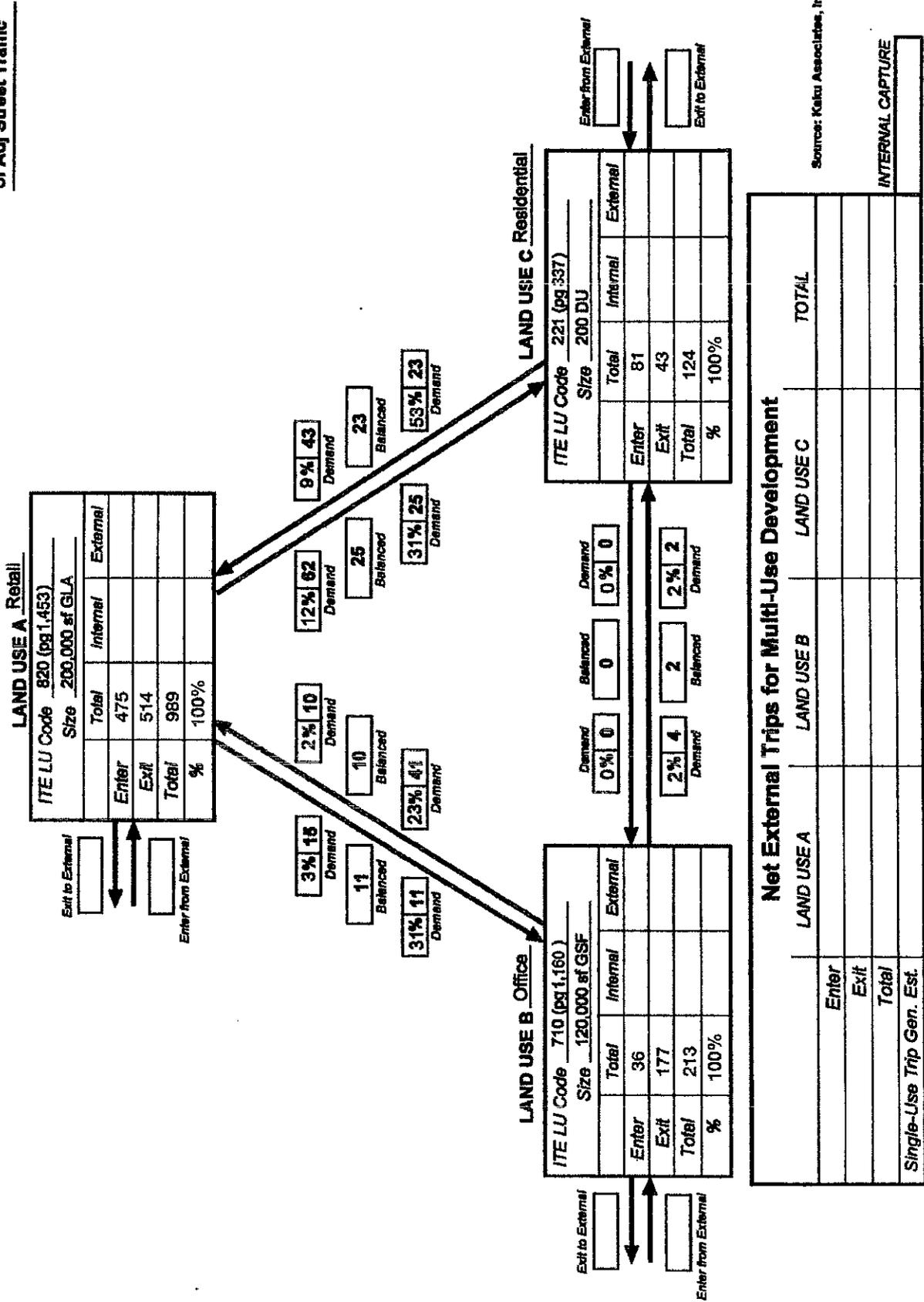
Step 7. The sample worksheet in Figure 7.5 illustrates Step 7. For the retail land use, 10 internal trips are estimated from the on-site office and 23 internal trips from the on-site residential. Therefore, the total internal trips entering the retail land use is 33. The internal trips exiting retail sum to 36 (11 to the on-site office and 25 to the on-site residential). In total, seven percent of the retail trips (69 of 989) are internal to the multi-use site. This procedure is followed for each land use.

---

Analyst \_\_\_\_\_  
Date \_\_\_\_\_

Name of Divpt \_\_\_\_\_  
Time Period PM Peak Hour  
of Adj Street Traffic \_\_\_\_\_

Figure 7.4 Steps 5 & 6 for Multi-Use Trip Generation Calculation Sample Problem



## Step 8. Estimate the Total External Trips for Each Land Use

Calculate the number of external trips (by direction) by subtracting the estimated internal trips from the total trips for each individual land use. Record values in tables for each land use and in the boxes marked "exit to external" and "enter from external."

---

### SAMPLE PROBLEM

(continued)

**Step 8. The sample worksheet in Figure 7.5 lists the external trip volumes for each land use. For the retail use, there are estimated to be 442 trips entering from outside the site (computed by subtracting 33 internal trips from 475 total trips) and 478 trips exiting to outside the site (514 minus 36).**

---

## Step 9. Calculate Internal Capture Rate and Total External Trip Generation for Multi-Use Site

Record the final external trip estimates for each land use onto the worksheet and in the table of "net external trips."

Compute the *net external trip generation* for the entire site by summing the external volumes for each of the site land uses.

Record the original estimates for total trip generation for each land use onto the worksheet in the row denoted "original trip generation estimate." Compute the overall *internal capture rate* by dividing the net external trip generation estimate by the original total trip generation estimate, and subtracting the quotient from 100 percent.

---

**Step 9. The sample worksheet in Figure 7.5 lists the net external volumes for each of the three land uses in the summary table. The entering volume estimate of 521 peak hour trips is the sum of the external trips entering retail (442 trips), entering office (25 trips), and entering residential (54 trips). The net external volume for the multi-use site is 1,184 (521 plus 663) and represents an 11 percent reduction.**

---

## 7.6 Cautions Regarding Recommended Procedure

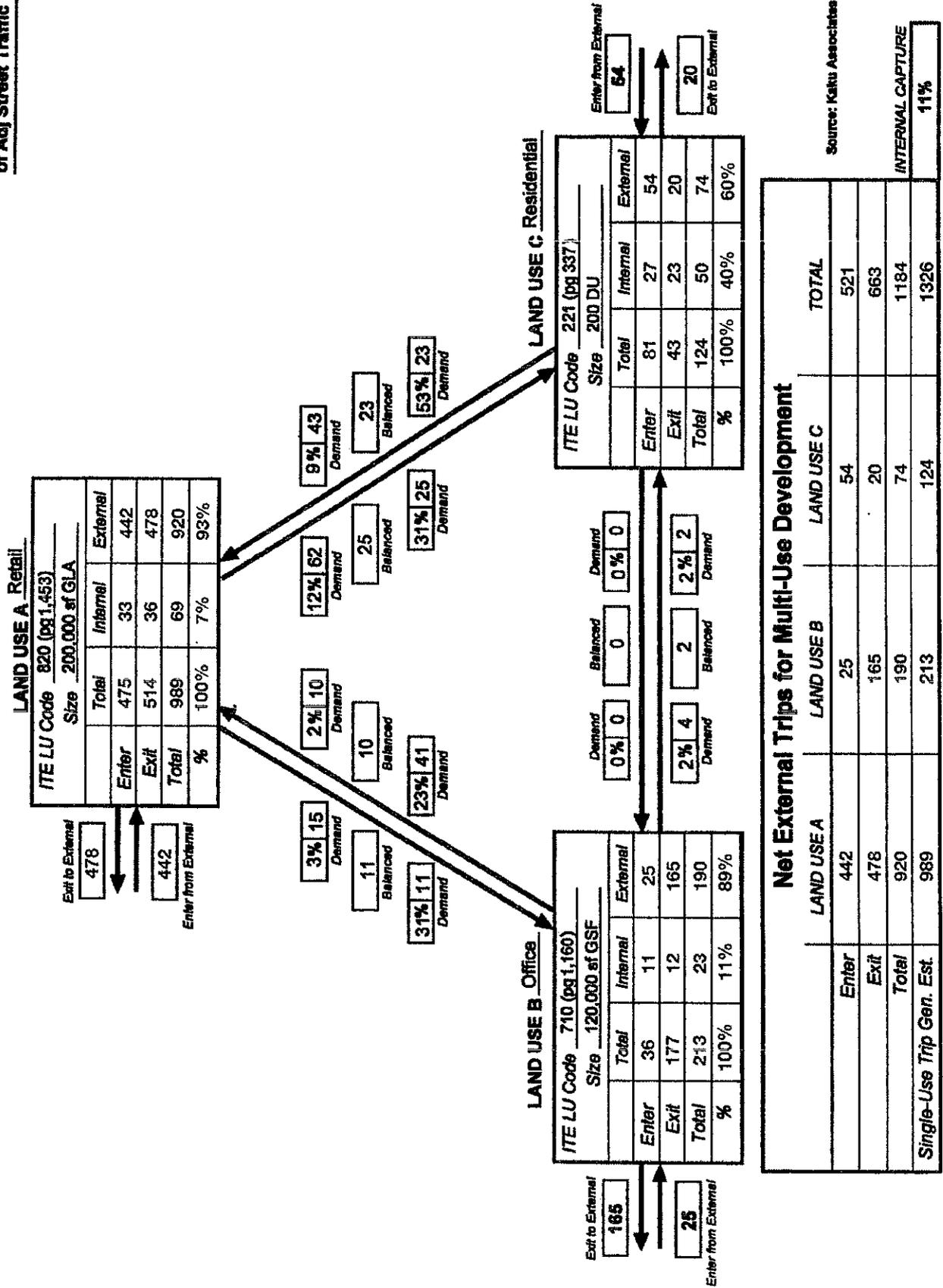
The data presented in Section 7.5 quantify the influence of several key factors on internal capture rates. Numerous other factors have a direct influence on travel at multi-use sites, factors for which the current data do not account. Additional data and analysis are desirable to better quantify the relationships between these factors and multi-use development trip generation and internal capture rates. A summary description of the pertinent information contained in several existing documents is included in Appendix C of this handbook.

**Limited Sample Size**—The estimated typical internal capture rates presented in Section 7.5 in Tables 7.1 and 7.2 rely directly on data collected at a limited number of multi-use sites in Florida. While ITE recognizes the limitations of these data, they represent the only known credible data on multi-use internal capture rates and are provided as illustrative of typical rates. *If local data on internal capture rates by land use pair can be obtained, the local data should be used (and the data submitted to ITE for use in future publications).*

Analyst \_\_\_\_\_  
Date \_\_\_\_\_

Name of Divpt PM Peak Hour  
Time Period of Adj Street Traffic

Figure 7.5 Steps 7-9 for Multi-Use Trip Generation Calculation Sample Problem



---

### **ADDITIONAL LAND USE MIXES**

The analyst should exercise caution when considering the effects of additional land use mixes. For example, one of the newer types of multi-use developments is the large entertainment center complex with cinemas, restaurants, nightclubs and retail space. Customer interviews in Florida and California have suggested that as many as 40 percent of cinema users also eat at on-site restaurants. In another survey, only 20 percent of visitors to the complex report visiting only one land use at the site. However, reliance on interview data alone will tend to overstate the actual amount of internal capture. Actual counts should be taken to supplement these data.

---

**Pass-By Trips**—The application of pass-by trip reductions presented in Chapter 5 should be likewise applicable to multi-use sites. However, none of the internal trips can be of a pass-by nature because they do not travel on the adjacent (external) street system. *Pass-by trip percentages are applicable only to trips that enter or exit the adjacent street system.* Use the pass-by trip estimation procedure in Chapter 5 of this handbook.

**Competing Markets**—Proximity to competing markets is expected to influence internal capture rates. *The greater the distance to external competing uses, the greater the likelihood of capturing trips internally within a multi-use development site.* Developments in a suburban community may have higher capture rates than those in urban developments since urban areas provide a higher number of alternative opportunities than many suburban developments. For example, residents in an urban mixed-use development have more choices in shopping opportunities and thus may travel outside the development site for their shopping needs, even though there are retail uses in their development site. Suburban residents, on the other hand, may not have as many alternative opportunities and therefore may be more likely to confine their trips to the mixed-use site for their shopping or other needs. However, at this time there are no site-trip generation data available on which to base adjustment factors of this type.

**Proximity and Density of On-Site Land Uses**—The proximity and density of the residential, retail, office and hotel uses will affect internal trip-making. *Generally, the greater the density and the closer the proximity of the complementary uses on site, the greater the level of internalization of trips.* The proximity should be measured in terms of both distance and impedance to the traveler. For example, the presence of foot paths

or bicycle paths, protected crosswalks or overpasses and pedestrian refuge areas greatly enhance the accessibility of paired on-site land uses. At this time, however, no site-trip generation data are available on which to base adjustment factors of this type.

---

### **Key Premise**

**Internal capture should increase with an increase in proximity, density and number of complementary land uses within a multi-use development.**

---

### **Other Site-Specific Issues**—

Many other issues potentially affect trip making at multi-use sites. For example, can those who work on-site afford to live on-site? How long will it take for the office uses to attract work trips from on-site residences? Is there an internal circulation system that enhances or discourages internal trips?

**Shared Parking**—Shared parking and multi-use trip generation estimation methodologies, though similar, are not interchangeable. Shared parking factors cannot be applied to estimate trip generation at multi-use developments.

---

**Shared parking factors cannot be applied to estimate trip generation at multi-use developments.**

---

## 7.7 Data Collection at Multi-Use Developments

*ITE wishes to increase the database on multi-use developments in order to provide internal capture data for a broader range of land uses. ITE would appreciate additional data from analyses of such developments.*

A data collection program for a multi-use development site should include verification that the site to be surveyed is appropriate for inclusion in the ITE database. It should also include a compilation of information describing site characteristics and field data collection. The field data collection at the site should have at least two components: in-person interviews on-site and a cordon traffic count. Conducting internal traffic counts should be considered at sites where internal streets exist and can be isolated and where internal streets carry most of the internal trips (both pedestrian and vehicular).

A data collection program that has all three components will provide the clearest understanding of internal and external trip-making at the multi-use site. If only an on-site interview is conducted, factoring of the survey results to calibrate to actual trip volumes will not be possible. In general, experience has shown that data collection efforts consisting solely of interviews tend to overstate the actual proportion of internal trips at a multi-use site.

*At a minimum, data collection should consist of on-site, in-person interviews coupled with a complete cordon count.*

### Site Selection

The site should be fully developed, operational and mature. New or partially developed sites may not generate trips (both external and internal) at the rate expected of a mature site. (Note: the degree of occupancy is one of the site characteristics to be collected, as described below.)

The driveways serving the multi-use site should not serve any adjacent property. If driveways are shared with another site, it is not possible to count the traffic destined for the multi-use site using traditional traffic counting methods. In addition, the selected multi-use site should have a minimal presence of through trips (i.e., external trips that pass through the site without stopping).

### Site Characteristics

Compile the necessary information to describe the multi-use development and each of its individual land uses. At a minimum, obtain information on the independent variables reported under each of the individual land uses in *Trip Generation*. For example, this would include, as appropriate, gross square footage (total and occupied), employees, hotel rooms (total and occupied), dwelling units (total and occupied), restaurant seats, presence of drive-through windows and

so forth. A map or sketch should also be prepared showing buildings, internal streets, access to the external street system and locations of counts and interviews.

If possible, the data collection program should obtain a description and assessment of the proximity/ accessibility of complementary uses within the site and a description and assessment of the proximity of competing markets outside the site.

### Traffic Counts (Cordon)

Driveway volumes at all entrances/exits at the multi-use site should be counted for as long of a period as possible. If only 48 hours of data can be obtained, volumes should be counted during the mid-week (Tuesday through Thursday) to avoid daily variations that may occur on Monday and Friday. If the selected period for design of site access could be the weekend, traffic counts and surveys should likewise be conducted during the weekend.

Ideally, 7 consecutive days of data are recommended if budgets allow and if site driveways are configured to enable complete and accurate counts. With 7 days of data, daily variations can be computed and a weekday average and weekend average can be calculated. Driveway counts should be conducted during the same periods as interviews.

## Traffic Counts (Internal)

For some multi-use developments, it will be possible to validate the survey results for overall internal trip-making with a comprehensive count of internal pedestrians and vehicles. In such cases, pedestrians and vehicles traveling among on-site land uses should be counted during the interview time periods.

## Interviews

Concurrent with gathering driveway volumes, interviews of workers, shoppers, visitors and residents of the site should be conducted. In general, the objective of the intercept survey is to obtain information on trip purposes at the multi-use site, the origins and destinations of trips entering and exiting the site and the mode of each trip.

Interviews of persons are typically conducted on site as they leave the site (or leave a single land use within the site). Each interview obtains information on the trips to and from the site. A sample list of interview questions is provided in Figures 7.6 and 7.7. The questions are written for on-site administration of the survey. If the survey will be conducted at the cordon driveway, the analyst will need to revise the questions to account for potential multiple on-site stops.

The actual field survey form should also include a space for the interviewer to record the date, name of the development, interviewer's location within the site,

time of the interviews (half-hour intervals should be sufficient) and interviewer's name.

A minimum of 100 interviews per time period should be conducted at the multi-use development. For larger developments (i.e., with at least 300,000 sq. ft. of office or retail space), a minimum of 200 interviews per time period should be completed.

## Submittal of Multi-Use Development Data to ITE

A summary of the survey and traffic count results should be submitted to ITE for use in updating the multi-use development database and trip estimation methodology in subsequent updates to the *Trip Generation Handbook*. The report should include a **description of the site and its setting**, a summary of the **data collection program**, the measured internal capture rates between on-site land uses, and a comparison of the **actual external trip generation of the site** to the sum of the trip generation estimates for individual uses within the site. It is strongly suggested that all trip generation studies for multi-use developments follow the procedures presented in this chapter.

Tables 7.3 and 7.4 present a suggested tabulation of multi-use internal capture data. Values should represent factored numbers summed from all of the interview stations. Table 7.3 summarizes the distribution of trip origins and destinations

for *trips heading to land uses within the multi-use development*.

If the survey instrument and format shown in Figure 7.6 is used, the "from" end of the trip is compiled from answers to Question C; the "to" end of the trip is compiled from responses to Question B. The analyst should also compile information on trips "from" the land use described in Question B to an on-site land use identified in Question A.

If the survey instrument and format shown in Figure 7.7 is used, the "from" end of the trip is compiled from answers to Question C; the "to" end of the trip is compiled from responses to Question A that indicate an on-site destination.

Table 7.4 summarizes the distribution of trip origins and destinations for *trips heading from land uses within the multi-use development*.

If the survey instrument and format shown in Figure 7.6 is used, the "from" end of the trip is compiled from answers to Question B; the "to" end of the trip is compiled from responses to Question A.

If the survey instrument and format shown in Figure 7.7 is used, the "from" end of the trip is compiled from answers to Question A; the "to" end of the trip is compiled from responses to Question B.

The pass-by data (Question D) should be summarized as a single value across all trip purposes.

Send the multi-use development study results to:

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Engineers  
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Suite 300 West  
Washington, DC 20005-3438  
Tel: +1 202-289-0222  
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# Report 365

## Travel Estimation Techniques for Urban Planning

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*Subject Areas*

Planning and Administration

Research Sponsored by the American Association of State  
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## CHAPTER 8

# TIME-OF-DAY CHARACTERISTICS

### INTRODUCTION

Through the mode-choice step in the travel forecasting process, the forecasting procedures usually consider total travel over the full 24-hour day. For many applications, travel must be estimated for specific periods or hours of the day. These applications may include the analysis of highway facilities, transit services, and emissions. Peak-period speeds and volumes are critical for assessing the level of service provided by the transportation system, the competitiveness of transit with autos on the highway network, and the size of the transit fleet.

Analyses of special times are generally required to judge transportation system requirements. During limited periods during the day—the peak time period—the transportation system is loaded, and sometimes overloaded, with travelers. For general highway traffic, the critical peak hour most often occurs during the afternoon when people are returning from work, going shopping, completing recreational trips, and being picked up at school. However, critical traffic movements may occur at other times, particularly during the morning commute hours.

In 1990, for the first time, the census provided start-time information for work trips. In aggregate, these data show that there is no such thing anymore as a peak hour. The most heavily loaded hour in trip starts is from 7:00 AM to 8:00 AM, and this hour accounts for only 32 percent of commuting trip start times.

Geographic location can add another dimension to the time-of-day stratification to account for unique peaking characteristics of individual corridors or subareas. This is particularly applicable where a subarea contains a major generator such as a hospital or university that has significantly different peaking times than conventional commuter trips.

A final issue with regard to peaking occurs after the assignment and aggregation of link volumes by period. Several issues with regard to capacity and facility design require peak-hour estimates of volumes on highways, transit lines, transit stations, and park-and-ride lots. Mode-specific factors capture more fully the unique peaking characteristics of each mode. For example, carpools on HOV facilities tend to have peaks that are sharper than general highway traffic.

Transit use is highly oriented to the AM and PM peak periods with lesser amounts of travel at other times. The differences between auto and transit use are most visible during the evening hours when many trips are made for social and shopping purposes. Compared with auto trips, few evening trips are made via transit. Also, the peak hour for transit travel usually occurs during the AM peak period—caused by a concentration of work trips—whereas the peak hour for auto-related trips usually occurs during the PM peak period.

The AM peak is most critical for air quality analysis, as morning emissions of volatile organic compounds (VOCs) and nitrous oxides (NO<sub>x</sub>) have a longer time to react to light than do pollutants emitted in the PM peak. As a result, ozone concentrations typically peak during the late morning or early afternoon hours. Afternoon winds also tend to disperse pollutants more than in the early morning.

On the other hand, the PM peak is critical for system analysis because areawide traffic volumes and congestion are typically higher during the afternoon peak. Ultimately, the choice of which peak period to model must take into account such considerations as the availability of count data, previous modeling efforts, local conditions, and the application for which the model is intended.<sup>1</sup>

Time-of-day factors are applied to the mode-specific trip tables produced by the mode-choice models. The most straightforward applications stratify the factors only by trip purpose; however, time-of-day factors can be stratified by both trip purpose and mode if mode-specific surveys and counts have been obtained. Otherwise, it is assumed that the same mix of purposes is uniform across modes.

The purpose of this chapter is to provide tables to allow determination of hourly travel from estimates of total daily travel. Material is provided in this chapter for both automobile travel and transit travel. The data are also extremely useful in converting daily work trips from census information to peak-hour all-purpose trips. The techniques used for vehicle travel are different from those used for transit time-of-day analysis; therefore, a separate section is provided for each.

<sup>1</sup>Greig Harvey and Elizabeth Deakin, *A Manual of Transportation Air Quality Modeling for Metropolitan Planning Organizations*. National Association of Regional Councils (1992).

## BASIS FOR DEVELOPMENT

Time-of-day analyses are used for several types of studies, and, since the introduction of Transportation System Management (TSM) requirements, are becoming a more critical part of the overall transportation planning process. Examples of time-sensitive studies are as follows:

1. Traffic impact studies are analyses to determine the impact a specific residential, commercial, or other type of development has on the area transportation network.
2. Trip accumulation studies are usually done to determine the peak accumulation of vehicles for parking studies, taking into account the mix of trip purposes involved.
3. Highway v/c studies are evaluations using peak factors (essentially the type of information provided later in this chapter) to determine peak-loading conditions in vehicles per hour (VPH) for highway traffic assignment and determination of capacity requirements.
4. TSM studies specifically address transportation solutions for the critical peak period, generally in the form of traffic engineering or operations improvements.
5. TDM has found a significant place in transportation planning in the past decade. As roadway capacities have filled, ways to fit more travelers in the same road space have become an alternative to widening or building new roadways. TDM strategies are used not only to lessen the number of vehicles on the network during the peak time periods, but also to shift some trips to non-peak time periods.

This shifting can seriously affect the time-of-day trip characteristics of a region. Adjustments in the trip table must be made to compensate for TDM efforts, either in place or planned, that affect the time when trips are made.

The procedures presented here are based on observed vehicle-miles of travel (VMT). VMT is the product determined when a given trip is multiplied by its trip length (distance). As such, it is truly a measure of travel and not a measure of the distribution of trips during a 24-hour period. The trip-length distribution may vary by trip purpose over a 24-hour period. However, within the context of acceptable transportation planning procedures, such as trip-distribution modeling, the VMT distribution can be used to approximate the distribution of trips by purpose.

## VEHICLE TRAVEL

Time-of-day analysis is usually undertaken at one of two points: (1) just after application of the auto-occupancy procedures to isolate a time period for further analysis or (2) after assignment of 24-hour travel in preparation for capacity

analysis. The general organization of the charts provided in this chapter is by the four urbanized area population groups. Each set of charts (by urbanized area population) is further stratified to present data to

- Analyze auto driver travel by trip purpose,
- Analyze total vehicle travel,
- Determine total vehicle travel, by time period or in aggregate, from internal auto driver trips,
- Determine trip volume by route type, subregion, and orientation to study area core, and
- Determine directional split of travel by route type, subregion, and orientation to the study area core.

The tables were developed using the NPTS with confirmation from analysis of travel data of home interview data sets from around the country.

## DIURNAL DISTRIBUTION

The use of diurnal factors in time-of-day analysis allows peak-hour assignments that are representative of the peak-hour direction of trips and the percent by hour. These factors are used to produce peak-hour directional volumes.

Twenty-four-hour production/attraction trip tables are converted to time-of-day-specific, origin/destination trip tables by applying time-of-day and directional split factors. The creation of time-of-day origin/destination trip tables from 24-hour origin/destination trip tables is somewhat easier as the tables need to be factored only by time-of-day factors, not by time-of-day and directional split factors.

## Use of Time-of-Day Tables

This section presents tables of travel by time of day and by purpose for the different population groups. An example is presented of factoring a daily vehicle trip table by purpose to an AM peak-hour trip table.

There are two basic approaches to developing estimates of directional peak-hour vehicle volume: (1) post-processing of daily highway assignments using link-based peak-hour and directional percentages and (2) preassignment factoring of daily trip tables by purpose, using factors for AM peak, PM peak, and off-peak periods.

The first approach historically has been used in conjunction with the assignment of a daily vehicle-trip table. The peak percentages for a link may be based on 24-hour machine counts of traffic, but most commonly the assigned ADT is multiplied by a single factor ranging between 8 and 12 percent of daily traffic to achieve an estimate of total bi-directional peak-hour travel. A directional split (e.g., 60/40) based on observations of traffic conditions is then applied. This procedure yields a rough approximation of peak traffic

that may be appropriate for smaller urban areas where the duration and intensity of congestion is limited.

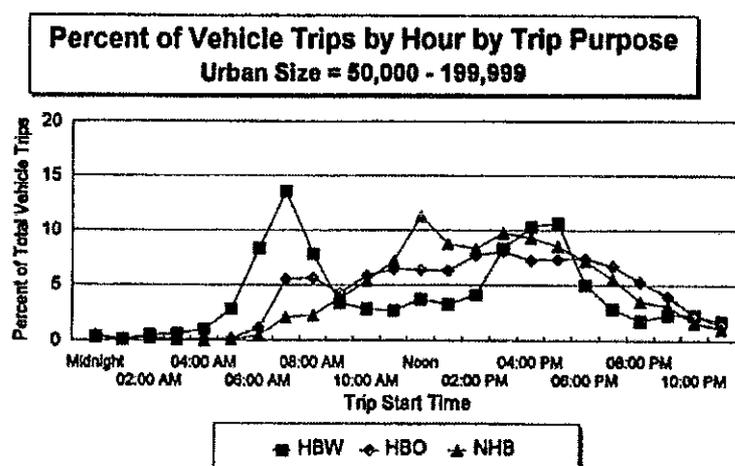
The preassignment approach uses time-of-day factors to create the AM peak, PM peak, and off-peak trip tables by purpose that are then used in the assignment of vehicle trips to the network. An example of this method is included at the end of

this section. Using this reassignment factoring process, average daily traffic assignments can be produced by summing the results of the AM peak, PM peak, and off-peak assignments. Table 41 presents the percent of vehicle trips by hour by trip purpose for different urban population groups. Table 42 shows the diurnal distribution of trips by time and purpose. The data

**TABLE 41** Percent of vehicle trips by hour by trip purpose

Hour Beginning	Urban Size = 50,000 to 199,999			All Purposes	
	HBW	HBO	NHB		
Midnight	0.33	0.40	0.49	0.41	
1:00 a.m.	0.07	0.17	0.12	0.12	
2:00 a.m.	0.50	0.23	0.27	0.33	
3:00 a.m.	0.61	0.07	0.12	0.27	
4:00 a.m.	1.00	0.08	0.00	0.36	
5:00 a.m.	2.79	0.18	0.06	1.01	
6:00 a.m.	8.34	1.10	0.46	3.30	
7:00 a.m.	13.57	5.53	2.07	7.06	
8:00 a.m.	7.84	5.64	2.27	5.25	
9:00 a.m.	3.36	4.27	3.76	3.80	
10:00 a.m.	2.79	5.86	5.40	4.68	
11:00 a.m.	2.65	6.44	7.22	5.44	
Noon	3.72	6.40	11.26	7.13	← 4th Highest Hour
1:00 p.m.	3.26	6.34	8.77	6.12	← 8th Highest Hour
2:00 p.m.	4.12	7.70	8.31	6.71	
3:00 p.m.	8.30	8.06	9.74	8.70	
4:00 p.m.	10.31	7.25	9.28	8.95	← Peak Hour
5:00 p.m.	10.66	7.32	8.56	8.85	
6:00 p.m.	5.01	7.44	7.19	6.55	
7:00 p.m.	2.79	6.71	5.52	5.01	
8:00 p.m.	1.72	5.24	3.46	3.47	
9:00 p.m.	2.29	3.95	3.06	3.10	
10:00 p.m.	2.26	2.25	1.55	2.02	
11:00 p.m.	1.69	1.37	1.06	1.37	

Source: 1990 NPTS.



**4th Highest Hour**

4th Highest / Peak Hour  
 $7.13 / 8.95 = 79.6\%$

**8th Highest Hour**

8th Highest / Peak Hour  
 $6.12 / 8.95 = 68.4\%$