

FINAL REPORT

**VALIDATION OF THE HOT AND COLD VEHICLE MODE
PERCENTAGES FOR THE STATE OF FLORIDA**

by

Roger L. Wayson
Brian Y. Kim
Patricia Tom
Mortaza Jamshidian

Department of Civil and Environmental Engineering
University of Central Florida
Orlando, FL 32816-2450
Telephone: (407) 823-2480
Fax: (407) 823-3315
E-mail: wayson@pegasus.cc.ucf.edu

UCF Account No. 16-20-783
Agency No. WPI 0510787
State Job No. 9970-3554-010
Contract No. BA-518

May 29, 1999

DISCLAIMER

The opinions, findings and conclusions expressed in this publication are those of the authors and not necessarily those of the Florida Department of Transportation or the U.S. Department of Transportation. This report was prepared in cooperation with the State of Florida Department of Transportation and the U.S. Department of Transportation.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Validation of the Hot and Cold Vehicle Mode Percentages for the State of Florida		5. Report Date May 29, 1999	
		6. Performing Organization Code 16-20-783	
7. Author's Roger L. Wayson, Brian Y. Kim, Patricia Tom, Mortaza Jamshidian		8. Performing Organization Report No.	
9. Performing Organization Name and Address University of Central Florida Civil & Environmental Engineering Department P.O. Box 162450 Orlando, FL 32816-2450		10. Work Unit No. (TRAJS)	
		11. Contract or Grant No. BA-518 WPI 0510787	
12. Sponsoring Agency Name and Address Florida Department of Transportation 605 Suwannee Street Tallahassee, FL 32399-0450		13. Type of Report and Period Covered Final Report August 15, 1997 – March 31, 1999	
		14. Sponsoring Agency Code	
15. Supplementary Notes Prepared in cooperation with the US Department of Transportation and Federal Highway Administration			
16. Abstract <p>In using MOBILE5a, the default values for transient (hot and cold) and stabilized mode percentages are normally used. However, they may not be applicable to regions and time periods outside of the scenarios under which they were derived. A research effort was undertaken by the Florida Department of Transportation (FDOT) and the University of Central Florida (UCF) to obtain vehicle mode percentages that are more representative of conditions in Florida. The first phase of this study was conducted using mail-back survey sheets and the data was used to calculate mode percentages as percent vehicle miles traveled (VMT) in terms of categorizing variables (i.e. area type, facility type, time of day, etc.). This report presents the methodology and results from the second phase of the study which were used to supplement and validate the data from the first phase. Different approaches were taken in the second phase in that the surveys involved verbally asking questions at intersections rather than using mail-back survey sheets and the mode percentages were based on travel times to an intersection rather than entire trips. The data from the first phase was also re-evaluated. Aggregation of the data into just peak and off-peak categories was possible based on statistical testing since statistical testing appears to indicate that the results from the two phases are similar. The data from the two phases were combined to produce the final percentages that may be used for the state of Florida and is reported here.</p>			
17. Key Words Emissions, Emission Factor, Motor Vehicles, Hot/Cold, Transient Mode, Highways, MOBILE		18. Distribution Statement No Restriction This Report is available to the public through the National Technical Information Service, Springfield,VA 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 43	22. Price

ABSTRACT

In using MOBILE5a, the default values for transient (hot and cold) and stabilized mode percentages are normally used. However, they may not be applicable to regions and time periods outside of the scenarios under which they were derived. Therefore, a research effort was undertaken by the Florida Department of Transportation (FDOT) and the University of Central Florida (UCF) to obtain vehicle mode percentages that are more representative of conditions in Florida. The first phase of this study was conducted using mail-back survey sheets. The collected information from the mail back survey was used to calculate mode percentages as percent vehicle miles traveled (VMT) in terms of categorizing variables (i.e. area type, facility type, time of day, etc.). These percentages were based on travel times corresponding to entire trip lengths.

This report presents the methodology and results from the second phase of the study. The results were used to supplement and validate the data from the first phase. Different approaches were taken in the second phase in that the surveys involved verbally asking questions at intersections rather than using mail-back survey sheets, and the mode percentages were based on travel times to an intersection rather than entire trips. The data from the first phase was also re-evaluated to produce percentages that correspond to travel times to an intersection. Aggregation of the data into just peak and off-peak categories was possible based on statistical testing. A statistical comparison of the two sets of results also showed that as a whole, the null hypothesis (two sets being equal) could not be rejected at an alpha value of 0.05. Therefore, the test appears to indicate that the results from the two phases are similar. The data from the two phases were combined to produce the final percentages to be used for the state of Florida and is reported here.

TABLE OF CONTENTS

LIST OF TABLES.....	iv
LIST OF FIGURES.....	v
INTRODUCTION.....	1
BACKGROUND.....	3
METHODOLOGY	4
Survey Sites.....	4
Survey Procedures.....	9
Survey Response Analysis	9
Statistical Analysis	12
ANALYSIS AND RESULTS.....	16
COMPUTER MODEL.....	27
Introduction.....	27
Comparative Models.....	27
Theory.....	28
Model Structure.....	31
Main Algorithm.....	32
CONCLUSION.....	36
REFERENCES.....	38

LIST OF TABLES

1. Original Phase 1 Hot and Cold Transient Mode Percentages Based on Total Travel Times.....	2
2. Original Phase 1 Hot and Cold Transient Mode Percentages Based on Total Travel Times with Work and AM/PM Peak Categories Aggregated.....	2
3. Site Locations for Surveying.....	4
4. Re-Evaluated Phase 1 Hot and Cold Transient Mode Percentages Based on Intersection Travel Times.....	17
5. Re-Evaluated Phase 1 Hot and Cold Transient Mode Percentages Based on Intersection Travel Times with AM/PM Peak Categories Aggregated.....	17
6. Re-Evaluated Phase 1 Hot and Cold Transient Mode Percentages Based on Intersection Travel Times with Home and AM/PM Peak Categories Aggregated....	18
7. Re-Evaluated Phase 1 Hot and Cold Transient Mode Percentages Based on Intersection Travel Times with Work and AM/PM Peak Categories Aggregated.....	18
8. Re-Evaluated Phase 1 Hot and Cold Transient Mode Percentages Based on Intersection Travel Times with Work, Home, and AM/PM Peak Categories Aggregated.....	18
9. Phase 2 Hot and Cold Transient Mode Percentages Based on Intersection Travel Times.....	19
10. Phase 2 Hot and Cold Transient Mode Percentages Based on Intersection Travel Times with AM/PM Peak Categories Aggregated.....	19
11. Phase 2 Hot and Cold Transient Mode Percentages Based on Intersection Travel Times with Home and AM/PM Peak Categories Aggregated.....	20
12. Phase 2 Hot and Cold Transient Mode Percentages Based on Intersection Travel Times with Work and AM/PM Peak Categories Aggregated.....	20
13. Phase 2 Hot and Cold Transient Mode Percentages Based on Intersection Travel Times with Work, Home, and AM/PM Peak Categories Aggregated.....	20
14. Phase 1 and 2 Combined Hot and Cold Transient Mode Percentages Based on Intersection Travel Times.....	21
15. Phase 1 and 2 Combined Hot and Cold Transient Mode Percentages Based on Intersection Travel Times with AM/PM Peak Categories Aggregated.....	21
16. Phase 1 and 2 Combined Hot and Cold Transient Mode Percentages Based on Intersection Travel Times with Home and AM/PM Peak Categories Aggregated....	22
17. Phase 1 and 2 Combined Hot and Cold Transient Mode Percentages Based on Intersection Travel Times with Work and AM/PM Peak Categories Aggregated.....	22
18. The Final Phase 1 and 2 Combined Hot and Cold Transient Mode Percentages Based on Intersection Travel Times with Work, Home, and AM/PM Peak Categories Aggregated.....	22
19. Number of Responses for Peak and Off-Peak Categories.....	23
20. Comparison of the Phase 1 and 2 Mode percentages Using the Wicoxon Signed Ranks Test for Matched Pairs.....	24

LIST OF FIGURES

1. Fort Lauderdale Survey Site.....	5
2. Jacksonville Survey Site.....	6
3. Orlando Survey Site.....	7
4. Tampa Survey Site.....	8
5. Phase 2 Survey Questions.....	10
6. Simple Path Configuration Example.....	29
7. Complex Path Configuration Example.....	29
8. Flow Diagram of the Vehicle Mode Prediction Model.....	31
9. Main Program Algorithm.....	33

INTRODUCTION

A required input for the EPA recommended model, MOBILE5a, is the fractions (or percentages) of vehicles in the hot and cold transient modes. Most states currently use the default values that were derived in the 1970s from driving patterns in Los Angeles and from surveys conducted in Alabama (1), Pittsburgh and Providence (2). The validity of these default values is questionable when considering their applicability to different regions and time periods. Therefore, a research effort sponsored by the Florida Department of Transportation (FDOT) and conducted by the University of Central Florida (UCF) has been undertaken to predict mode percentages for the state of Florida.

The first phase of this study involved the distribution of survey sheets at selected intersections in major population areas in the state of Florida (3). Chi-Square tests revealed that mode percentages are not dependent on the specific city in Florida. The final transient mode percentages from that study are reproduced in Tables 1 and 2. The values in Table 2 were derived by aggregating the work and non-work categories. The purpose for this aggregation was to lessen data requirements. The second phase of the study presented in this report is a validation effort of the phase 1 results. Although the survey method was again used, the method was very different in that a few short questions were verbally asked instead of using mail-back survey sheets.

Table 1
Original Phase 1 Hot and Cold Transient Mode Percentages Based on Total Travel Times

Category ^a	Urban Arterial		Urban collector		Fringe Arterial		Fringe Collector		CBD ^b	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
W-H-AM	30.65	1.30	29.02	1.42	30.24	0.90	31.86	0.71	29.28	2.86
W-H-PM	29.01	1.68	25.67	1.48	27.68	1.21	30.18	1.03		
W-H-OP	32.60	1.65	32.87	1.21	30.25	1.23	30.47	1.39		
W-NH-AM	30.93	4.53	33.11	2.43	31.38	3.57	29.43	3.64		
W-NH-PM	32.62	12.74	30.05	12.46	33.59	11.57	33.14	11.44		
W-NH-OP	28.64	10.46	23.97	9.42	29.62	8.79	28.52	9.92		
NW-H-AM	Not Enough Information				41.45	7.24	27.66	4.10	32.63	10.15
NW-H-PM					31.25	0.00	29.76	2.30		
NW-H-OP					31.80	6.02	36.93	0.52		
NW-NH-AM	34.04	13.44	32.30	17.10	34.03	12.30	32.47	12.40		
NW-NH-PM	35.08	7.41	30.71	10.24	39.13	6.42	42.30	8.37		
NW-NH-OP	36.19	13.91	35.85	11.67	35.95	12.00	36.52	13.32		

^aW = Work; NW=Non-Work; H = Home Based; NH = Non-Home Based; AM = Morning Peak; PM = Evening Peak; OP = Off-Peak.

^bDue to insufficiency of data, the results were combined.

Table 2
Original Phase 1 Hot and Cold Transient Mode Percentages Based on Total Travel Times with Work and AM/PM Peak Categories Aggregated

Category ^a	Urban Arterial		Urban collector		Fringe Arterial		Fringe Collector		CBD ^b	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
H-P	29.83	1.49	27.35	1.45	34.42	2.95	29.31	2.59	31.75	8.24
H-OP	32.60	1.65	32.87	1.21	31.40	4.77	35.24	0.75		
NH-P	33.83	9.96	31.53	12.04	35.51	8.89	35.79	9.64		
NH-OP	34.22	13.01	32.74	11.08	34.30	11.16	34.43	12.43		

^aH = Home Based; NH = Non-Home Based; P = Peak; OP = Off-Peak.

^bDue to insufficiency of data, the results were combined.

BACKGROUND

Emissions from vehicles are highly dependent on engine and catalytic converter temperatures. In general, emissions are highest just after the engine is started and lowest after the engine and catalytic converter are allowed to stabilize to a normal operating temperature. The difference in emission rates for these modes is so great that they must be considered in order to accurately predict emission rates at any location (4).

The three possible modes of operation of a vehicle are the hot transient, cold transient, and stabilized modes. According to the Federal Test Procedure (FTP), the transient mode is defined as the first 505 seconds of operation of a vehicle. The terms hot and cold start refer to engine and catalyst temperature start conditions. A catalyst-equipped vehicle that has been in the off condition (soak period) for less than or equal to one hour is designated as a hot start while a cold start refers to the soak period being greater than one hour. For non-catalyst equipped vehicles, a four hour period is used to define hot and cold starts. A cold start corresponds to a cold transient mode and a hot start to a hot transient mode. Once correct operating temperatures are reached, the vehicle is in the hot stabilized mode. The default values recommended by EPA for use in MOBILE5a if no other information is available is 27.3% for hot transient and 20.6% for cold transient. However, EPA encourages development of specific hot and cold start percentages for use in MOBILE5a.

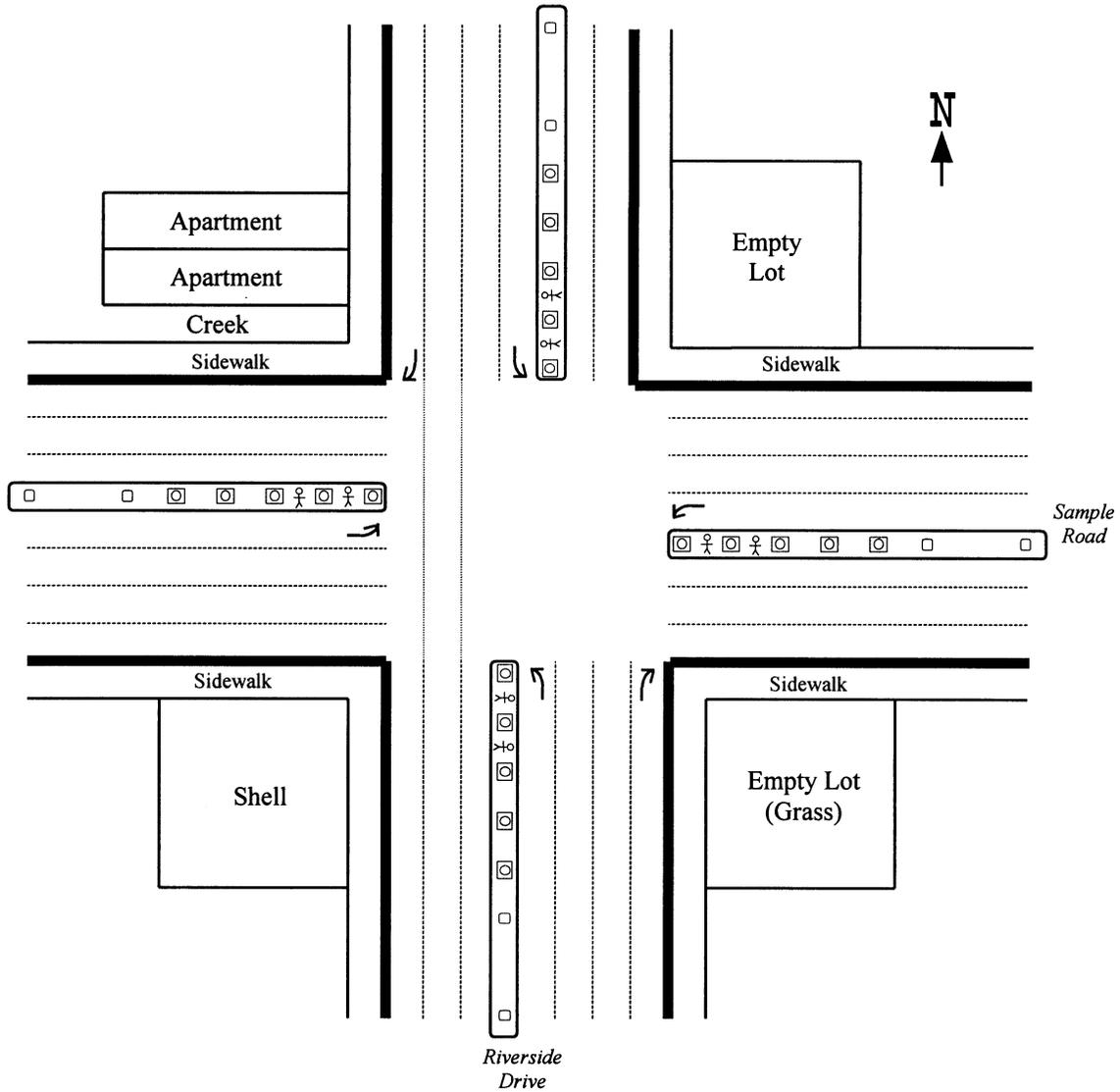
METHODOLOGY

Survey Sites

Four intersections were chosen in different cities in Florida to provide representative sampling. The cities were the same as the ones used in phase 1 and were representative of the four largest urban areas in the State. The sites are listed in Table 3 and the site layout maps are shown in Figures 1 through 4. Permission for surveying was obtained before sampling from each Florida Department of Transportation (FDOT) district office. The determination of area type (CBD, urban, and fringe) for each intersection was based on the population density of the area while the facility types (arterial and collector) were determined by considering each street rather than the intersection as a whole. The sites were chosen by inspection with the provision that sufficient combinations of area and facility types be used and survey personnel safety considerations. In addition, intersections used in phase 1 were excluded. The cities themselves were not used as a categorizing variable because the previous study had shown that different cities in Florida were not statistically significant factors on a 95% confidence level.

Table 3
Site Locations for Surveying

City	Intersection	Area Type	Facility Types
Fort Lauderdale	Sample Road and Riverside Drive	Fringe	Arterial and Collector
Jacksonville	University Blvd. and Phillips Hwy.	Urban	Arterial and Arterial
Orlando	Aloma Avenue and Lakemont Avenue	Urban	Arterial and Collector
Tampa	Jackson Street and Florida Avenue	Central Business District (CBD)	CBD Local Streets

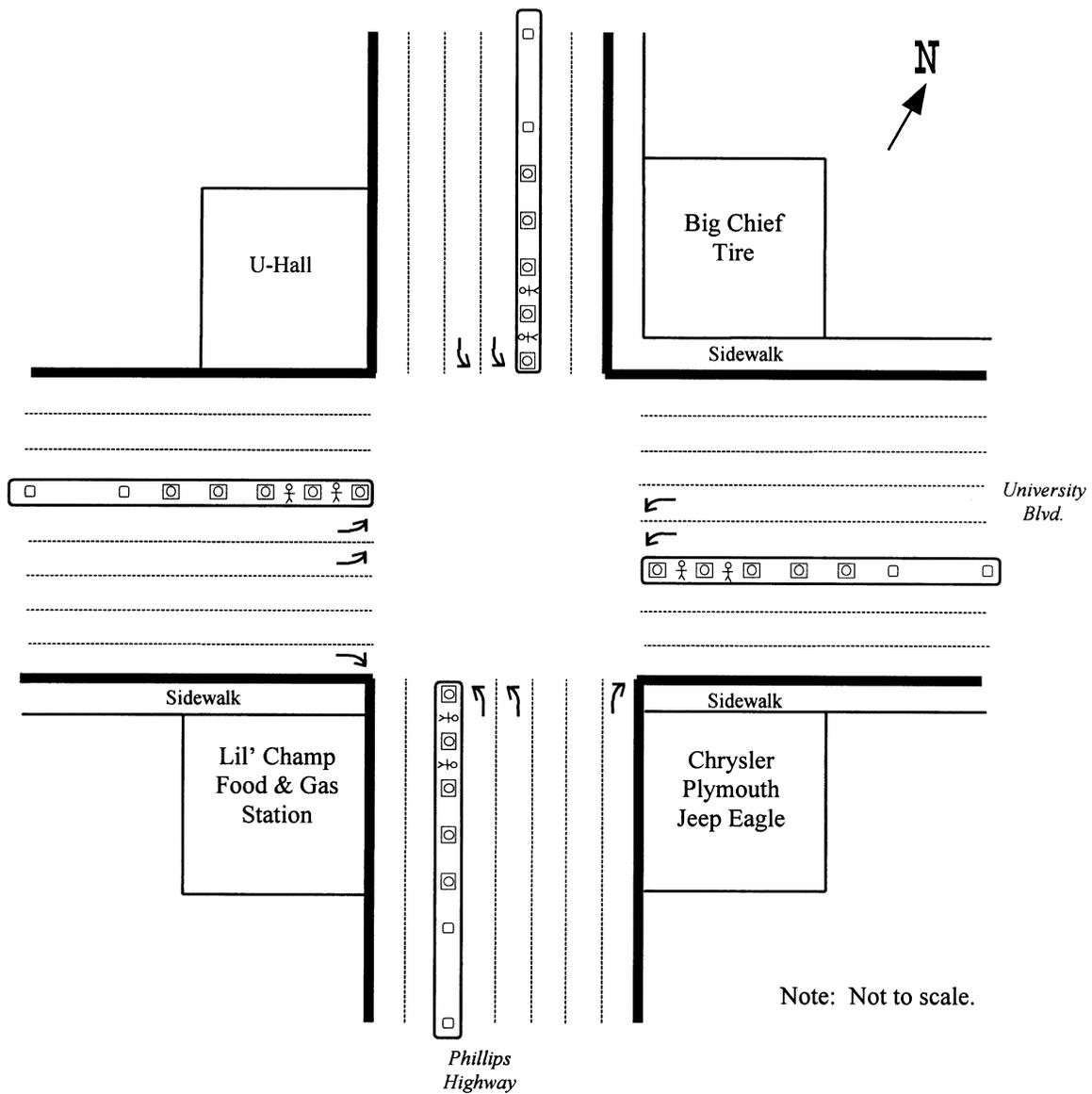


Note: Not to scale.

KEY

- ⊕ Surveyors
 - Sign Locations (125' and 200')
 - ⊞ Cone Locations (0', 25', 50', 75', and 100')
- (See pictorial descriptions page for further details)

Figure 1
Fort Lauderdale Survey Site

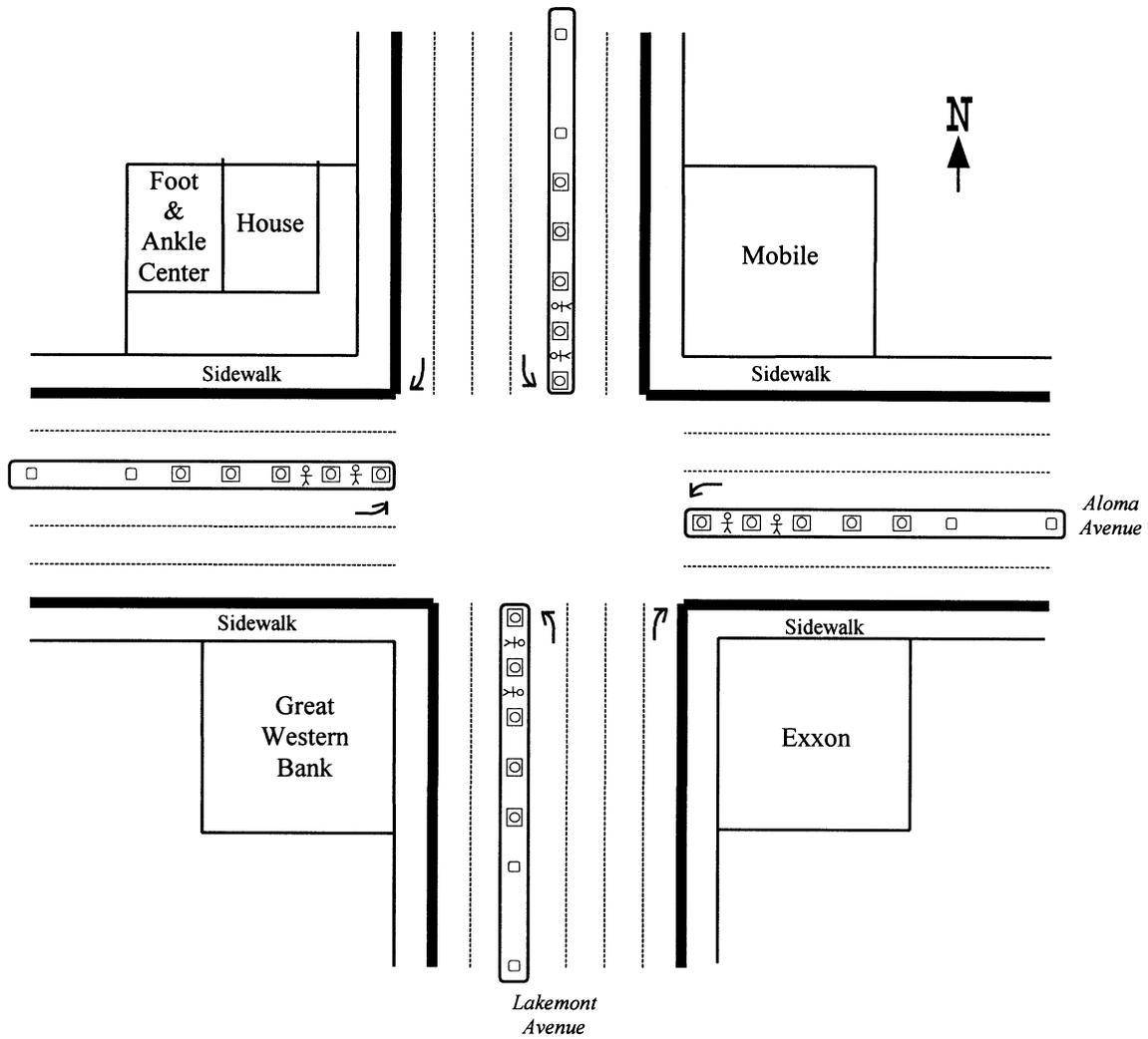


Note: Not to scale.

KEY

- ⊕ Surveyors
 - Sign Locations (125' and 200')
 - ⊗ Cone Locations (0', 25', 50', 75', and 100')
- (See pictorial descriptions page for further details)

Figure 2
Jacksonville Survey Site

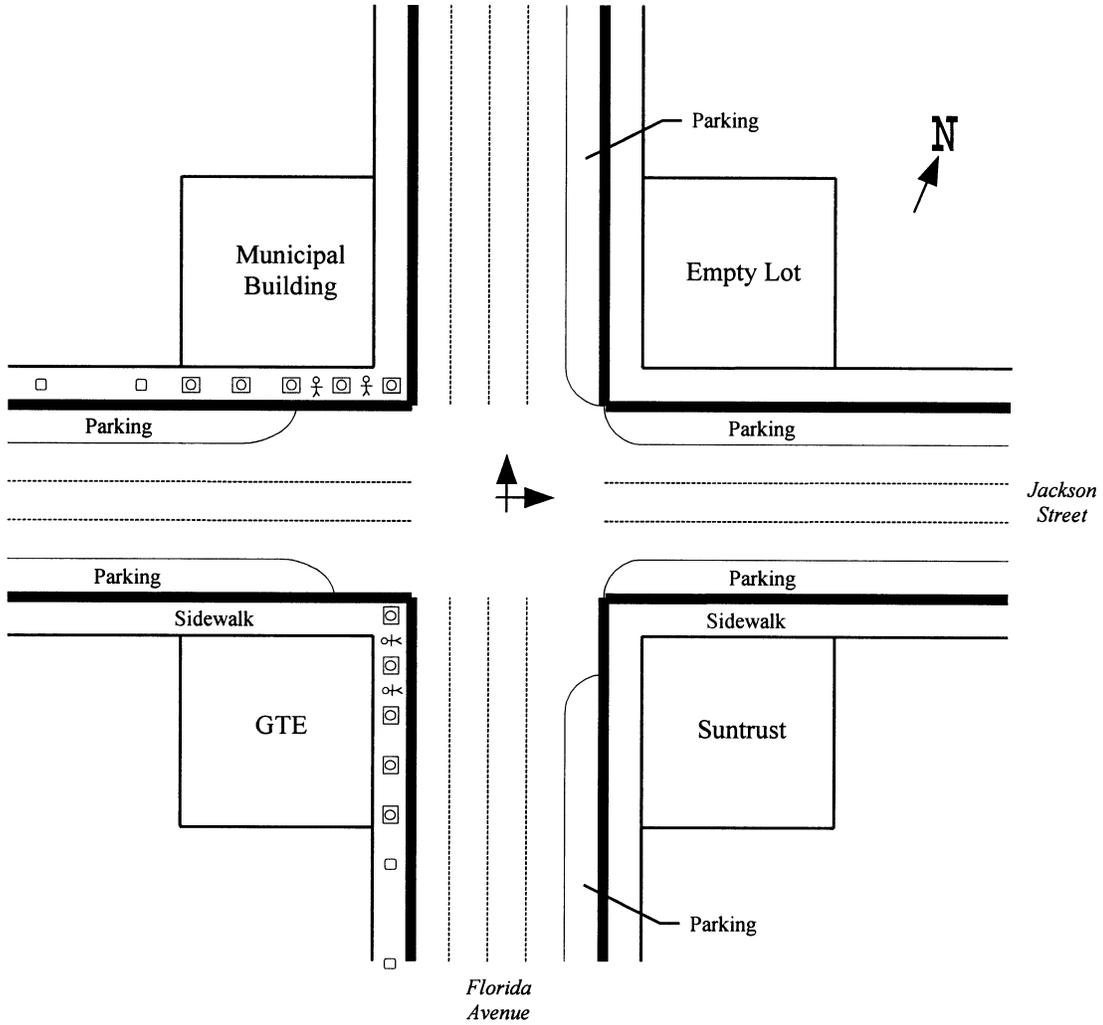


Note: Not to scale.

KEY

- ☺ Surveyors
 - Sign Locations (125' and 200')
 - ⊠ Cone Locations (0', 25', 50', 75', and 100')
- (See pictorial descriptions page for further details)

Figure 3
Orlando Survey Site



Note: Not to scale.

KEY

- ⊠ Surveyors
 - Sign Locations (125' and 200')
 - ⊞ Cone Locations (0', 25', 50', 75', and 100')
- (See pictorial descriptions page for further details)

Figure 4
Tampa Survey Site

Survey Procedures

For those intersections with raised medians (i.e. for two-way streets), surveyors stood on the medians and surveyed vehicles that were preparing to make left turns. For the Tampa intersection (the only one with one-way streets), surveyors stood on the driver's side curb of each street to ask questions. Consequently, vehicles in the left-turn lanes were surveyed. As a prerequisite, each of the surveyors were required to attend a safety training session which provided information on such matters as how to approach vehicles, importance of survey wear (i.e. orange vests), and what to do under adverse conditions (i.e. rain). In addition, the surveyors were trained for courtesy and timeliness. If all four questions could not be asked during a red cycle, the vehicle in question was motioned by the surveyor to move on. The data for this vehicle was consequently incomplete and was not used. This was preferred over the alternative situation (delaying vehicles) which would have impeded the flow of traffic.

Similar to the first phase of the project, the surveys in this study only included light-duty vehicles. Therefore, the results may be skewed to that vehicle type. Also, since only collectors and arterials were used, the resulting percentages would not be appropriate for freeways or neighborhood streets.

Survey Response Analysis

Mode percentages are used in MOBILE5a to determine average emission factors for a given region. Since a vehicle is in its final mode once the destination is reached, the total distance (or time) traveled would tend to skew mode percentages to represent the final condition of the vehicle rather than during the trip. This was evident in the data at

the end of phase 1. Therefore, it was concluded that a more accurate estimate of the emission factor would require mode percentages of the vehicle at the midpoint of its trip. Since determining percentages at midpoints for each vehicle in a survey area is not realistic, travel times to carefully selected intersections were used to approximate an average travel time to a midpoint of a trip.

The four survey questions for phase 2 are shown in Figure 5. The first two questions were used to categorize the transient mode percentages also using the time of day, area type, and facility type. Since the phase 1 study showed that non-catalyst equipped vehicles (i.e. older than 1975) represented a very small percentage of the total survey participants, all vehicles were considered to be catalyst equipped. Therefore, a criteria of 1 hour was used as the soak period in determining hot and cold start mode percentages. If the answer to question 3 was less than 1 hour, the vehicle was classified as being in the hot start mode when the trip began, and if the answer was greater than 1 hour, then the vehicle was grouped in the cold start mode at the trip start.

<p>1. Is this Trip Work Related?</p> <p><input type="checkbox"/> Yes</p> <p><input type="checkbox"/> No</p> <p>2. Are you coming from home, going home, or neither?</p> <p><input type="checkbox"/> Yes (from home or going home ----- home based)</p> <p><input type="checkbox"/> No (neither ----- non-home based)</p> <p>3. How long was your vehicle parked before you started it for this trip?</p> <p><input type="checkbox"/> equal to or less than one hour</p> <p><input type="checkbox"/> more than one hour</p> <p>4. How long has it taken you from the moment you started your vehicle to get to this point?</p>

Figure 5
Phase 2 Survey Questions

In an effort to accurately represent driving patterns, travel times greater than 300 minutes (six hours) were excluded from the analysis. This is justified because most drivers are not likely to be able to drive more than six hours without taking some sort of break or stopping for fuel. Therefore, any travel times greater than six hours are likely to have been an exaggeration or a misunderstanding of the survey question. In the responses that were eliminated, the travel times were typically much greater than six hours; the most extreme case being 48 hours.

The equations used to determine mode percentages for phase 2 should exactly repeat values calculated using the equations from phase 1. Although the percentages actually refer to vehicle miles traveled (VMT), the phase 2 equations are presented in terms of travel times since vehicle speed was assumed to be constant for each category. Therefore, using distances instead of time in equations 3 to 6 would have produced identical results to equations 1 and 2 shown here.

$$\text{Hot Start Fraction} = (\text{Number of Hot Starts} / \text{Total Number of Responses}) \quad (1)$$

$$\text{Cold Start Fraction} = (\text{Number of Cold Starts} / \text{Total Number of Responses}) \quad (2)$$

$$\text{Transient \%} = (\text{Total Transient Travel Time} / \text{Total Travel Time})(100\%) \quad (3)$$

$$\text{Stabilized \%} = (\text{Total Stabilized Travel Time} / \text{Total Travel Time})(100\%) \quad (4)$$

$$\text{Cold Transient \%} = (\text{Cold Start Fraction})(\text{Transient \%}) \quad (5)$$

$$\text{Hot Transient \%} = (\text{Hot Start Fraction})(\text{Transient \%}) \quad (6)$$

The total transient travel time for each category was determined by summing the transient travel time for each individual survey and dividing by the sum of the total travel times. If an individual had been driving for more than 505 seconds before reaching an intersection, the transient travel time for that driver was 505 seconds and the stabilized travel time was the total travel time to the intersection minus 505 seconds. If the driving time was less than 505 seconds, then the entire trip to the intersection was in the transient mode. The transient and stabilized percentages must sum to 100% and likewise for the hot and cold start percentages. Therefore, calculating one value in either set would allow a trivial calculation of the other (i.e. subtracting from 100%).

The data from phase 1 was re-evaluated to determine mode percentages based on trips to an intersection. In addition to the destination-based morning and afternoon travel times, the travel time to an intersection had been obtained in phase 1 by verbally asking the drivers how long they took to reach the intersection. This re-evaluation was conducted to provide mode percentages representative of more realistic average driving patterns in an area.

Statistical Analysis

One of the goals in surveying was to sample a large enough population to obtain statistically valid results. Therefore, the sample size for each category was estimated from the following equation:

$$n = (z/H)^2 pq$$

where n = sample size

z = test statistic

H = accuracy requirement (\pm)

p = population proportion

$q = 1-p$

For example, an extreme accuracy requirement of $H = \pm 0.01$ (1 %) and conservative estimates of the proportions (i.e. $p=0.5$ and $q=0.5$), the sample size would be approximately 9506 as shown below:

$$n = (1.96/0.01)^2(0.5)(0.5) = 9506$$

A sample size this large was not needed, and therefore, a more realistic requirement was considered:

$$n = (1.96/0.02)^2(0.5)(0.5) = 2401$$

$$n = (1.96/0.03)^2(0.5)(0.5) = 1067$$

$$n = (1.96/0.04)^2(0.5)(0.5) = 600$$

$$n = (1.96/0.05)^2(0.5)(0.5) = 384$$

Accuracy values (H) of ± 0.04 (4%) and ± 0.05 (5%) are too large in light of the fact that some mode percentages determined in phase 1 were very small (i.e. 1% and 2%). Since there was no way of accurately predicting the sample size for each category, only the total sample size could be used as a crude indicator of the adequacy of the data. For low

category sample sizes of 100 and 200, the corresponding accuracy values are shown below:

$$H_{100} = (1.96)[(0.5)(0.5)/100]^{1/2} = \pm 0.098$$

$$H_{200} = (1.96)[(0.5)(0.5)/200]^{1/2} = \pm 0.069$$

However, due to the fact that some of the hot and cold mode percentages are relatively low, an accuracy value of ± 0.069 or 7% is large in comparison to the overall value and the percentages corresponding to sample sizes below 200 must be used with caution. Even mode percentages derived from a sample size of 9506 ($H = \pm 0.01$) should be scrutinized for reliability depending on the mode percentage values. It should be remembered that statistical testing is a valuable tool but does not always lead to absolute answers. The magnitude of a calculated mode percentage should always be compared to the accuracy value, which is dependent on the sample size of the category in question.

The validation process required a comparison of the phase 1 and phase 2 results, and statistical testing was conducted. Since the number (n) of comparable results in the final percentage tables was sometimes less than 30, the most appropriate testing for the sample size was determined to be the Wilcoxon Signed Ranks Test for Matched Pairs.

This testing was used with the conditions shown below:

H_0 : The frequency distributions of the two sets of values are identical (null hypothesis).

H_a : The frequency distributions of the two sets are shifted away from each other (alternate hypothesis).

Reject H_0 if $T < T_0$.

The value, T , is the two-tailed test statistic that is equal to the smaller of the two (positive and negative) calculated rank sums, and T_0 is the critical value. Although frequency distributions are included, the Wilcoxon Test is a Matched Pairs Test in that it shows whether or not the two sets of values are statistically dissimilar. The Wilcoxon Test was used for this project.

ANALYSIS AND RESULTS

Tables 4 through 8 show the re-evaluated results from phase 1 while Tables 9 through 13 show the resulting mode percentages for phase 2. As previously mentioned, the new phase 1 values are based on travel times to an intersection rather than to a final destination are assumed to be representative of the midpoint of the trip. The original analysis of the mode percentages for phase 1 was such that each driver provided two travel times (AM and PM) corresponding to an entire trip rather than to an intersection. But in the re-evaluation process, the verbally asked question of how long it took to get to an intersection was used so that only one response per driver was obtained. In effect, this reduced the phase 1 data by half. The usage of actual travel time was also different than the method used in phase 1 where the traveled distances (or time) for home-based trips were determined using the midpoints of the areas represented by zip codes.

Tables 4 through 8 and 9 through 13 show a systematic aggregation of the categorizing factors for phase 1 and 2, respectively. This was done in an attempt to reduce the burden of factors required to use the mode percentages. Tables 14 through 18 are the result of combining the phase 1 and 2 results while Table 19 indicates the sample size for each peak and off-peak categories used in Tables 8, 13, and 18. These sample sizes serve as an indication of the accuracy of each derived percentage. Considering only the combined data, two categories (urban-collector-peak and central business district) had sample sizes close to 200. Since the combined mode percentages in Table 18 for urban-collector-peak are relatively large, more reliability may be placed in these values than in some of the other categories. Besides these two, there are at least two other categories that need to be mentioned. The fringe-arterial-peak and fringe-collector-peak categories

Table 4
Re-Evaluated Phase 1 Hot and Cold Transient Mode Percentages Based on
Intersection Travel Times

Category ^a	Urban Arterial		Urban collector		Fringe Arterial		Fringe Collector		CBD	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
W-H-AM	34.52	0.54	NEI	NEI	36.43	0.99	49.02	0.51	49.51	0.00
W-H-PM	NEI	NEI	NEI	NEI	NEI	NEI	NEI	NEI	NEI	NEI
W-H-OP	NEI	NEI	NEI	NEI	NEI	NEI	NEI	NEI	NEI	NEI
W-NH-AM	50.14	2.71	NEI	NEI	44.01	1.16	54.30	1.77	52.69	0.00
W-NH-PM	NEI	NEI	13.42	13.42	59.60	19.87	NEI	NEI	40.25	6.71
W-NH-OP	38.46	1.98	34.73	2.10	37.85	1.67	38.07	2.18	32.34	1.99
NW-H-AM	NEI	NEI	NEI	NEI	NEI	NEI	NEI	NEI	NEI	NEI
NW-H-PM	NEI	NEI	52.36	0.00	29.53	0.59	NEI	NEI	49.66	0.00
NW-H-OP	56.90	0.00	55.35	1.91	44.38	1.25	46.12	1.76	34.85	1.71
NW-NH-AM	NEI	NEI	NEI	NEI	NEI	NEI	NEI	NEI	NEI	NEI
NW-NH-PM	NEI	NEI	50.94	12.74	38.32	4.03	NEI	NEI	41.68	7.82
NW-NH-OP	44.11	1.03	34.34	3.94	36.09	3.22	37.45	3.64	38.51	4.11

^aW = Work; NW=Non-Work; H = Home Based; NH = Non-Home Based; AM = Morning Peak; PM = Evening Peak; OP = Off-Peak.

Note: NEI = Not Enough Information.

Table 5
Re-Evaluated Phase 1 Hot and Cold Transient Mode Percentages Based on
Intersection Travel Times with AM/PM Peak Categories Aggregated

Category ^a	Urban Arterial		Urban collector		Fringe Arterial		Fringe Collector		CBD	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
W-H-P	34.52	0.54	NEI	NEI	36.43	0.99	49.02	0.51	49.51	0.00
W-H-OP	NEI	NEI	NEI	NEI	NEI	NEI	NEI	NEI	NEI	NEI
W-NH-P	50.14	2.71	13.42	13.42	44.35	1.52	54.30	1.77	46.80	2.92
W-NH-OP	38.46	1.98	34.73	2.10	37.85	1.67	38.07	2.18	32.34	1.99
NW-H-P	NEI	NEI	52.36	0.00	29.53	0.59	NEI	NEI	49.66	0.00
NW-H-OP	56.90	0.00	55.35	1.91	44.38	1.25	46.12	1.76	34.85	1.71
NW-NH-P	NEI	NEI	50.94	12.74	38.32	4.03	NEI	NEI	41.68	7.82
NW-NH-OP	44.11	1.03	34.34	3.94	36.09	3.22	37.45	3.64	38.51	4.11

^aW = Work; NW=Non-Work; H = Home Based; NH = Non-Home Based; P= Peak;OP = Off-Peak.

Note: NEI = Not Enough Information.

Table 6
Re-Evaluated Phase 1 Hot and Cold Transient Mode Percentages Based on
Intersection Travel Times with Home and AM/PM Peak Categories Aggregated

Category ^a	Urban Arterial		Urban collector		Fringe Arterial		Fringe Collector		CBD	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
W-P	38.30	1.14	13.42	13.42	39.52	1.20	50.58	0.89	48.35	1.24
W-OP	38.46	1.98	34.73	2.10	37.85	1.67	38.07	2.18	32.34	1.99
NW-P	NEI	NEI	52.56	1.95	31.18	1.36	NEI	NEI	47.42	2.19
NW-OP	44.62	0.99	40.54	3.30	37.72	2.82	39.26	3.26	37.26	3.18

^aW = Work; NW=Non-Work; P= Peak;OP = Off-Peak.

Note: NEI = Not Enough Information.

Table 7
Re-Evaluated Phase 1 Hot and Cold Transient Mode Percentages Based on
Intersection Travel Times with Work and AM/PM Peak Categories Aggregated

Category ^a	Urban Arterial		Urban collector		Fringe Arterial		Fringe Collector		CBD	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
H-P	34.52	0.54	52.36	0.00	34.18	0.87	49.02	0.51	49.60	0.00
H-OP	56.90	0.00	55.35	1.91	44.38	1.25	46.12	1.76	34.85	1.71
NH-P	50.14	2.71	32.33	12.93	43.40	1.91	54.30	1.77	44.09	5.51
NH-OP	40.37	1.65	34.57	2.93	36.89	2.52	37.74	2.93	34.64	2.78

^aH = Home; NH=Non-Home; P= Peak;OP = Off-Peak.

Table 8
Re-Evaluated Phase 1 Hot and Cold Transient Mode Percentages Based on
Intersection Travel Times with Work, Home, and AM/PM Peak Categories
Aggregated

Category ^a	Urban Arterial		Urban collector		Fringe Arterial		Fringe Collector		CBD	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
P	38.30	1.14	46.75	3.34	37.28	1.23	50.58	0.89	47.76	1.84
OP	40.60	1.63	37.93	2.76	37.77	2.37	38.74	2.80	34.70	2.57

^aP= Peak;OP = Off-Peak.

Table 9
Phase 2 Hot and Cold Transient Mode Percentages Based on Intersection Travel Times

Category ^a	Urban Arterial		Urban collector		Fringe Arterial		Fringe Collector		CBD	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
W-H-AM	36.06	6.76	41.97	10.95	23.58	3.54	14.50	10.87	25.65	8.55
W-H-PM	23.77	12.95	38.84	20.01	19.92	14.11	32.20	5.08	58.61	6.84
W-H-OP	21.77	14.51	28.96	15.16	26.03	14.71	22.28	17.33	19.21	14.78
W-NH-AM	19.48	12.99	15.03	15.03	19.41	8.63	NEI	NEI	39.68	22.67
W-NH-PM	16.22	23.05	16.74	33.48	9.61	28.84	20.31	30.47	46.49	23.24
W-NH-OP	16.43	21.09	15.86	23.32	20.62	22.91	9.85	27.09	16.10	17.32
NW-H-AM	27.66	11.85	41.87	29.31	22.03	10.49	53.16	0.00	9.84	24.60
NW-H-PM	18.56	17.75	20.26	25.33	14.52	27.58	28.76	57.51	43.22	27.01
NW-H-OP	18.44	19.72	32.55	21.77	20.69	15.52	22.02	25.85	21.60	18.52
NW-NH-AM	39.07	3.91	19.85	19.85	18.38	13.13	72.11	24.04	NEI	NEI
NW-NH-PM	24.37	21.12	12.17	10.96	17.14	17.14	16.94	33.87	50.00	50.00
NW-NH-OP	22.17	20.66	18.89	22.76	17.72	17.72	25.49	22.31	23.55	17.67

^aW = Work; NW=Non-Work; H = Home Based; NH = Non-Home Based; AM = Morning Peak; PM = Evening Peak; OP = Off-Peak.

Note: NEI = Not Enough Information.

Table 10
Phase 2 Hot and Cold Transient Mode Percentages Based on Intersection Travel Times with AM/PM Peak Categories Aggregated

Category ^a	Urban Arterial		Urban collector		Fringe Arterial		Fringe Collector		CBD	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
W-H-P	25.46	12.12	40.22	16.52	21.60	9.82	27.48	7.17	41.26	6.60
W-H-OP	21.77	14.51	28.96	15.16	26.03	14.71	22.28	17.33	19.21	14.78
W-NH-P	17.32	19.56	15.58	18.69	17.45	12.22	41.71	20.85	42.60	22.94
W-NH-OP	16.43	21.09	15.86	23.32	20.62	22.91	9.85	27.09	16.10	17.32
NW-H-P	20.12	16.77	23.81	25.91	18.91	17.69	38.28	35.34	24.35	24.35
NW-H-OP	18.44	19.72	32.55	21.77	20.69	15.52	22.02	25.85	21.60	18.52
NW-NH-P	26.89	18.15	13.56	12.51	17.89	14.91	37.53	28.15	NEI	NEI
NW-NH-OP	22.17	20.66	18.89	22.76	17.72	17.72	25.49	22.31	23.55	17.67

^aW = Work; NW=Non-Work; H = Home Based; NH = Non-Home Based; P= Peak;OP = Off-Peak.

Note: NEI = Not Enough Information.

Table 11
Phase 2 Hot and Cold Transient Mode Percentages Based on Intersection Travel
Times with Home and AM/PM Peak Categories Aggregated

Category ^a	Urban Arterial		Urban collector		Fringe Arterial		Fringe Collector		CBD	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
W-P	22.58	14.76	32.45	17.21	20.70	10.35	28.94	8.98	41.65	8.99
W-OP	18.59	18.41	22.16	19.41	24.23	17.42	19.10	19.72	17.34	16.31
NW-P	21.81	17.11	19.45	20.28	18.65	16.91	37.97	32.54	24.98	24.98
NW-OP	19.83	20.08	28.23	21.96	19.97	16.06	22.82	25.03	22.41	18.17

^aW = Work; NW=Non-Work; P= Peak;OP = Off-Peak.

Table 12
Phase 2 Hot and Cold Transient Mode Percentages Based on Intersection Travel
Times with Work and AM/PM Peak Categories Aggregated

Category ^a	Urban Arterial		Urban collector		Fringe Arterial		Fringe Collector		CBD	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
H-P	23.29	14.01	31.95	21.30	20.28	13.25	30.03	15.02	38.20	9.89
H-OP	20.17	16.98	31.23	19.37	22.44	15.27	22.31	21.41	19.87	15.78
NH-P	20.15	19.16	14.32	14.94	17.63	13.62	39.29	25.26	42.76	24.43
NH-OP	17.99	21.01	17.15	23.11	19.06	20.04	16.80	25.20	17.22	17.43

^aH = Home; NH=Non-Home; P= Peak;OP = Off-Peak.

Table 13
Phase 2 Hot and Cold Transient Mode Percentages Based on Intersection Travel
Times with Work, Home, and AM/PM Peak Categories Aggregated

Category ^a	Urban Arterial		Urban collector		Fringe Arterial		Fringe Collector		CBD	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
P	22.29	15.63	25.42	18.90	19.64	13.36	31.94	17.25	38.74	11.74
OP	19.05	19.03	25.52	20.82	21.51	16.56	20.94	22.29	18.38	16.72

^aP= Peak;OP = Off-Peak.

Table 14
Phase 1 and 2 Combined Hot and Cold Transient Mode Percentages Based on
Intersection Travel Times

Category ^a	Urban Arterial		Urban collector		Fringe Arterial		Fringe Collector		CBD	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
W-H-AM	35.42	2.58	41.97	10.95	33.92	1.42	47.09	1.21	35.81	4.71
W-H-PM	23.77	12.95	38.84	20.01	19.92	14.11	32.20	5.08	58.61	6.84
W-H-OP	21.77	14.51	28.96	15.16	26.03	14.71	22.28	17.33	19.21	14.78
W-NH-AM	29.61	8.74	15.03	15.03	39.67	2.26	55.14	1.72	46.45	10.93
W-NH-PM	16.22	23.05	15.54	25.89	25.91	25.91	20.31	30.47	42.05	14.02
W-NH-OP	22.00	16.21	26.63	11.18	37.28	2.42	37.16	2.97	27.27	6.78
NW-H-AM	27.66	11.85	41.87	29.31	22.03	10.49	53.16	0.00	9.84	24.60
NW-H-PM	18.56	17.75	28.78	18.37	25.20	8.40	28.76	57.51	49.49	4.34
NW-H-OP	18.88	19.47	37.79	17.22	35.91	6.00	40.46	7.42	32.12	5.39
NW-NH-AM	39.07	3.91	19.85	19.85	18.38	13.13	72.11	24.04	NEI	NEI
NW-NH-PM	24.37	21.12	15.60	11.14	30.24	8.82	16.94	33.87	41.39	9.74
NW-NH-OP	29.30	14.20	28.22	11.39	35.35	3.79	37.20	4.08	36.81	5.64

^aW = Work; NW=Non-Work; H = Home Based; NH = Non-Home Based; AM = Morning Peak; PM = Evening Peak; OP = Off-Peak.

Note: NEI = Not Enough Information.

Table 15
Phase 1 and 2 Combined Hot and Cold Transient Mode Percentages Based on
Intersection Travel Times with AM/PM Peak Categories Aggregated

Category ^a	Urban Arterial		Urban collector		Fringe Arterial		Fringe Collector		CBD	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
W-H-P	27.53	9.57	40.22	16.52	31.10	3.91	44.94	1.68	43.05	5.27
W-H-OP	21.77	14.51	28.96	15.16	26.03	14.71	22.28	17.33	19.21	14.78
W-NH-P	22.50	16.37	15.32	18.11	39.04	3.38	53.27	3.26	44.48	12.27
W-NH-OP	22.00	16.21	26.63	11.18	37.28	2.42	37.16	2.97	27.27	6.78
NW-H-P	20.12	16.77	30.47	19.78	24.30	9.00	38.28	35.34	42.14	7.14
NW-H-OP	18.88	19.47	37.79	17.22	35.91	6.00	40.46	7.42	32.12	5.39
NW-NH-P	26.89	18.15	16.36	12.51	26.43	10.23	37.53	28.15	41.39	9.74
NW-NH-OP	29.30	14.20	28.22	11.39	35.35	3.79	37.20	4.08	36.81	5.64

^aW = Work; NW=Non-Work; H = Home Based; NH = Non-Home Based; P= Peak;OP = Off-Peak.

Table 16
Phase 1 and 2 Combined Hot and Cold Transient Mode Percentages Based on
Intersection Travel Times with Home and AM/PM Peak Categories Aggregated

Category ^a	Urban Arterial		Urban collector		Fringe Arterial		Fringe Collector		CBD	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
W-P	25.78	11.91	31.74	17.05	33.72	3.71	47.15	2.12	43.44	6.84
W-OP	21.89	15.61	27.28	12.31	36.54	3.24	35.88	4.22	25.89	8.15
NW-P	21.81	17.11	25.05	16.93	24.79	9.30	37.97	32.54	41.98	7.73
NW-OP	23.68	17.01	33.13	14.42	35.52	4.38	38.03	4.91	34.92	5.55

^aW = Work; NW=Non-Work; P= Peak;OP = Off-Peak.

Table 17
Phase 1 and 2 Combined Hot and Cold Transient Mode Percentages Based on
Intersection Travel Times with Work and AM/PM Peak Categories Aggregated

Category ^a	Urban Arterial		Urban collector		Fringe Arterial		Fringe Collector		CBD	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
H-P	24.94	12.08	34.72	18.44	28.70	5.70	44.49	3.92	42.73	5.99
H-OP	20.37	16.87	35.10	16.58	34.51	7.20	36.73	9.58	27.13	8.91
NH-P	23.68	16.86	15.92	14.78	35.70	5.20	51.70	5.85	43.18	11.26
NH-OP	24.12	15.64	27.35	11.28	36.22	3.17	37.18	3.54	30.29	6.42

^aH = Home; NH=Non-Home; P= Peak;OP = Off-Peak.

Table 18
The Final Phase 1 and 2 Combined Hot and Cold Transient Mode Percentages
Based on Intersection Travel Times with Work, Home, and AM/PM Peak
Categories Aggregated

Category ^a	Urban Arterial		Urban Collector		Fringe Arterial		Fringe Collector		CBD	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
P	24.52	13.57	27.90	17.01	30.80	5.52	46.48	4.47	42.87	7.18
OP	22.55	16.12	30.52	13.48	35.92	3.94	37.09	4.60	29.43	7.10

^aP= Peak;OP = Off-Peak.

Table 19
Number of Responses for Peak and Off-Peak Categories

		Phase 1	Phase 2	Combined
Urb-Art	Peak	104	609	713
	Off-Peak	363	1659	2022
	Total	467	2268	2735
Urb-Col	Peak	30	197	227
	Off-Peak	384	641	1025
	Total	414	838	1252
Fri-Art	Peak	344	163	507
	Off-Peak	2409	285	2694
	Total	2753	448	3201
Fri-Col	Peak	288	77	365
	Off-Peak	1203	128	1331
	Total	1491	205	1696
CBD	Peak	108	129	237
	Off-Peak	666	296	962
	Total	774	425	1199

for the combined data set have sample sizes of approximately 500 and 400, respectively. While these sample sizes do provide lower error values (H), their corresponding mode percentages are also relatively low. In fact, the hot transient mode percentage for the fringe-collector-peak category is statistically the least accurate since it is the only percentage with an accuracy value greater than the percentage itself.

Table 20 represents the results of statistically testing the data contained in Tables 8 and 13. Table 8 is the results of phase 1 while Table 13 is the results from phase 2. Tests were not conducted on other tables mainly due to insufficiency of sample size to produce reliable percentages. As shown in Table 20, the outcome of the test with an alpha (α) value of 0.05 is that the null hypothesis (the two sets being equal) was not rejected. Since the test is based on rejection of the null hypothesis, it cannot be flatly

stated that the two data sets are similar. However, the implication of not being able to reject the null hypothesis is that the two sets may be similar. From statistical tables, the p-value was found to be greater than 0.1. This test provided sufficient evidence to allow the two sets of results (phase 1 and 2) to be combined (Table 18).

When comparing the first and second phase results, it is obvious that hot transient mode percentages from phase 1 are consistently lower than the corresponding values from phase 2. The hot transient percentages from phase 1 (Table 8) range from 0.89 to 2.80 while the percentages from phase 2 (Table 13) range from 11.74 to 22.29. The difference in cold transient percentages is less obvious but still noticeable where phase 1 ranges from 34.27 to 50.58 and phase 2 ranges from 18.38 to 38.74. These differences can result in the speculation that surveying in phase 2 may have been skewed since the surveying sites were not as varied as they were in phase 1. Only four sites were sampled in phase 2 as opposed to 26 in phase 1. However, since the surveying method was more refined in phase 2, using less assumptions concerning travel times and category classifications, the results from phase 2 are thought to be more representative by the authors. In addition, as indicated in Table 19, total sample sizes for both phases are comparable even though phase 1 involved sampling a greater number of sites. It should also be remembered that phase 1 was for the total trip whereas phase 2 was for the midpoint of the trip. This makes the data seem very reasonable in both cases.

In general, Table 8 (results from phase 1 data) appears to indicate that the cold transient percentages are lower than their hot counterparts. This is in contrast to the phase 2 results in Table 13 which appear to show that hot and cold values are comparable although hot values tend to be systematically higher. This difference may, again, have

been due to assumptions used in phase 1. However, Tables 8 and 13 both agree in that cold transient mode percentages are highest for fringe collectors and CBDs under the peak category. This seems to reasonable since a large proportion of drivers would be driving relatively short distances during peak hours from home to work or vice versa. Although not evident in Tables 8 and 13, the combined results in Table 18 show that the urban area types had the highest hot transient percentages which is an indication that more people drive longer distances in urban areas. On average, Table 8 shows that the hot and cold transient percentages derived from this project are about 18% lower and 12% higher, respectively, than the EPA default values of 27.3% (hot) and 20.6% (cold). The authors feel this is a true statement. The difference in these percentages may not be limited to Florida.

COMPUTER MODEL

Introduction

Besides using survey data, transient mode percentages can also be predicted using transportation planning theory. In a best case situation, the survey data validate the transportation planning model output. The procedures required to develop such a model is presented in this part of the report. Since TRANPLAN is the most widely used transportation planning software, the methodology for the new model is based on this software. However, the model can also be applied to other planning software with minor modifications since most transportation planning packages use similar program structures. This would be true in Florida where FSUTMS is used.

The process involves the use of a transportation planning software that assigns traffic volumes to a network of transportation facilities. The resulting loaded network file contains information embedded in its link elements that can be used to accumulate trip times along each path in order to determine mode percentages. Although there are different methods that can be employed to determine mode percentages, they are all essentially based on the concept of accumulation along pathways.

Comparative Models

The Traffic Assignment Program for Emission Studies (TAPES) developed at the University of Tennessee in Knoxville uses a complete model approach. TAPES incorporates all-or-nothing, iterative assignment, and equilibrium assignment algorithms to assign traffic volumes to a network (5). Therefore, it is not dependent on a transportation planning software to obtain loaded network files. TAPES accumulates the

hot and cold transient mode trips during the assignment process by designating each link in a path as either transient or stabilized depending on whether or not the link comes before or after the 505 second mark along a path. The link that actually contains this cutoff point (505 seconds) is approximated as having half of its trips in the transient mode and half in the stabilized mode.

A module (NETMRG) in the MINUTP transportation planning package, developed by the COMSIS Corporation, can also be used to predict mode percentages. This module accumulates trips along each pathway using a loaded network produced by running MINUTP. While not as configurable as the complete method used in the TAPES model, the module method is easier to implement for individuals with experience in using a transportation planning package. This latter approach is the basis for the new model presented in this report.

Theory

In order to determine mode percentages, travel times along each path must be determined. In short, this is accomplished by identifying the starting and ending points (zones) of a path as well as its direction. Then the travel time associated with each link on the path is accumulated as the path is traced from beginning to end. For example, the path from zone 1 to zone 2 shown in Figure 6 would involve the accumulation of four travel times corresponding to the four links in between the two zones. In addition, traffic volumes on each link and trip frequencies would have to be used as weighting factors. Figure 6 is a simplistic example of a pathway configuration where the complexities associated with a multi-path network are not shown.

In contrast, the network in Figure 7, while still simplistic, reveals the complexities

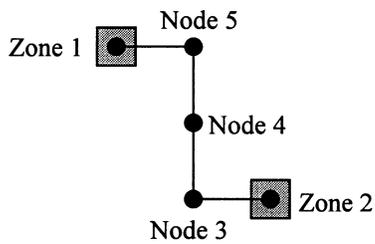


Figure 6
Simple Path Configuration Example

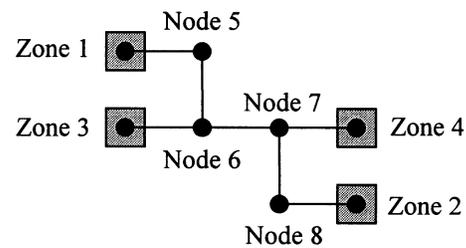


Figure 7
Complex Path Configuration Example

involved with analyzing more than one path. Accumulation of travel times along each path is done in a similar manner as previously described. The difficulty arises when the different paths overlap. For example, the link represented by nodes 6 and 7 is common for the path between zones 1 and 2 and the path between zones 3 and 4. A less obvious example of a common link would be that represented by zone 3 and node 6 which is common for the path between zones 1 and 3 and the path between zones 3 and 4. In analyzing a common link, the volume corresponding to each pathway must be used, rather than a total volume. Therefore, if the transportation planning software does not provide the separate volumes, it must be approximated using a reasonable ideology. The reason for these separate traffic volumes is to obtain accurate weights that can be applied to travel times.

Once travel times are accumulated for each link along a path, the links are classified into area and facility types. From these categorized links (containing the accumulated travel times), transient travel times are determined and then summed along

with the accumulated travel times in their respective categories. Each of the summed values are weighted according to traffic volumes and trip frequencies along each link. The final hot and cold transient mode percentages are determined by multiplying the total transient mode percentages by corresponding hot and cold start mode fractions that were obtained from the survey data. Since transportation planning software cannot normally predict start mode data, special algorithms must be written.

Along with the overall, categorized percentages, values for each link can also be determined. The steps required to do this are identical to those required to determine the aforementioned procedures except that links are kept separate instead of combining them into categories. The resulting percentages (cold, hot, and stabilized) can be added to the original loaded network file producing a final network file that can be used in conjunction with a graphical plotting program such as a geographic information system (GIS) software to plot and analyze the spatial distributions of the mode percentages. TRANPLAN network files typically contain three empty data fields (LG1, LG2, and LG3) per each link that can be used to hold the mode percentages.

When an area includes trips coming into it from external zones, the corresponding travel times and start mode data must be provided. If the travel time data is not available from the transportation planning software, then it must be approximated using a reasonable method. Likewise, if the external zones cannot be identified, then the start mode data for these externally-originating trips must also be approximated.

Model Structure

As shown in Figure 8, a vehicle mode prediction model developed for TRANPLAN or most other planning software requires several input files. Arguably, the most important one is the loaded network file since it contains most of the link information. In addition, path data and a trip table file are required to identify paths and provide trip frequencies, respectively. In TRANPLAN, the path file can be obtained by running an appropriate command file. Although the trips inside a zone may not be important from a transportation planning point of view, these typically short trips can have significant effects on air quality analysis. Therefore, internal zone data is a necessity. Start mode percentages are also necessary, and they can be obtained from the

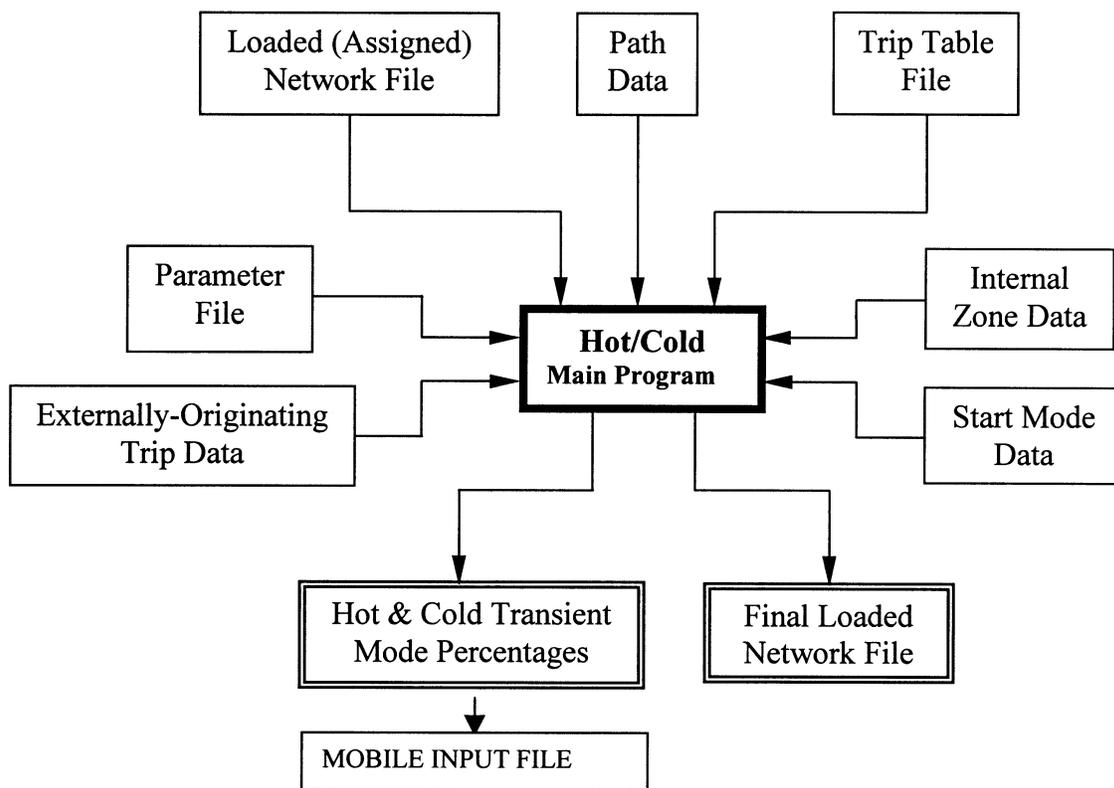


Figure 8
Flow Diagram of the Vehicle Mode Prediction Model

survey data. The externally-originating trip data contains both start mode data as well as travel times corresponding to trips that start from zones outside of an area under study. And finally, the parameter file is an ASCII file that contains all of the input and output file names, and as a result, it is the only file that needs to be “manually” provided to the main program.

Unlike the input files, there are only two output files. The hot/cold results file is an ASCII file that contains the final hot and cold transient mode percentages categorized under area and facility types. This file, with area default information, could automatically generate a MOBILE input file as shown in Figure 8. The mode percentages in this file could be directly compared to the results obtained from the surveys. The final loaded network file is identical to the original loaded network file except for the inclusion of the hot, cold, and stabilized percentages in the previously mentioned LG1, LG2, and LG3 data fields.

Main Algorithm

The program listing shown in Figure 9 is the main algorithm for the new model. The listing is presented to exemplify the relative simplicity of the main calculation routines. As indicated, a modern form of the BASIC programming language was used to write the program. This language was chosen for its English-like commands and long-variable naming conventions that would allow an easier conceptual understanding of the listing than other languages that use archaic commands and restricts variable name lengths. Although the program was written with TRANPLAN in mind, it is sufficiently general that it can easily be modified for any transportation planning package.

```

REM ***** PART A - Accumulate travel time and determine volume for each link *****
FOR path=1 TO lastpath
  FOR link = start(path) TO end(path)
    traveltime(path,link) = traveltime(path,link-1) + time(link)
    trafficvolume(path,link) = numbertrips(path) * volume(path,link)
  NEXT
NEXT

REM ***** PART B - Categorize links into area/facility types and sum travel times and volumes *****
FOR area = 1 TO 3
  FOR facility = 1 TO 2
    FOR path = 1 TO lastpath
      FOR link = 1 TO lastlink
        IF linkarea(link) = area AND linkfacility(link) = facility THEN
          vol(area, facility) = vol(area, facility) + trafficvolume(path,link)
          voltime(area, facility) = voltime(area, facility) + traveltime(path,link) * trafficvolume(path,link)
          IF traveltime(path,link) <= 505 THEN
            transvoltime(area, facility) = transvoltime(area, facility) + traveltime(path,link) * trafficvolume(path,link)
          ELSE
            transvoltime(area, facility) = transvoltime(area, facility) + 505 * trafficvolume(path,link)
          END IF
        END IF
      NEXT
    NEXT
    weightedtime(area, facility) = voltime(area, facility) / vol(area, facility)
    weightedtranstime(area, facility) = transvoltime(area, facility) / vol(area, facility)
  NEXT
NEXT

REM ***** PART C - Determine categorized mode percentages *****
FOR area = 1 TO 3
  FOR facility = 1 to 2
    transpercent(area, facility) = 100 * weightedtranstime(area, facility) / weightedtime(area, facility)
    coldtranspercent(area, facility) = transpercent(area, facility) * coldstartfraction(area, facility)
    hottranspercent(area, facility) = transpercent(area, facility) * hotstartfraction(area, facility)
    stabilizedpercent(area, facility) = 100 - transpercent(area, facility)
  NEXT
NEXT

REM ***** PART D - Determine mode percentages for each link *****
FOR path = 1 TO lastpath
  FOR link = start(path) TO end(path)
    volumetime(path, link) = volumetime(path, link) + traveltime(path, link) * trafficvolume(path, link)
    IF traveltime(path, link) <= 505 THEN
      transvolumetime(path, link) = transvolumetime(path, link) + traveltime(path, link) * trafficvolume(path, link)
    ELSE
      transvolumetime(path, link) = transvolumetime(path, link) + 505 * trafficvolume(path, link)
    END IF
  NEXT
NEXT
FOR link = 1 TO lastlink
  FOR path = 1 TO lastpath ' ***** This middle section accumulates values in overlapping links
    linkvolumetime(link) = linkvolumetime(link) + volumetime(path, link)
    linktransvolumetime(link) = linktransvolumetime(link) + transvolumetime(path, link)
    linkvolume(link) = linkvolume(link) + trafficvolume(path, link)
  NEXT ' ***** End of middle section
  linktime(link) = linkvolumetime(link) / linkvolume(link)
  linktranstime(link) = linktransvolumetime(link) / linkvolume(link)
NEXT
FOR link = 1 TO lastlink
  linktranspercent(link) = 100 * linktranstime(link) / linktime(link)
  coldlinktranspercent(link) = linktranspercent(link) * linkcoldstartfraction(link)
  hotlinktranspercent(link) = linktranspercent(link) * linkhotstartfraction(link)
  stabilizedlinkpercent(link) = 100 - linktranspercent(link)
NEXT

```

Figure 9
Main Program Algorithm

Other routines that are required to read and write data are not shown, but they have been assumed to have been implemented. For easier understanding, the main program has been separated into four parts.

Part A accumulates travel times along a path and records the times in an array called “traveltime.” Traffic volumes are also recorded for each link in the “trafficvolume” array taking into account the fact that volumes must be multiplied by the number of trips (from trip frequency) to produce weighted values. Unlike travel times, traffic volumes do not accumulate along a path since the flow along a path refers to one volume. However, the program assumes that a preliminary routine has separated the volumes on each link so that an individual link can be associated with one of several different volumes depending on the path under study.

Part B categorizes each link into area and facility types and weights travel times on each link by their respective volumes. This is accomplished by first summing the products of each categorized travel time and its corresponding volume, and then dividing by the total volume. The codes used for area types, 1 to 3, refer to fringe, urban, and CBD while the facility codes, 1 and 2, refer to arterial and collector.

Part C determines the hot, cold, and stabilized mode percentages for each of the area and facility type combinations. The start mode arrays, “coldstartfraction” and “hotstartfraction,” contain data obtained from the start mode data file. As with the survey data analysis, transient mode percentages are derived from proportions of travel times rather than distances. Therefore, in order for the percentages to represent vehicle miles traveled (VMT) percentages, vehicle speed must be assumed to be constant for each area and facility type combinations.

Part D contains routines that mimic the analyses performed in parts A through C. The major difference is that the purpose of part D is to determine mode percentages for individual links rather than for overall area and facility type categories. As indicated, the middle section is required because travel times for overlapping (common) links must be aggregated to produce one value for each link. Unlike part C, each link must be provided with start mode data. A routine (not shown) was assumed to have read the start mode data file and assigned the fractional values to the arrays, “linkcoldstartfraction” and “linkhotstartfraction.”

CONCLUSIONS

Travel times (or distances) to an intersection will produce mode percentages that are more representative of average conditions in a region than overall travel times. Therefore, the phase 1 data of this project was re-evaluated to match the method used in phase 2 where travel times to an intersection was used. Although differences are apparent in the phase 1 and 2 results, the Wilcoxon Signed Ranks Test for Matched Pairs indicates that the two sets may be similar. This outcome justified merging the two sets of results. The combined results in Table 18 are presented as the final values for use in the state of Florida. The data was aggregated so that only peak and off-peak categories are available for the different area and facility types. This was done in an effort to reduce the factor requirements for using the percentages and to provide more data points for each of the calculated percentages. These values may be manually implemented immediately by FDOT personnel to construct MOBILE5a input files. Although the other combined results in Tables 14 through 17 may also be used, caution must be exercised due to accuracy limitations caused by small sample sizes.

Although the methodology for a new vehicle mode prediction model was presented for use with TRANPLAN, it can easily be modified for use with any transportation planning package including FSUTMS which uses the same methodology as TRANPLAN. The model takes a module approach where output files (i.e. loaded network file) from a transportation planning program are used to accumulate travel times along paths. The predicted mode percentages can be categorized into area and facility type combinations or assigned to individual links that can be plotted to analyze spatial

distributions of the percentages. A MOBILE5a file could also be automatically generated using area specific default values for other parameters.

The authors believe that these new mode percentages are much more accurate for the State of Florida than the dated and area specific default values suggested by EPA. In addition, the derived values may be useable outside of the State of Florida.

REFERENCES

1. Ellis, G.W., W.T. Camps, and A. Treadway. "The Determination of Vehicular Cold and Hot Operating Fractions for Estimating Highway Emissions." Federal Highway Administration, Office of Environmental Policy. Washington D.C.: September 1978.
2. Midurski, T.P. and A.H. Castaline. "Determination of Percentages of Vehicles Operating in the Cold Start Mode." U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Report EPA 450/3-77-023. August 1977.
3. Wayson, Roger L., C. David Cooper, Marta Lynne Brenner, "The Determination of Hot and Cold Start Percentages for the State of Florida to be Used in Mobile Source Emissions," FL-ER-66-97, Florida Dept. of Transp., State of Florida, February 26, 1997.
4. Enns, Phil, John German, and Jim Markey. "Review of Federal Test Procedure Modifications Report." U.S. Environmental Protection Agency, Office of Mobile Sources. Report EPA 420-R-93-007. May 1993.
5. Venigalla, Mohan Muralidhar. "A Network Assignment Based Approach to Modeling Mobile Source Emissions." A Dissertation Presented for the Doctor of Philosophy Degree, The University of Tennessee, Knoxville. May 1994.