Southwest Region University Transportation Center

Investigation of Improvements to Truck Volume Assignments and Public Transportation Benefits Methodologies in TTI's *Urban Mobility Report*

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16. Abstract

The Texas A&M Transportation Institute's (TTI's) often-cited *Urban Mobility Report (UMR)* provides transportation decision-makers with urban-area congestion statistics and trends. Data and their availability have continued to evolve rapidly over the years that this report has been produced, and TTI researchers have updated the *UMR* methodology as new data sources and information become available.

The objectives of this project were to (a) investigate the *UMR* methodology assumptions related to the daily volume distributions for trucks and possible methodology improvements, and (b) investigate the *UMR* methodology related to the benefits of transit ridership and transit delay reduction calculations and possible methodology improvements.

To satisfy the first objective, TTI researchers collected vehicle classification data from Georgia, Texas, Washington, and Colorado. While there were only 36 sites used to investigate potentially new truck distribution graphs, the results indicate that trucks have a different time-of-day distribution than a distribution created from all vehicles together. Because the sample size of these findings is relatively low, researchers hope to investigate these findings on larger samples prior to making methodological changes in the *UMR.*

To satisfy the second objective, TTI researchers collaborated with public transit experts at the University of South Florida, Center for Urban Transportation Research. Chapter 4 provides several proposed methodological improvements to the transit benefits methodology for the 2013 *UMR*, including (a) explicitly accounting for the miles traveled by roadway-based transit vehicles operating in mixed traffic conditions, and (b) more accurately accounting for the potential shift to private passenger vehicles in a post-transit environment by transit riders for the passenger miles they have actually traveled by transit. Researchers plan to incorporate these proposed changes into the 2013 *UMR*. Chapter 4 also documents future improvement opportunities for the short term and long term.

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INVESTIGATION OF IMPROVEMENTS TO TRUCK VOLUME ASSIGNMENTS AND PUBLIC TRANSPORTATION BENEFITS METHODOLOGIES IN TTI'S *URBAN MOBILITY REPORT*

by

William L. Eisele, Ph.D., P.E.
Senior Research Engineer
Texas A&M Transportation Institute

David L. Schrank, Ph.D.
Associate Research Scientist
Texas A&M Transportation Institute

Dong Hun (Don) Kang, Ph.D.
Associate Transportation Researcher
Texas A&M Transportation Institute

Steven E. Polzin, Ph.D.
Director, Mobility Policy
Center for Urban Transportation Research
University of South Florida
Tampa, Florida

and

Xuehao Chu, Ph.D.
Senior Research Associate, Mobility Policy
Center for Urban Transportation Research

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Southwest Region University Transportation Center
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National Center for Transit Research
Center for Urban Transportation Research
University of South Florida
Tampa, FL 33620-5375

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The authors would also like to thank that National Center for Transit Research at the Center for Urban Transportation Research at the University of South Florida for funding.

The authors would also like to thank the project monitor, Mr. Paul Czech of the Minnesota Department of Transportation. The authors would also like to thank the numerous transportation agencies and their staff who provided vehicle classification data used in this report.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

INTRODUCTION

The Texas A&M Transportation Institute's often-cited *Urban Mobility Report (UMR)* provides transportation decision-makers with urban-area congestion statistics and trends. The *Urban Mobility Report* has been produced by the Texas A&M Transportation Institute (TTI) for nearly 25 years. The report has become the gold standard for information on traffic congestion and mobility in the U.S. The report includes congestion statistics for all U.S. urban areas and contains information on the impacts of treatments—both operational and public transportation related. The report also discusses the impacts of congestion on truck freight transportation in the United States.

The data and their availability have continued to evolve rapidly over the years that this report has been produced, and it is imperative that the methodology change to make use of new and improved data. Over the years, TTI researchers have updated the *UMR* methodology as new data sources and information became available.

Project Objectives

The objectives of the project upon which this report is based were:

1. Investigate *UMR* methodology assumptions related to the daily volume distributions for trucks and possible methodology improvements.
2. Investigate the *UMR* methodology related to the benefits of transit ridership and transit delay reduction calculations and possible methodology improvements.

TRUCK VOLUME ASSIGNMENTS IN THE *UMR*

The first objective of this work was to investigate the *UMR* methodology assumptions related to the daily volume distribution assignments for trucks. The *2012 Urban Mobility Report* methodology describes the use of typical time-of-day traffic distribution profiles to estimate hourly traffic flows from average daily traffic volumes obtained from the Federal Highway Administration's (FHWA's) Highway Performance Monitoring System (HPMS; *1-3*). The methodology is based upon previous analytical efforts that have developed typical traffic profiles at the hourly level (*4,5*). These traffic distribution profiles were developed for the following different scenarios (resulting in 16 unique profiles):

- Functional class: freeway and non-freeway (principal arterial).
- Day type: weekday and weekend.
- Traffic congestion level: percentage reduction in speed from free flow (varies for freeways and principal arterials).
- Directionality: peak traffic in the morning (AM), peak traffic in the evening (PM), and approximately equal traffic in each peak.

The daily volume distributions currently used in the *UMR* include all vehicle types. TTI researchers also get a percent trucks value from HPMS; therefore, total volume for trucks can be estimated. However, the profiles in the *UMR* are not separated out for "trucks only." That was the impetus for this research—to identify when/where it may be appropriate to distribute truck volume differently than "all vehicles," as currently assumed in the *UMR*.

PUBLIC TRANSPORTATION BENEFITS IN THE *UMR*

The second objective of this research was investigating the *UMR* methodology related to the benefits of transit ridership and transit delay reduction calculations and possible methodology improvements. Buses and trains carry a significant number of trips in many large areas and provide important benefits in many smaller ones. Peak-period public transportation service during congested hours can improve the transportation capacity, provide options for travel, and allow those without a vehicle to gain access to jobs, schools, medical facilities, and other destinations. Managed lane facilities such as high-occupancy toll (HOT) lanes that have variable pricing to manage traffic and ensure uncongested (free-flow) conditions provide a reliable transit option. In the case of public transportation lines that do not use roads, the service can also be reliable, as the lines are not affected by the vehicle breakdowns or collisions that plague the roadway system, and they are not as affected by weather, road work, and other congestion-causing events.

The delay benefits associated with public transportation service are calculated using the "what if many of the transit riders were in the general traffic stream" case. Additional traffic on already-crowded road networks would affect all the other peak-period travelers as well. This is an artificial case in the sense that the effects of a transit service shutdown would be much more significant and affect more than just the transit riders or roadway travelers. Public transportation patrons who rely on the service for their basic transportation needs would find travel much more difficult—making jobs, schools, medical facilities, and other trip destinations much harder to reach. Businesses that count on the reliable service to access consumers would suffer—as would workers who rely on public transportation service.

COLLABORATION

TTI researchers coordinated with subject-matter experts at the Tier 1 Transit University Transportation Center (UTC) at the University of South Florida (USF), Center for Urban Transportation Research (CUTR), and they provided technical assistance related to investigating the *UMR* public transportation benefits methodology. Researchers at CUTR were successful in obtaining supplemental funds to complete the collaboration and the analysis contained in Chapter 4 of this report.

Researchers at the Region 10 UTC at the University of Washington provided valuable insights and contacts for Washington State truck data.

TRUCK DISTRIBUTION DATA COLLECTION, ANALYSIS METHODS, AND CONCLUSIONS

Data Collection and Data Reduction

Researchers collected truck volume data from four state departments of transportation (DOTs)—Georgia, Texas, Washington, and Colorado. Formats of the raw traffic volume data from differing states were not the same due to the various reporting measures of the state DOTs. Hence, they were reduced to common formats for the purpose of this study. Researchers collected data from approximately 200 different sites from these four state DOTs.

Data from freeways and arterials were most desirable because those are the functional classifications included in the *UMR*. Nearly half of the 200 sites obtained were from Colorado collector streets, and they were removed from the dataset. Because some roadways were not in urban or suburban locations, the results were not expected to be representative of distributions of most interest for the *UMR* and were also removed. Ultimately, there were 36 classification sites remaining in the analysis dataset. Researchers defined truck volume as FHWA vehicle classes 4 through 13 and all-vehicle volume as vehicle classes 1 through 13.

Analysis Steps

Researchers used the following steps to analyze the hourly truck volume data:

1. Separate weekday and weekend data.
2. Separate freeway and non-freeway data.
3. Estimate hourly traffic volumes of all vehicles and trucks.
4. Identify traffic distributions by charting average hourly percentages of daily volume.
5. Group traffic distribution charts by peak distribution, freeway/non-freeway weekday/weekend.
6. Plot new hourly traffic distributions with the distributions from the *Urban Mobility Report.*

Conclusions and Future Work

While there were only 36 sites used to investigate potentially new truck distribution graphs, the results generally indicated that trucks have a different time-of-day distribution than a distribution created from all vehicles together. The following are highlights of the findings documented in this report:

- Weekday has a higher proportion of trucks than weekend, and freeway has a higher proportion of trucks than non-freeway (Table 3-1).
- In general, truck distribution profiles do not follow the patterns of all-vehicle profiles (Figures 3-1 and 3-2).
- The non-freeway truck distribution for the AM-PM peak profile shows that trucks are in with the peak periods of the all-vehicle distributions (Figure 3-3 and Figure 3-7). While this is based upon only three samples and requires more research, it is hypothesized that this could be due to deliveries being made during peak periods.
- On weekends, the truck distributions have a similar form as all-vehicle distributions, but

the truck volumes begin to form sooner (Figure 3-4 and Figure 3-8).

- For morning-peaking distributions for weekdays, the newly developed truck distributions show a typical midday peak pattern during the regular work hours, and freeway trucks start forming about an hour earlier than on non-freeway roads (Figure 3-5). Similarly, along afternoon-peaking roadways, the truck distributions show a smooth midday peak for freeway but a plateau between 8 AM and 4 PM (Figure 3-6).

The results suggest that the distribution for trucks in the *UMR* is different than for all vehicles. However, because the sample size of these findings is relatively low, researchers hope to investigate these findings on larger samples prior to making methodological changes in the *UMR*.

PUBLIC TRANSPORTATION BENEFITS METHODOLOGY CHANGES

The second objective of this research project was to investigate the *UMR* methodology related to the benefits of transit ridership and transit delay reduction calculations and possible methodology improvements. TTI researchers collaborated with public transit experts at the USF CUTR to assist in the development of suggested methodological changes to improve the public transportation benefits methodology used in the *UMR*.

Chapter 4 provides documentation of CUTR's recommended improvements for the *2013 UMR*. TTI researchers will look to incorporate these changes into the *2013 UMR*. The proposed approaches presented in Chapter 4 provide several improvements to the transit benefits methodology in the *UMR*, including:

- Explicitly accounting for the miles traveled by roadway-based transit vehicles operating in mixed traffic conditions.
- More accurately accounting for the potential shift to private passenger vehicles in a post-transit environment by transit riders for the passenger miles they have actually traveled by transit. This is facilitated by:
    - Using average daily weekday passenger-miles traveled (PMT) from the National Transit Database rather than average daily weekday equivalent converted from annual total PMT by dividing it with 300 days.
    - Disaggregating PMT for roadway-based transit modes to functional classes by the distribution of vehicle revenue miles for these transit modes rather than by the distribution of base roadway traffic.
    - Using mode shift factors from on-board surveys rather than assuming that every PMT on transit would be shifted to private passenger vehicles in a post-transit environment.
    - Accounting for path circuity rather than assuming the same path of travel between transit and roadway for a given origin-destination pair.

Chapter 4 also documents future improvement opportunities for the short term and long term. Researchers will investigate these methodological improvements as resources allow.

CHAPTER 1
INTRODUCTION AND BACKGROUND

The Texas A&M Transportation Institute's (TTI's) often-cited *Urban Mobility Report (UMR)* provides transportation decision-makers with urban-area congestion statistics and trends. The *Urban Mobility Report* has been produced by the Texas A&M Transportation Institute for nearly 25 years. The report has become the gold standard for information on traffic congestion and mobility in the U.S. The report includes congestion statistics for all U.S. urban areas and contains information on the impacts of treatments—both operational and public transportation related. The report also discusses the impacts of congestion on truck freight transportation in the United States.

The data and their availability have continued to evolve rapidly over the years that this report has been produced, and it is imperative that the methodology change to make use of new and improved data. Over the years, TTI researchers have updated the *UMR* methodology as new data sources and information became available.

PROJECT OBJECTIVES

The objectives of the project upon which this report is based were:

1. Investigate *UMR* methodology assumptions related to the daily volume distributions for trucks and possible methodology improvements.
2. Investigate the *UMR* methodology related to the benefits of transit ridership and transit delay reduction calculations and possible methodology improvements.

The next two sections provide additional background for each of these two objectives.

TRUCK VOLUME ASSIGNMENTS IN THE *UMR*

The first objective of this work was to investigate the *UMR* methodology assumptions related to the daily volume distribution assignments for trucks. The *2012 Urban Mobility Report* methodology describes the use of typical time-of-day traffic distribution profiles to estimate hourly traffic flows from average daily traffic volumes obtained from the Federal Highway Administration's (FHWA's) Highway Performance Monitoring System (HPMS; *1-3*). The methodology is based upon previous analytical efforts that have developed typical traffic profiles at the hourly level (*4,5*). These traffic distribution profiles were developed for the following different scenarios (resulting in 16 unique profiles):

- Functional class: freeway and non-freeway (principal arterial).
- Day type: weekday and weekend.
- Traffic congestion level: percentage reduction in speed from free flow (varies for freeways and principal arterials).
- Directionality: peak traffic in the morning (AM), peak traffic in the evening (PM), and approximately equal traffic in each peak.

Figure 1-1 shows an example of one of these profiles for weekday traffic for no to low congestion levels. It is easy to see from these lines that two of the profiles are clearly AM peaking and two are PM peaking (as designated in the Figure 1-1 legend).

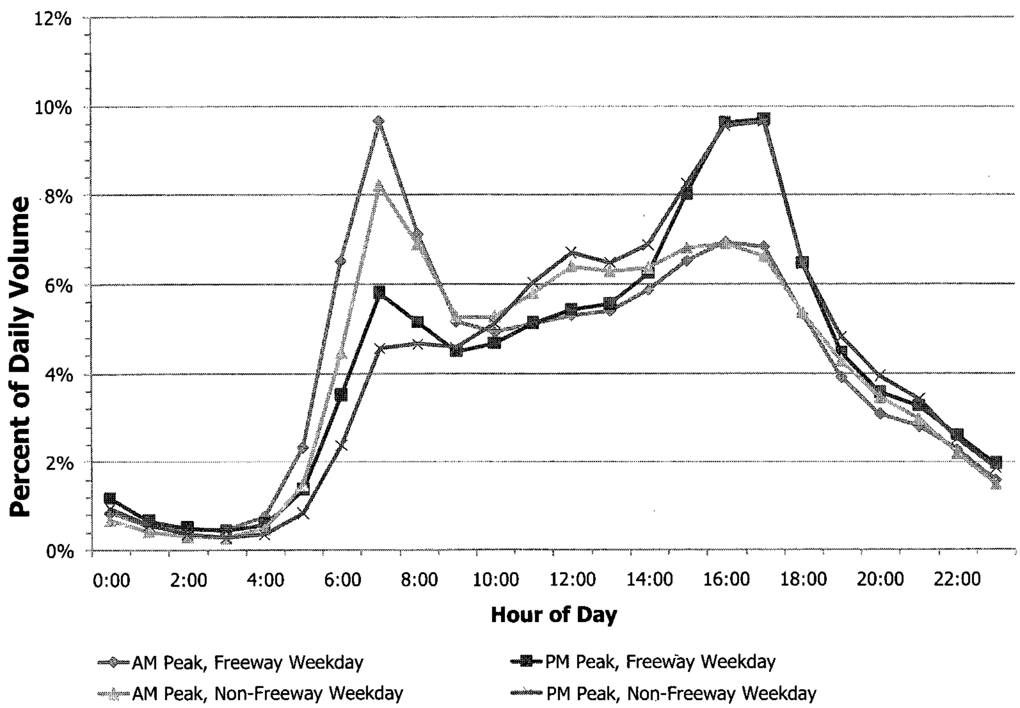


Figure 1-1. Weekday Traffic Distribution Profile for No to Low Congestion (Adapted from [*2*])

The daily volume distribution shown in Figure 1-1 includes all vehicle types. TTI researchers also get a percent trucks value from HPMS; therefore, total volume for trucks can be estimated. However, the profiles in the *UMR* are not separated out for "truck only." That was the impetus for this research—to identify when/where it may be appropriate to distribute truck volume differently than "all vehicles," as currently assumed in the *UMR*.

PUBLIC TRANSPORTATION BENEFITS IN THE *UMR*

The second objective of this research was investigating the *UMR* methodology related to the benefits of transit ridership and transit delay reduction calculations and possible methodology improvements. Buses and trains carry a significant number of trips in many large areas and provide important benefits in many smaller ones. Peak-period public transportation service during congested hours can improve the transportation capacity, provide options for travel, and allow those without a vehicle to gain access to jobs, schools, medical facilities, and other destinations. In the case of public transportation lines that do not use roads, the service can be particularly reliable, as the lines are not affected by the vehicle breakdowns or collisions that plague the roadway system, and they are not as affected by weather, road work, and other congestion-causing events.

The delay benefits associated with public transportation service are calculated using the "what if many of the transit riders were in the general traffic stream" case. Additional traffic on already-crowded road networks would affect all the other peak-period travelers as well. This is an artificial case in the sense that the effects of a transit service shutdown would be much more significant and affect more than just the transit riders or roadway travelers. Public transportation patrons who rely on the service for their basic transportation needs would find travel much more difficult—making jobs, schools, medical facilities, and other trip destinations much harder to reach. Businesses that count on the reliable service to access consumers would suffer—as would workers who rely on public transportation service.

Details of the current *UMR* public transportation methodology are documented on the *UMR* website (*2*). The methodology uses survey results from the American Public Transportation Association (APTA) to determine the percentage of ridership by mode that occurs in the peak periods (*6*). Commuter rail is assigned entirely to freeways. Heavy rail, light rail, and bus ridership are assigned to freeways and arterials based on existing vehicle-miles traveled (VMT) proportions.

Through this research project, TTI researchers collaborated with researchers at the University of South Florida (USF), Center for Urban Transportation Research (CUTR) to investigate updated methods to determine the post-transit travel behavior scenario to estimate the amount of additional vehicle traffic required to accommodate the transit passengers that might choose roadway travel.

COLLABORATION

TTI researchers coordinated with subject-matter experts at the Tier 1 Transit University Transportation Center (UTC) at USF CUTR, and they provided technical assistance related to investigating the *UMR* public transportation benefits methodology. Researchers at CUTR were successful in obtaining supplemental funds to complete the collaboration and the analysis contained in Chapter 4 of this report.

Researchers at the Region 10 UTC at the University of Washington provided valuable insights and contacts for Washington State truck data.

WORK PLAN

Researchers performed three tasks to complete this research project. The tasks are described here.

Task 1—Kickoff Meetings and Project Scoping

TTI researchers attended a kickoff meeting with researchers at CUTR in Tampa, Florida. Researchers discussed current *UMR* procedures, necessary data, project responsibilities, and timelines. The purpose of these meetings was to ensure that both outside agencies understood TTI's existing *UMR* methodology and needs. Due to supplemental funds, CUTR researchers were able to take a large role with the public transportation methodology investigation.

As part of this task, a member of the research team also met with the project monitor, Mr. Paul Czech of the Minnesota Department of Transportation, to provide an overview of the project and obtain early feedback.

Task 2—Coordinate Efforts and Provide Analyses

TTI researchers have been producing the *UMR* for more than 20 years and are very familiar with the issues surrounding data availability and applicability for the current methodology. This task was imperative for TTI researchers to coordinate the efforts at CUTR to ensure the suggested methodology enhancements are implementable. All of the truck volume assignment research was performed at TTI based upon data provided by other state transportation agencies.

Task 3—Produce Report of Methodology Improvements

The third task included the development of this final report, which documents all data gathered, analyses performed, and results achieved.

REPORT ORGANIZATION

This report has been organized around five chapters, a reference list, and an appendix as follows:

- Chapter 1: Introduction and Background—provides background to the project and project objectives.
- Chapter 2: Truck Distribution Data Collection and Analysis Methods—describes the data collection, data reduction, and data analysis methods for the truck distribution assignment research.
- Chapter 3: Truck Distribution Analysis Results—describes analysis results from implementing the analysis methods described in Chapter 2 for the truck distribution assignment research.
- Chapter 4: Recommended Methodological Improvements to the Public Transportation Methodology—provides an overview of the methodological recommendations to the public transportation benefits methodology developed by CUTR.
- Chapter 5: Conclusions and Future Work—describes the research conclusions as well as future research needs related to the topic.
- References—provides a numbered list of references sourced in the report.
- Appendix: Percentage of Daily Volume Distributions—contains truck assignment distributions for all conditions with resulting average distributions.

CHAPTER 2
TRUCK DISTRIBUTION DATA COLLECTION AND ANALYSIS METHODS

Researchers collected truck volume data from four state departments of transportation (DOTs)—Georgia, Texas, Washington, and Colorado. Formats of the raw traffic volume data from differing states were not the same due to the various reporting measures of the state DOTs. Hence, they were reduced to common formats for the purpose of this study. In the following sections, data collection and data reduction steps are described in detail.

DATA COLLECTION

To utilize truck volume data in the context of the *Urban Mobility Report*, researchers tried to obtain raw travel data recorded by the following criteria:

- Hourly volumes.
- Twenty-four hours per day.
- Weekdays and weekends.
- FHWA 13 vehicle classifications.

The raw data files received from the state DOTs included the following urban areas:

- Atlanta, Georgia.
- San Antonio, Texas.
- Austin, Texas.
- Dallas, Texas.
- Waco, Texas.
- Temple, Texas.
- Seattle, Washington.
- Denver, Colorado.

Atlanta data were collected from 55 automated traffic recorder sites in District 7 of the Georgia Department of Transportation (GDOT) for the year 2010. The raw data were received as a Microsoft Access® database file. The database contained hourly traffic volume tables divided by functional classification of the roads. Each table contained county name, site identification (ID), date, hour, direction, lane, and traffic volume per each FHWA 13 vehicle classification. The 55 traffic recorder sites were categorized by functional classifications of the roads as follows:

- Twenty-seven traffic recorder sites for interstate.
- Five traffic recorder sites for other freeways and expressways.
- Six traffic recorder sites for other principal arterials.
- Seventeen traffic recorder sites for minor arterials.

There were two different sets of traffic volume data from the Texas Department of Transportation (TxDOT). The first set of data consisted of two text files for year 2010 and year 2011 from 12 sites in the San Antonio, Austin, and Dallas TxDOT districts. Each file contained station ID, direction, lane, data, hour, and traffic volume per each FHWA 13 vehicle classification. The second set of data were obtained from equipment deployed in the Waco

TxDOT District along I-35. The traffic records were gathered from 17 sites during January and February of 2013 near Waco and Temple. They contained sensor ID, date, hour, location, small volume, medium volume, large volume, average speed, average occupancy, and total lanes.

Seattle data were collected from seven permanent recorder sites along the freeways around the Puget Sound area for the year 2011. The data were received as a text file in a report form where the traffic data were segmented in columns and sections at each page. To extract the raw data from the report, a simple computer program was developed to parse them into common formats for analysis. The resulting raw data file contained recorder ID, direction, date, hour, traffic volumes by car/van/pickup, single truck, double truck, and triple truck.

Denver data were obtained from 121 recorder sites from arterials and major collectors for two days from the year 2010 through the year 2012. The traffic records were stored in an Excel® file with station ID, functional classification, date, hour, direction, and traffic volume per each FHWA 13 vehicle classification. The 121 traffic recorder sites were categorized by functional classifications of the roads as follows:

- Nine traffic recorder sites for other principal arterials.
- Thirty-two traffic recorder sites for minor arterials.
- Eighty traffic recorder sites for major collectors.

DATA REDUCTION

For the purpose of integrating truck volume into the *Urban Mobility Report* framework, all hourly traffic counts were reduced to two categories: "all vehicles" and "trucks." When traffic volumes were recorded according to FHWA 13 vehicle classes, as shown in Figure 2-1, all vehicle volumes and truck volumes were calculated by the following equations:

$$All\ Vehicle\ Volume = \sum_{i=1}^{13} Class\ i\ count$$

$$Truck\ Volume = \sum_{i=4}^{13} Class\ i\ count$$

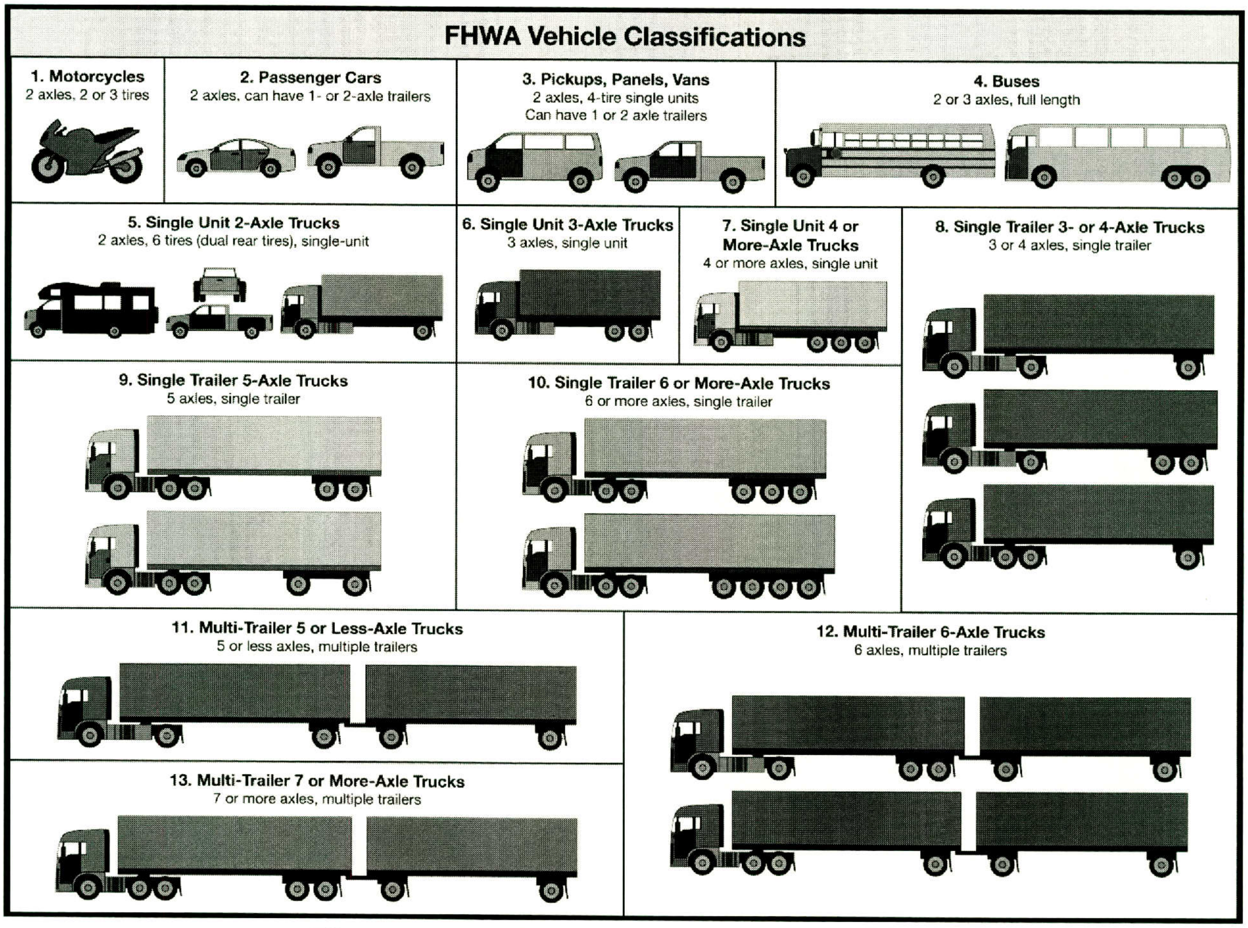


Figure 2-1. FHWA 13 Vehicle Classifications (Adapted from [7])

For Seattle, since vehicle counts did not follow FHWA 13 vehicle classifications, all vehicle volumes and truck volumes were calculated by the following equations:

$$\textit{All Vehicle Volume} = \textit{Car/Van/Pickup count} + \textit{Single Truck Count} + \textit{Double Truck Count} + \textit{Triple Truck Count}$$

$$\textit{Truck Volume} = \textit{Single Truck Count} + \textit{Double Truck Count} + \textit{Triple Truck Count}$$

For Waco, Texas, and Temple, vehicle counts were recorded by Wavetronix® radar detectors with three categories—small, medium, and large vehicles—by their lengths. Hence, all vehicle volumes and truck volumes were calculated by the following equations:

$$\textit{All Vehicle Volume} = \textit{Small Vehicle Count} + \textit{Medium Vehicle Count} + \textit{Large Vehicle Count}$$

$$\textit{Truck Volume} = \textit{Medium Vehicle Count} + \textit{Large Vehicle Count}$$

In addition to the different vehicle classes, Atlanta, Austin, Dallas, and San Antonio records were collected by lane. In this case, traffic counts of all lanes of the same sites were summed by vehicle class prior to truck volume calculation.

Table 2-1 shows the summary of datasets after the data reduction process. Functional classifications of the roads were regrouped to "freeway" and "non-freeway" to include only interstates, other freeways, and other principal arterials. As a result, most of the Denver sites were excluded because they included collector streets.

Table 2-1. Summary of Urban Traffic Volume Data Collection Sites

State	Major Metro Area	Site ID	FWY/ Non-FWY	Route Number	Description	Sample Year	Sample Month	Total Sample Period (days)	Weekday/ Weekend
GA	Atlanta	5463	FWY	I-75	I-75: S of Cleveland Av @Old Hapeville Rd SW, Atl, Fultn Co.	2010	Apr.–Sep.	92	Weekdays, Weekends
GA	Atlanta	5474	FWY	I-76	I-75/I-85 at Grady Curve	2010	Jan.–Sep.	182	Weekdays, Weekends
GA	Atlanta	5486	FWY	I-77	I-75 @Northside Dr	2010	Jan.–Mar.	79	Weekdays, Weekends
GA	Atlanta	5505	FWY	I-20	I-20:bn McDaniel St & Windsor St	2010	Jan.–Sep.	119	Weekdays, Weekends
GA	Atlanta	5508	FWY	I-20	I-20:@Capitol Ave	2010	May–Sep.	117	Weekdays, Weekends
GA	Atlanta	5524	FWY	I-85	I-85:bn Sylvan Rd & Cleveland Av	2010	Jan.–Sep.	221	Weekdays, Weekends
GA	Atlanta	5534	FWY	I-285	I-285:bn I-85 & Washington Rd CR1389	2010	Jan.–Jul.	113	Weekdays, Weekends
GA	Atlanta	5542	FWY	I-286	I-285:bn I-20 & SR8	2010	Jan.–Sep.	160	Weekdays, Weekends
GA	Atlanta	5555	FWY	I-287	I-285:@Forest Park Rd	2010	Jan.–Sep.	221	Weekdays, Weekends
GA	Atlanta	5969	FWY	I-85	I-85:@Exit Ramp to SR13/Spring Buford Conn, Atl, Fultn Co.	2010	Jan.–Sep.	196	Weekdays, Weekends
GA	Atlanta	6370	FWY	I-75	I-75:@Chattahoochee River	2010	Jan.–Sep.	209	Weekdays, Weekends
GA	Atlanta	3385	FWY	SR 410	SR410/Stone Mtn Fwy:bn I-285 & Brocket Rd CR5152	2010	Jan.–Aug.	188	Weekdays, Weekends
GA	Atlanta	0458	FWY	SR 400	SR 400 N of Mansell Rd	2010	Jan.–Mar.	33	Weekdays, Weekends
GA	Atlanta	5452	FWY	SR 400	SR400/US19:S of Mt Vernon Hwy bn Abernathy & I-285, Atl	2010	Jan.–Sep.	211	Weekdays, Weekends
GA	Atlanta	0178	Non-FWY	SR 14/US 29	SR14/US29:S of Johns Riv Rd near SR74, Fairbrn, Fultn Co.	2010	Jan.–Sep.	138	Weekdays, Weekends
GA	Atlanta	0190	Non-FWY	SR 14/US 30	SR14/US29:@Lumber yard S of Alexandr Av, Union City	2010	Jan.–Sep.	217	Weekdays, Weekends
GA	Atlanta	5016	Non-FWY	SR 3	SR3/N'side Dr:bn Marietta St & 14th St	2010	Jan.–Sep.	174	Weekdays, Weekends
TX	Austin	131	Non-FWY	US 183	3.3 Miles South of SH 71	2011	Jan.–Dec.	305	Weekdays, Weekends
TX	Austin	276	FWY	IH 35	0.9 Mile South of FM 2001	2011	Jan.–Dec.	337	Weekdays, Weekends

Table 2-1. Summary of Urban Traffic Volume Data Collection Sites (continued)

State	Major Metro Area	Site ID	FWY/ Non-FWY	Route Number	Description	Sample Year	Sample Month	Total Sample Period (days)	Weekday/ Weekend
TX	Denton (Dallas)	027	Non-FWY	FM 428	1.0 Mile Northeast of SL 288	2011	Jan.–Dec.	262	Weekdays, Weekends
TX	San Antonio	305	FWY	IH 410	0.5 Mile East of FM 2790	2011	Jan.–Dec.	354	Weekdays, Weekends
TX	San Antonio	317	FWY	SL 1604	0.4 Mile East of SH 16	2011	Jan.–Dec.	221	Weekdays, Weekends
TX	San Antonio	327	FWY	US 281	0.4 Mile North of Loop 1604	2011	Jan.–Dec.	303	Weekdays, Weekends
TX	Waco	9196	FWY	IH 35	Waco North- Bellmead (I35@BehrensCir)	2013	Jan.–Feb.	41	Weekdays, Weekends
TX	Waco	9208	FWY	IH 35	Waco South (I35@Corporation Blvd)	2013	Jan.–Feb.	41	Weekdays, Weekends
TX	Temple	9202	FWY	IH 35	Temple North (I35@Industrial Blvd)	2013	Jan.–Feb.	41	Weekdays, Weekends
TX	Temple	10362	FWY	IH 35	Temple South (I35@CentralAve)	2013	Jan.–Feb.	41	Weekdays, Weekends
WA	Seattle	D1	FWY	SR 405	AT 112TH AVE SE UXING–BELLEVUE	2011	Jan.–Dec.	339	Weekdays, Weekends
WA	Seattle	D10	FWY	SR 520	W/O 76TH AVE NE UXING–SEATTLE	2011	Jan.–Dec.	137	Weekdays, Weekends
WA	Seattle	P1	FWY	SR 005	N/O 164TH STREET SW–EVERETT	2011	Jan.–Dec.	90	Weekdays, Weekends
WA	Seattle	P19	FWY	SR 522	W/O SR 9 I/C–WOODINVILLE	2011	Jan.–Dec.	363	Weekdays, Weekends
WA	Seattle	S809	FWY	SR 005	S/O SR 516 I/C–MIDWAY	2011	Jan.–Nov.	91	Weekdays, Weekends
WA	Seattle	S824	FWY	SR 405	N/O SR 527 I/C–BOTHELL	2011	Feb.–Dec.	323	Weekdays, Weekends
WA	Seattle	S839	FWY	SR 599	E/O SR 99 I/C–TUKWILA	2011	Jan.–Nov.	331	Weekdays, Weekends
CO	Denver	107663	Non-FWY	NA	ON 6TH AVE W/O YORK ST	2012	Jun.	2	Weekdays only
CO	Denver	107703	Non-FWY	NA	ON 8TH AVE E/O YORK ST	2012	Jun.	2	Weekdays only

ANALYSIS METHODS

Researchers used the following steps to analyze hourly truck volume data:

1. Separate weekday and weekend data.
2. Separate freeway and non-freeway data.
3. Estimate hourly traffic volumes of all vehicles and trucks.
4. Identify traffic distributions by charting average hourly percentages of daily volume.
5. Group traffic distribution charts by peak distribution, freeway/non-freeway weekday/weekend.
6. Plot new hourly traffic distributions with the distributions from the *Urban Mobility Report.*

Step 1. Separate Weekday and Weekend Data

The first step to build hourly traffic volume distributions was to separate weekday traffic and weekend traffic for each site because weekend is known to have different distributions compared to weekday distributions. Weekend data were identified from the sample dates.

Step 2. Separate Freeway and Non-Freeway Data

Another stratification can be made by separating the sites by freeway and non-freeway. When a dataset is collected from interstates or other freeways and expressways, it is identified as freeway. Otherwise, it is non-freeway. In the current study, non-freeway data were only taken from other principal arterials in terms of FHWA functional classification codes.

Step 3. Estimate Hourly Traffic Volumes of All Vehicles and Trucks

Sampling periods of most traffic data span over several months. To estimate hourly traffic volumes, traffic counts from a site were averaged for one-hour time intervals by the following criteria:

- Vehicle type: all vehicles and trucks.
- Day type: weekday and weekend.
- Direction: one site may have had samples for each direction.

Table 2-2 and Figure 2-2 show samples of the hourly traffic volume table and charts from Austin traffic recorder site S131.

In Figure 2-2, all vehicles show typical peak patterns of AM peak and PM peak for weekdays and midday peak for weekends. However, it is not very distinguishable for trucks due to their relatively low volumes compared to all vehicle volumes, as shown in Table 2-2.

Table 2-2. Hourly Traffic Volume Estimates from Austin S131 Site

Non-FWY Austin S131	North				South			
	Weekdays		Weekends		Weekdays		Weekends	
Hour of Day	All Vehicles	Trucks	All Vehicles	Trucks	All Vehicles	Trucks	All Vehicles	Trucks
0	63	7	180	4	115	6	217	4
1	43	6	131	3	73	6	136	3
2	43	6	98	3	69	7	139	3
3	76	8	66	3	55	9	83	3
4	187	14	84	3	78	15	60	4
5	660	30	183	5	196	20	82	5
6	1,598	53	309	10	455	43	183	8
7	1,906	60	402	13	471	49	273	12
8	1,295	59	503	14	459	64	353	14
9	777	57	625	14	487	67	480	16
10	636	57	686	17	525	70	601	19
11	608	58	744	17	582	72	702	20
12	594	56	783	18	644	72	780	19
13	595	57	803	17	700	73	806	20
14	576	57	774	17	869	81	842	17
15	575	50	740	15	1139	72	814	16
16	615	40	702	13	1623	70	791	14
17	683	40	662	13	1782	51	731	13
18	577	25	584	12	1321	35	691	10
19	403	16	484	8	779	21	571	9
20	318	12	421	7	537	13	475	7
21	268	8	379	6	441	12	411	6
22	185	7	299	4	347	11	359	6
23	119	7	225	4	212	7	256	4
Total	13,399	792	10,867	242	13,958	948	10,836	251

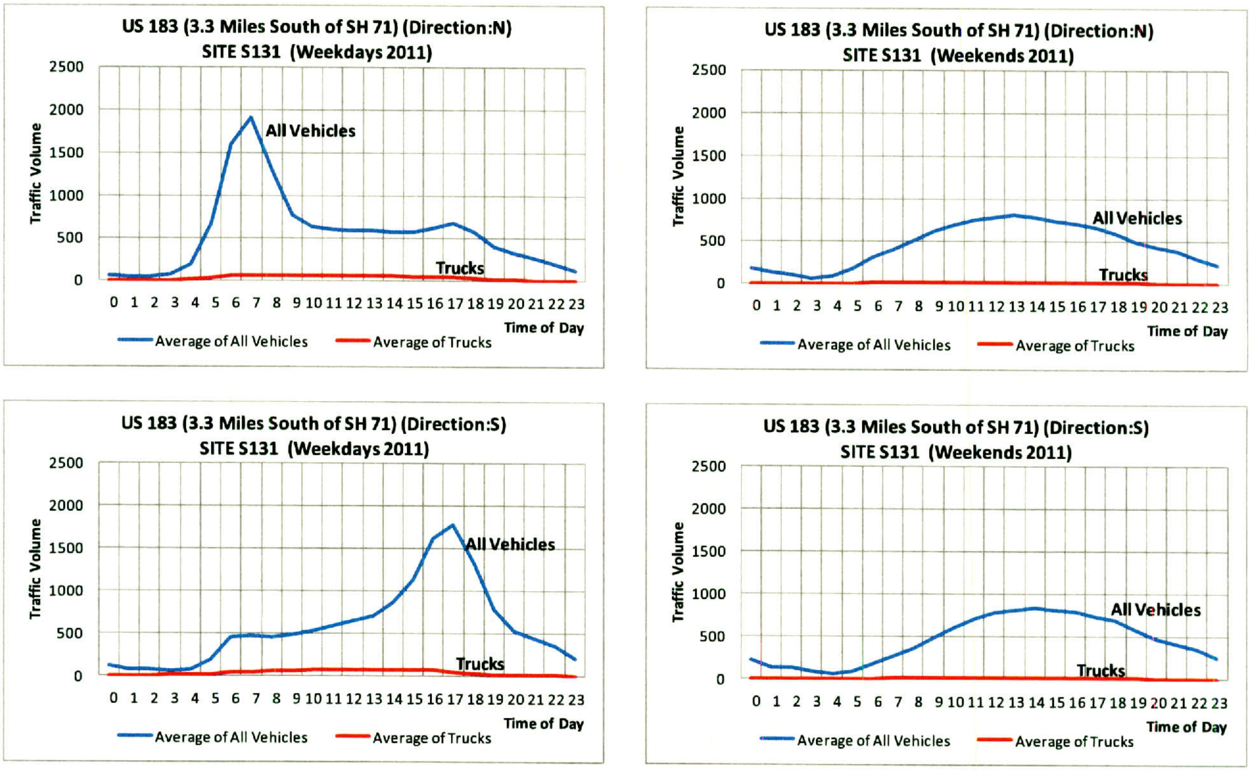


Figure 2-2. Hourly Traffic Volume Distribution from Austin S131 Site

Step 4. Identify Traffic Distributions by Charting Average Hourly Percentages of Daily Volume

When the hourly truck volumes are plotted with all vehicles, as shown in Figure 2-2, the truck volume distributions look almost flat at the bottom. To identify truck traffic distributions, hourly traffic volumes were converted to percentages of daily traffic volume per each category by the following equations:

$$All\ vehicle\ volume\ \%\ at\ period\ i = \frac{All\ vehicle\ volume\ at\ period\ i * 100}{Daily\ total\ all\ vehicle\ volume}$$

$$Truck\ volume\ \%\ at\ period\ i = \frac{Truck\ volume\ at\ period\ i * 100}{Daily\ total\ truck\ volume}$$

Table 2-3 and Figure 2-3 show the resulting hourly traffic percentages table and charts converted from Table 2-2 and Figure 2-2. In Figure 2-3, truck distributions are now conspicuous.

Table 2-3. Hourly Traffic Volume Percentages from Austin S131 Site

Non-FWY Austin S131	North				South			
	Weekdays		Weekends		Weekdays		Weekends	
Hour of Day	All Vehicles	Trucks	All Vehicles	Trucks	All Vehicles	Trucks	All Vehicles	Trucks
0	0.5%	0.9%	1.7%	1.5%	0.8%	0.6%	2.0%	1.6%
1	0.3%	0.8%	1.2%	1.3%	0.5%	0.7%	1.3%	1.2%
2	0.3%	0.8%	0.9%	1.3%	0.5%	0.8%	1.3%	1.0%
3	0.6%	1.0%	0.6%	1.2%	0.4%	0.9%	0.8%	1.2%
4	1.4%	1.8%	0.8%	1.4%	0.6%	1.6%	0.6%	1.7%
5	4.9%	3.8%	1.7%	2.2%	1.4%	2.1%	0.8%	2.1%
6	11.9%	6.7%	2.8%	4.2%	3.3%	4.5%	1.7%	3.2%
7	14.2%	7.6%	3.7%	5.5%	3.4%	5.2%	2.5%	4.7%
8	9.7%	7.5%	4.6%	5.8%	3.3%	6.8%	3.3%	5.4%
9	5.8%	7.2%	5.8%	5.9%	3.5%	7.0%	4.4%	6.4%
10	4.7%	7.2%	6.3%	7.0%	3.8%	7.4%	5.5%	7.5%
11	4.5%	7.3%	6.8%	7.0%	4.2%	7.6%	6.5%	7.8%
12	4.4%	7.1%	7.2%	7.5%	4.6%	7.6%	7.2%	7.6%
13	4.4%	7.1%	7.4%	7.1%	5.0%	7.7%	7.4%	7.8%
14	4.3%	7.2%	7.1%	6.9%	6.2%	8.5%	7.8%	6.7%
15	4.3%	6.4%	6.8%	6.4%	8.2%	7.6%	7.5%	6.2%
16	4.6%	5.0%	6.5%	5.5%	11.6%	7.4%	7.3%	5.8%
17	5.1%	5.0%	6.1%	5.2%	12.8%	5.4%	6.7%	5.1%
18	4.3%	3.2%	5.4%	4.9%	9.5%	3.7%	6.4%	4.2%
19	3.0%	2.0%	4.5%	3.5%	5.6%	2.2%	5.3%	3.4%
20	2.4%	1.5%	3.9%	2.8%	3.8%	1.4%	4.4%	3.0%
21	2.0%	1.0%	3.5%	2.3%	3.2%	1.2%	3.8%	2.5%
22	1.4%	0.9%	2.8%	1.8%	2.5%	1.2%	3.3%	2.3%
23	0.9%	0.9%	2.1%	1.8%	1.5%	0.8%	2.4%	1.7%
Total	100%	100%	100%	100%	100%	100%	100%	100%

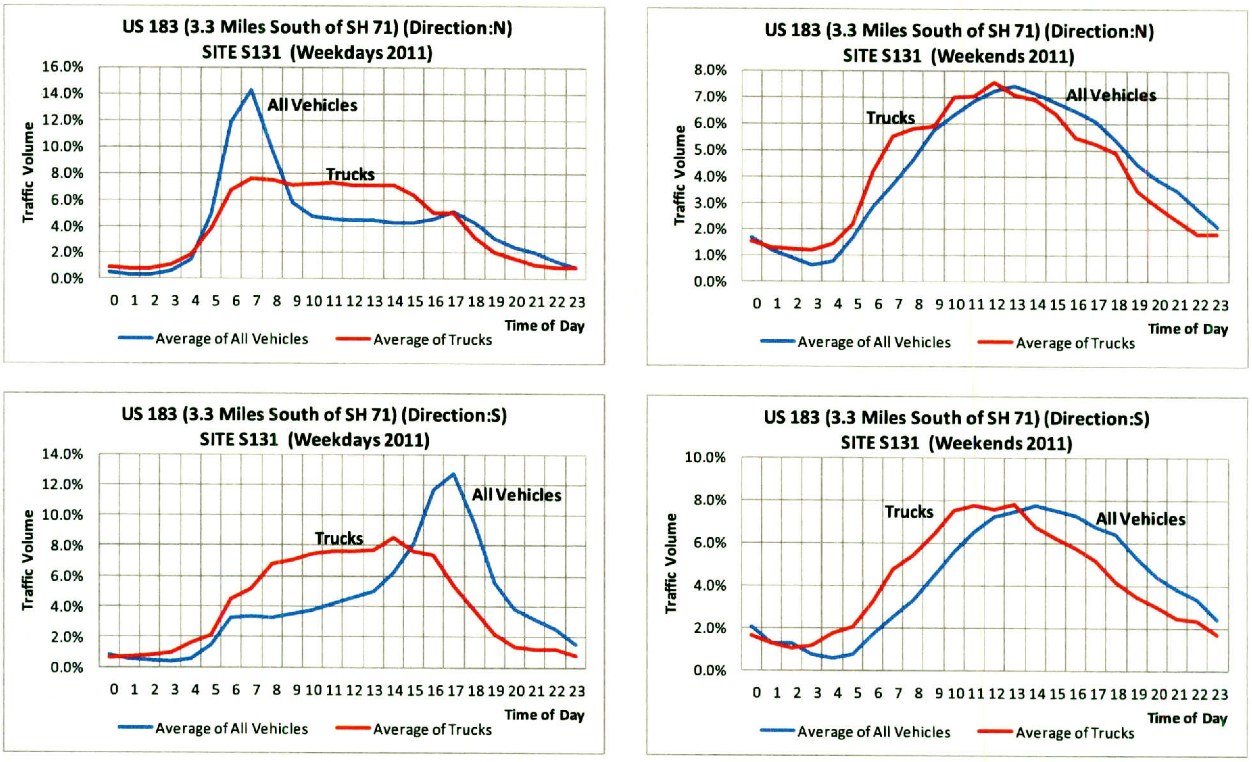


Figure 2-3. Hourly Traffic Percentage Distribution from Austin S131 Site

Step 5. Group Traffic Distribution Charts by All-Vehicle Peak Distribution, Freeway/Non-Freeway, and Weekday/Weekend

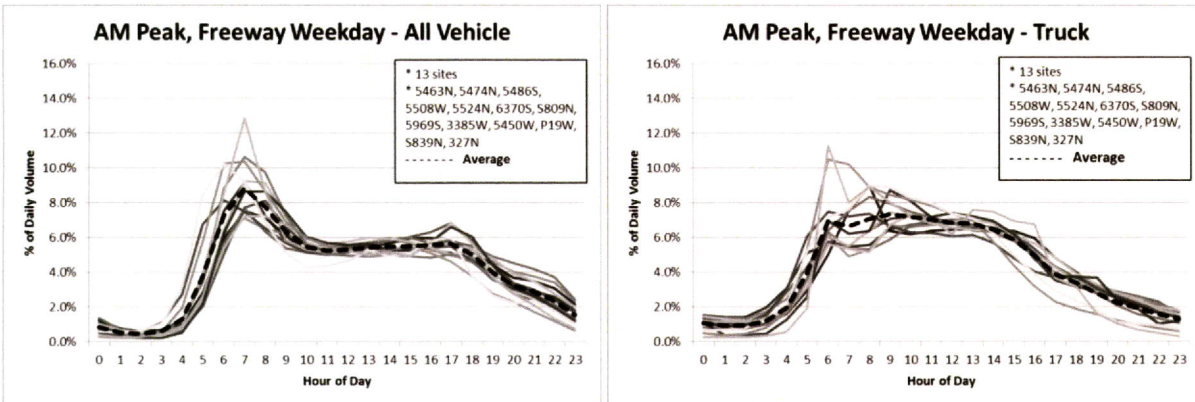
By visual inspection, traffic distributions of the sample sites were identified as AM peak, PM peak, or AM-PM peak for weekday traffic. Weekend traffic showed a typical midday peak. Distribution was classified by type of peak distribution for all vehicles. The peak distribution samples were further categorized by freeway and non-freeway according to the functional classification of each site. Table 2-4 shows the number of freeway and non-freeway samples by peak distributions.

Table 2-4. Number of Samples by Traffic Profile

	Peak Type[1]	Number of Freeway Samples	Number of Non-Freeway Samples
Weekday	AM Peak	13	3
	PM Peak	25	8
	AM-PM Peak	21	4
Weekend	Midday Peak	58	10

[1]Peak distribution by all-vehicle percent.

Figure 2-4 shows the AM peak distributions from 13 samples for all vehicles (A) and trucks (B). First, the grouping of peak patterns was done by distributions of all vehicles. Then, the truck distributions were plotted for the same sample sites. During this charting and grouping process, outliers were identified by visual inspection and removed. Outliers were easily identifiable due to the erratic patterns or excessive peaks when they were plotted. Freeway peak distributions had very few outliers, while non-freeway peak distributions had nine times more outliers than freeways. This is hypothesized to be due to the fact that non-freeway sites have relatively lower traffic counts and therefore are prone to be affected by certain incidents or temporary changes in traffic environment.



(A) AM Peak, Freeway Weekday—All Vehicles **(B) AM Peak, Freeway Weekday—Trucks**

Figure 2-4. AM Peak Distributions by All Vehicles and Corresponding Truck Distributions

Step 6. Plot New Hourly Traffic Distributions with the Distributions from the *Urban Mobility Report*

The peak distributions grouped in Step 5 were reduced to one averaged distribution per each combination, as shown as dotted lines in the Figure 2-4 example. The averaged all-vehicle and truck distributions were then plotted together with the same peak profiles from *UMR* for further analysis. Figure 2-5 shows an example of the final AM peak distribution. The other peak distributions are provided in the next chapter.

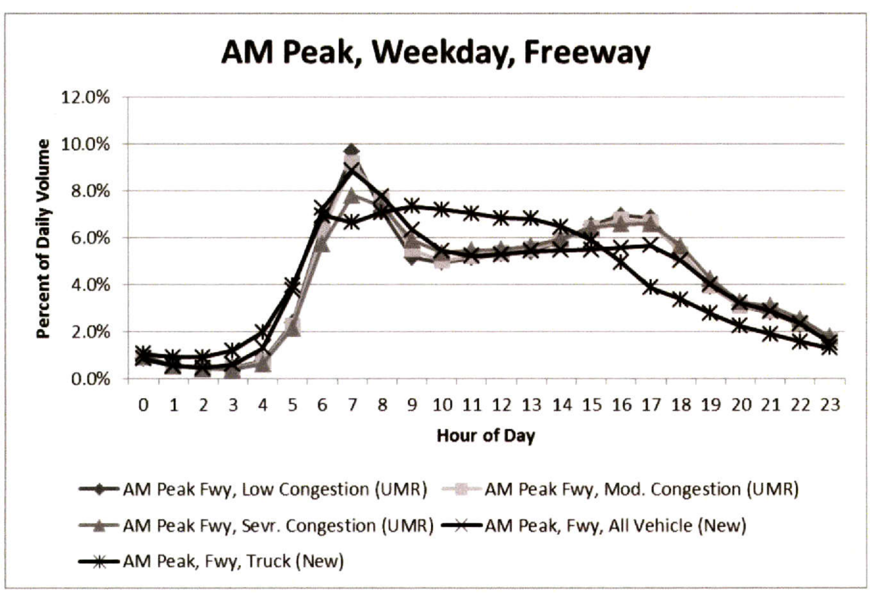


Figure 2-5. Average AM Peak Distributions with *UMR* Profile

CHAPTER 3
TRUCK DISTRIBUTION ANALYSIS RESULTS

TRUCK VOLUME DATA

All truck volume data gathered from the urban areas were analyzed by common groupings. Table 3-1 shows the sum of all traffic volumes and truck volumes by weekday/weekend and freeway and non-freeway from the sample sites. As Table 3-1 illustrates, weekday had a higher proportion of trucks than weekend, and freeway had a higher proportion of trucks than non-freeway. More specifically, weekday freeway had the highest ratio of 13 percent trucks, and weekend non-freeway had the lowest at 3 percent trucks. Overall, trucks were 10 percent of the whole traffic volume of the urban traffic. However, the proportions could be changed drastically by the types and locations of the roads. When we considered the truck volumes of the busy trade corridor I-35 near Waco, Texas, truck percentage was about 31 percent, while it was only 6 percent of freeway traffic near Atlanta, Georgia.

Table 3-1. Total Traffic Volumes and Truck Volumes

	Freeway/ Non-Freeway	Sum of All Traffic Volumes	Sum of Truck Volume	Truck %
Weekday	Freeway	1,488,598	189,235	13%
	Non-Freeway	403,552	23,963	6%
	Weekday total	**1,892,150**	**213,198**	**11%**
Weekend	Freeway	1,276,130	106,234	8%
	Non-Freeway	257,074	6,751	3%
	Weekend total	**1,533,203**	**112,986**	**7%**
Grand Total		**3,425,353**	**326,184**	**10%**

Note: Table 3-1 developed from sites in Table 2-1.

ALL-VEHICLE AND TRUCK TRAFFIC DISTRIBUTIONS

Hourly percentages of average daily traffic of all vehicles and trucks were analyzed and are shown in Figures 3-1 through 3-4. In the charts, each line represents the average percentages summarized from the detailed plots for individual roads shown in the Appendix (dotted lines in the charts). In general, truck distribution profiles did not follow the patterns of all vehicles. As shown in the plots, most of the truck distributions showed a midday peak with lower variability on freeways than on non-freeways. One exception was the non-freeway truck distribution of AM-PM peak profiles shown in Figure 3-3. The figure shows bimodal peaks in AM and PM peak periods. This finding was based on only three samples from Denver and Atlanta (refer to the Appendix). As Figure 3-4 illustrates, the weekend distribution profile (for all vehicles) peaked at around 2 PM, while trucks showed earlier peaks of 10 AM for non-freeway trucks and noon for freeway trucks.

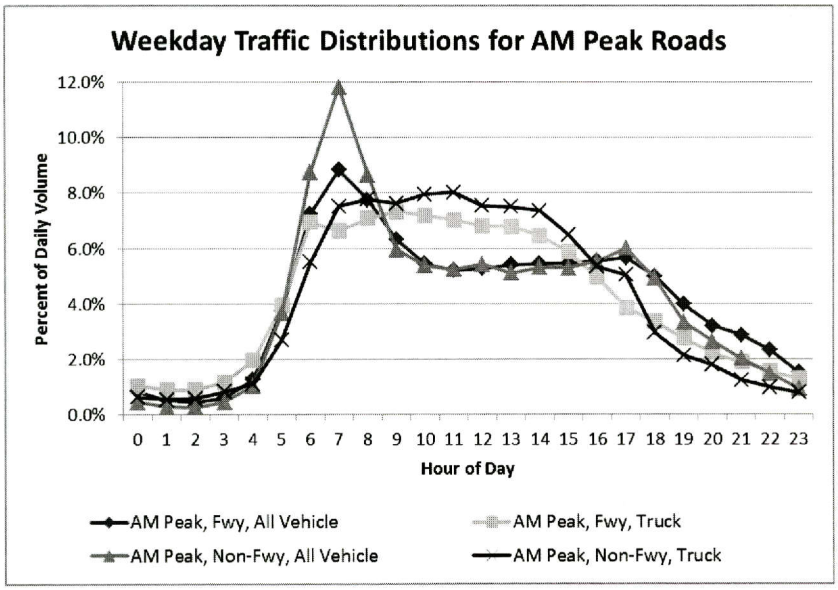


Figure 3-1. Weekday Traffic Distributions for Roads with AM Peak

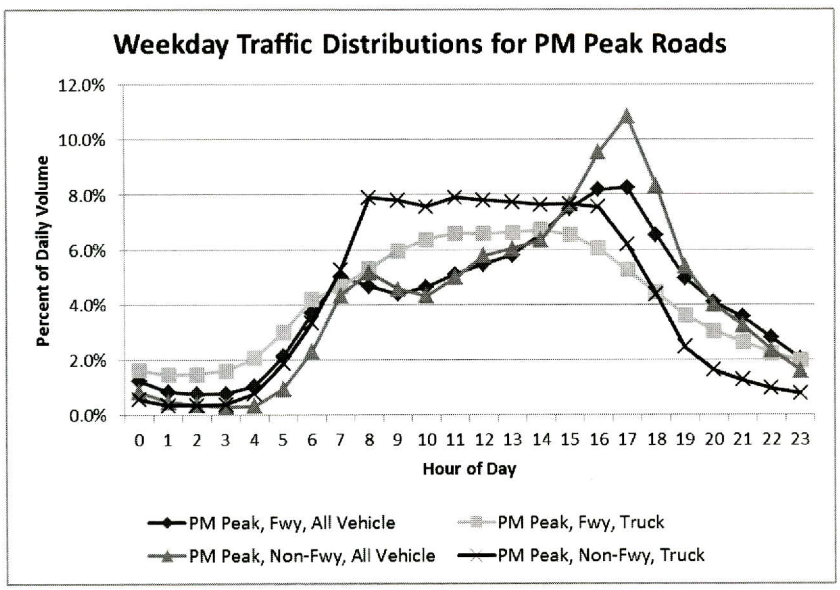


Figure 3-2. Weekday Traffic Distributions for Roads with PM Peak

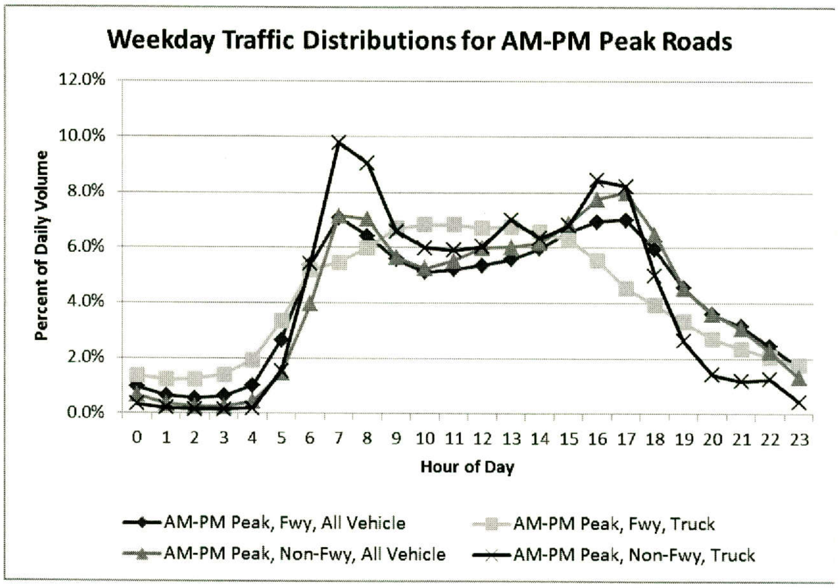


Figure 3-3. Weekday Traffic Distributions for Roads with AM-PM Peak

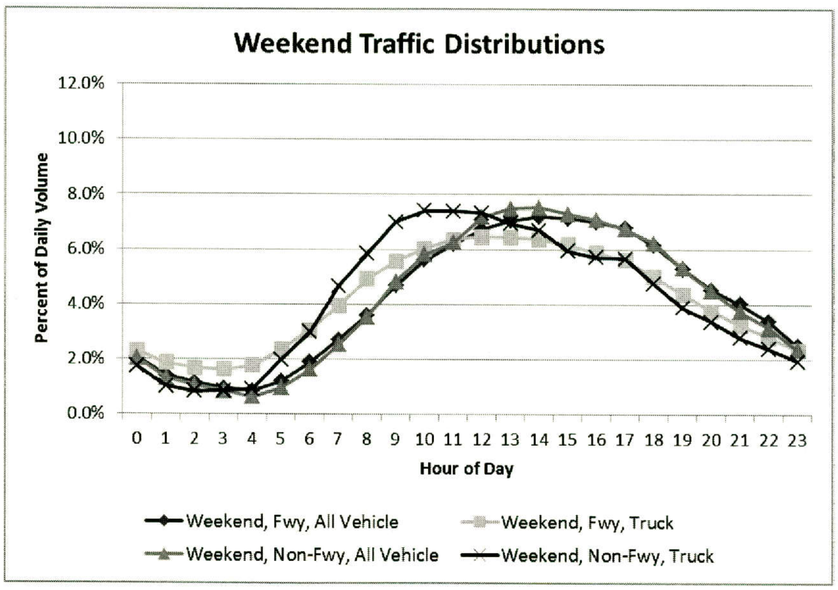
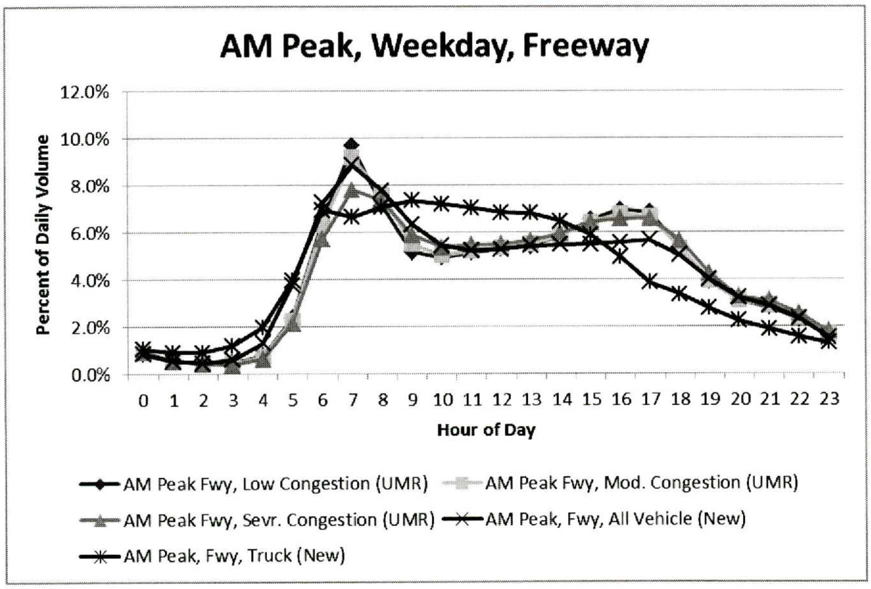


Figure 3-4. Weekend Traffic Distributions

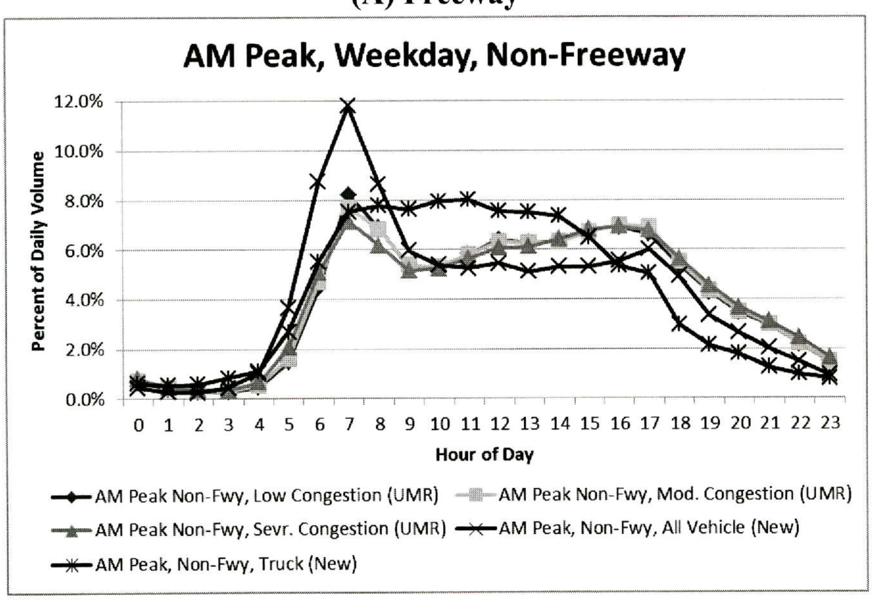
COMPARISON BETWEEN DEVELOPED AND CURRENT *UMR* AVERAGES

The newly developed traffic distributions were compared with the traffic distribution profiles from the *Urban Mobility Report*. The *UMR* distribution profiles were compiled by congestion level based on speed reduction factors. Therefore, there were three curves—showing low congestion, moderate congestion, and severe congestion—for each peak pattern. Since speed data were not available for this analysis, the all-vehicle and truck curves of the newly developed distributions were not separated by congestions levels. However, all matching *UMR* curves were plotted together with new all-vehicle and truck distributions in each chart.

Figure 3-5 shows a comparison of the AM peak distributions (all vehicles and trucks) of the newly developed curves with the three AM peak distributions from the *UMR*. The new AM peak distributions for all vehicles were in general very consistent with the *UMR* distributions in both cases of freeway (A) and non-freeway (B). Truck distributions showed a typical midday peak pattern during the regular work hours, though freeway trucks started forming a peak one hour earlier than non-freeway.



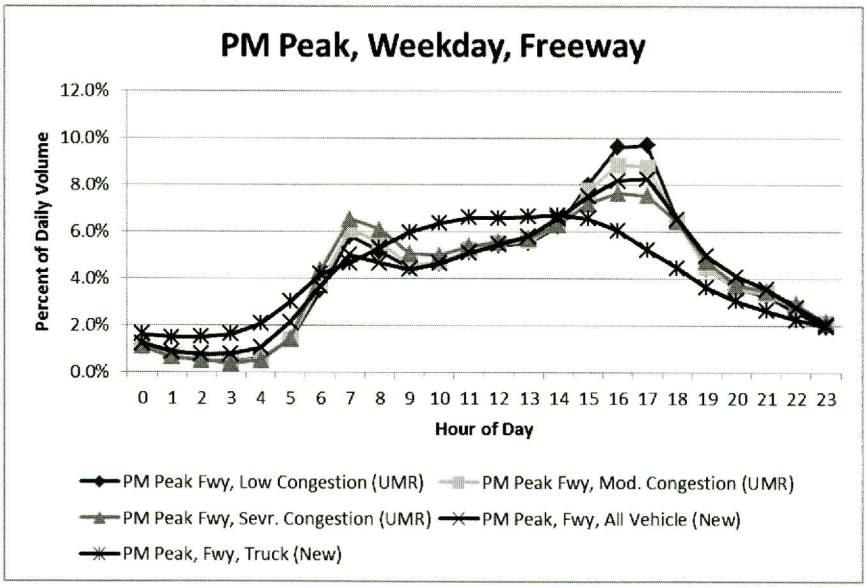
(A) Freeway



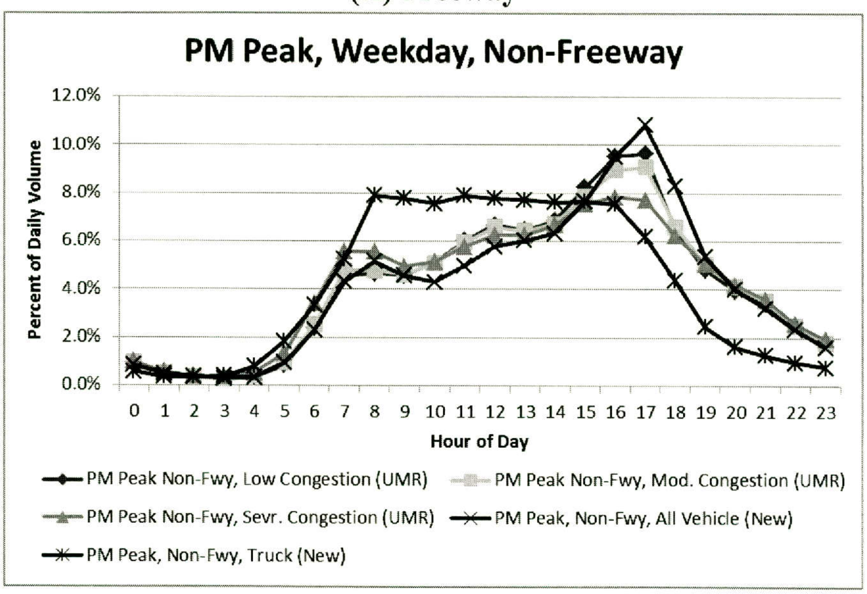
(B) Non-Freeway

Figure 3-5. Comparison with *UMR* Distributions: AM Peak, Weekday

Figure 3-6 displays a comparison of the PM peak distributions (all vehicles and trucks) of the new data with the three PM peak distributions from the *UMR*. The new PM peak distribution for all vehicles was overall very consistent with the *UMR* distributions. Truck distributions showed a smooth midday peak for freeway but a plateau between 8 AM and 4 PM.



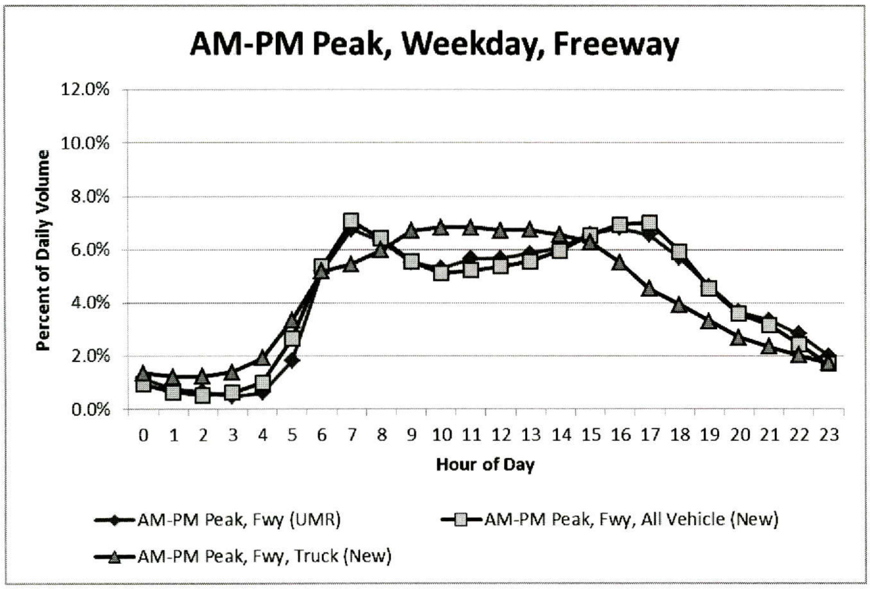
(A) Freeway



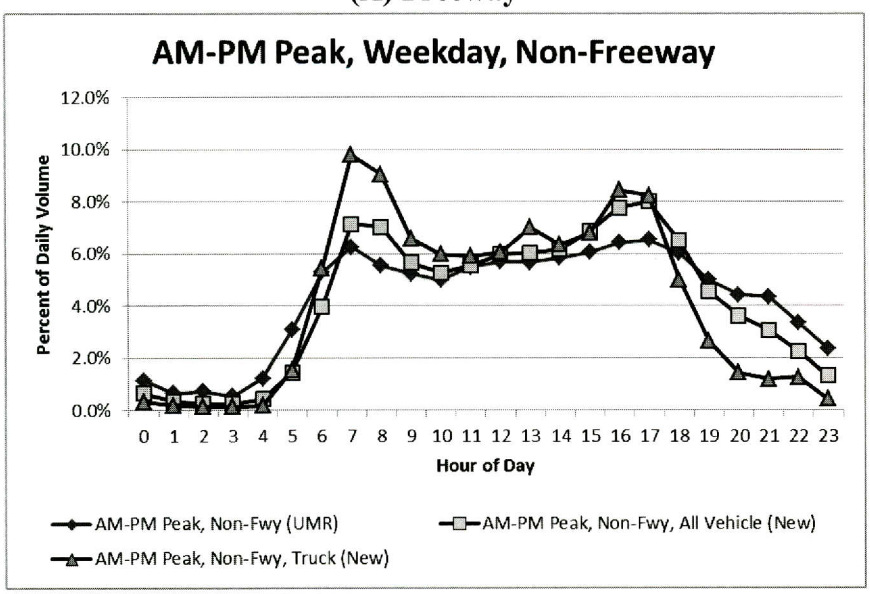
(B) Non-Freeway

Figure 3-6. Comparison with *UMR* Distributions: PM Peak, Weekday

Figure 3-7 shows the comparison between the distributions of the *UMR* report and the newly developed distributions with peaks at both of the peak periods. In the freeway distributions (Figure 3-7 [A]), the new all-vehicle curve followed the *UMR* distribution very closely, and the new truck distribution showed a smooth midday peak. However, as seen in Figure 3-7(B), the non-freeway truck distribution did not show the typical midday peaking but followed the AM-PM peak of all vehicles. Because it was based on only three samples from Atlanta and Denver, this unusual non-midday truck distribution needs to be verified in the future by more samples from various urban areas.



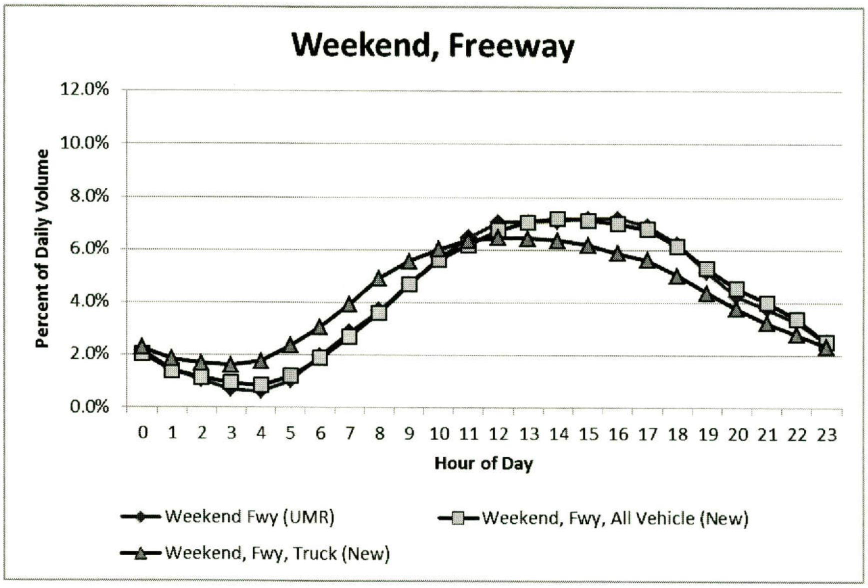
(A) Freeway



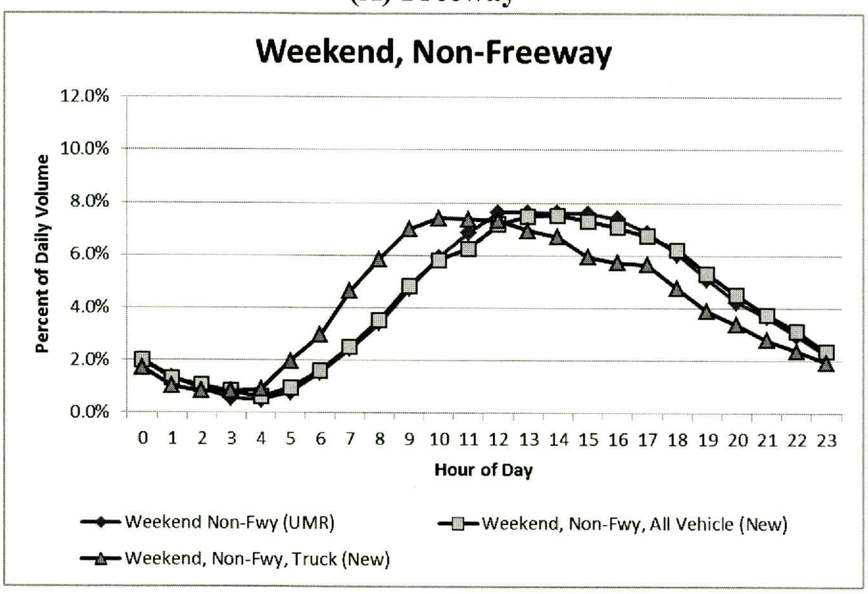
(B) Non-Freeway

Figure 3-7. Comparison with *UMR* Distributions: AM-PM Peak, Weekday

In the *UMR*, weekend traffic distributions are almost identical, and the newly developed distributions confirmed the *UMR* distributions. As Figure 3-8 illustrates, the all-vehicle distribution of the newly developed distribution exactly matched the *UMR* distributions for both freeway and non-freeway. For freeway, the truck distribution peaked at noon with a slightly flatter curve than the rest of the vehicles. For non-freeway, the truck volumes began growing about two hours ahead of the all-vehicle distribution during the daytime.



(A) Freeway



(B) Non-Freeway

Figure 3-8. Comparison with *UMR* Distributions: Weekend

PERCENTAGE OF TRAFFIC DISTRIBUTIONS BY PERIOD OF DAY

The traffic distribution profiles in the previous sections were analyzed by hour. As another approach, the hourly percentages were summed and averaged by periods of interest. In Table 3-2, the percent of daily traffic volume during a certain period is shown by vehicle type by distribution profile. For example, in the freeway segments with AM peak profile, the figure shows that 34 percent of trucks traveled through the segments during the midday period, but only 18 percent of trucks traveled during the PM peak period. Overall, trucks moved more frequently during the midday than the other periods regardless of type of road and peak distribution profiles of all vehicles. In addition, a relatively high percentage of trucks moved overnight on freeways, as shown in Figure 3-9. Because the midday time periods in Table 3-2 are for five hours and the peaks are four hours, the periods in Table 3-2 are further divided in Table 3-3 and Table 3-4 to show the percentage of daily traffic by hour of day for freeway and non-freeway.

Table 3-2. Percentage of Daily Traffic by Periods of Interest

		Freeway				Non-Freeway			
Distribution Profile	**Type of Vehicle**	**AM Peak Period (6:00–10:00)**	**Midday (10:00–15:00)**	**PM Peak Period (15:00–19:00)**	**Overnight (19:00–5:00)**	**AM Peak Period (6:00–10:00)**	**Midday (10:00–15:00)**	**PM Peak Period (15:00–19:00)**	**Overnight (19:00–5:00)**
AM Peak	All Vehicle	30%	27%	22%	21%	35%	27%	22%	17%
	Truck	28%	**34%**	18%	20%	28%	**38%**	20%	13%
	UMR	28%	27%	25%	19%	24%	30%	26%	19%
PM Peak	All Vehicle	18%	28%	30%	24%	16%	27%	36%	20%
	Truck	20%	**33%**	22%	25%	24%	**39%**	26%	11%
	UMR	20%	27%	31%	21%	17%	31%	32%	21%
AM-PM Peak	All Vehicle	24%	27%	26%	22%	24%	27%	31%	18%
	Truck	23%	**34%**	20%	23%	32%	**33%**	27%	8%
	UMR	24%	29%	26%	22%	22%	28%	25%	27%
Midday Peak (Weekend)	All Vehicle	13%	33%	27%	27%	13%	34%	27%	26%
	Truck	18%	**32%**	23%	28%	20%	**36%**	22%	22%
	UMR	13%	33%	28%	26%	12%	36%	28%	24%

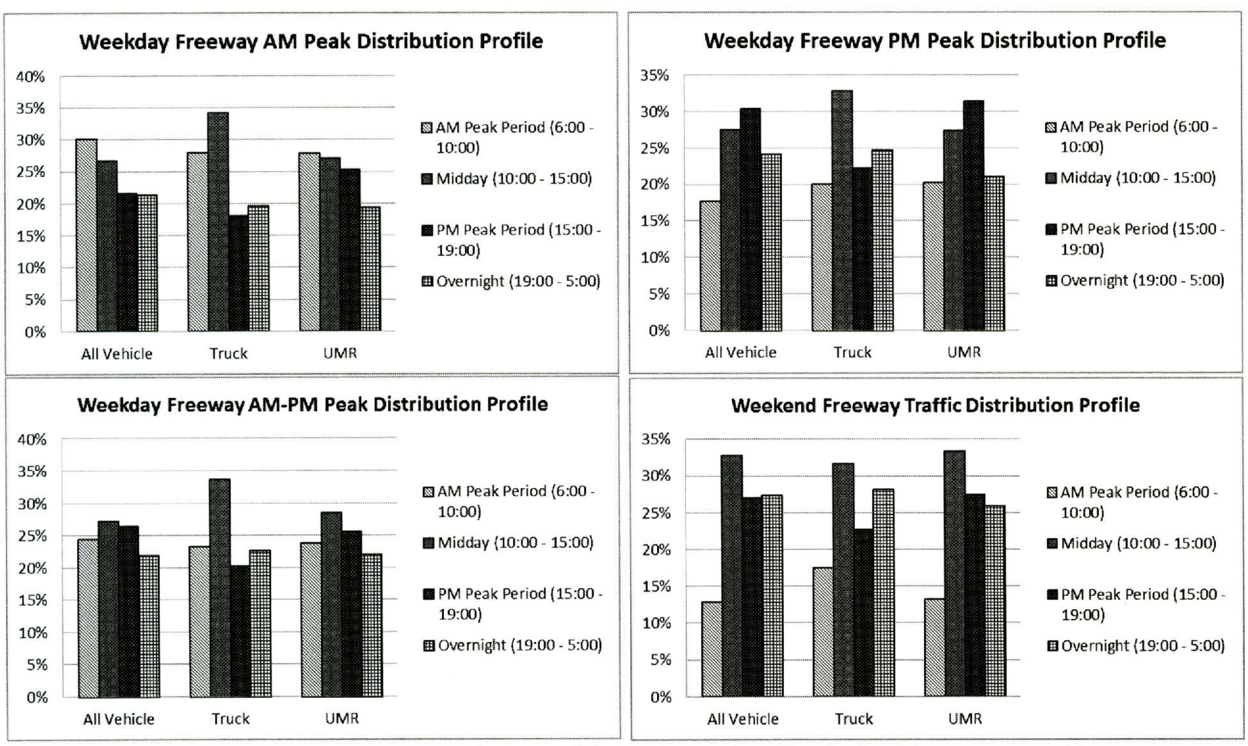


Figure 3-9. Percentage of Daily Traffic Volume by Period of Interest on Freeway

Table 3-3. Freeway Daily Traffic Percentage by Hour of Day

Hour of Day	AM Peak			PM Peak			AM-PM Peak			Midday Peak (Weekend)		
	All Vehicle	Truck	*UMR*	All Vehicle	Truck	*UMR*	All Vehicle	Truck	*UMR*	All Vehicle	Truck	*UMR*
0:00	0.8%	1.0%	0.9%	1.2%	1.6%	1.1%	1.0%	1.4%	1.2%	2.1%	2.3%	2.2%
1:00	0.5%	0.9%	0.5%	0.9%	1.5%	0.7%	0.6%	1.2%	0.8%	1.4%	1.9%	1.5%
2:00	0.5%	0.9%	0.4%	0.8%	1.5%	0.5%	0.5%	1.2%	0.7%	1.1%	1.7%	1.1%
3:00	0.6%	1.2%	0.4%	0.8%	1.6%	0.4%	0.6%	1.4%	0.5%	0.9%	1.6%	0.7%
4:00	1.3%	2.0%	0.7%	1.0%	2.1%	0.5%	1.0%	1.9%	0.6%	0.8%	1.8%	0.6%
5:00	3.8%	3.9%	2.2%	2.1%	3.0%	1.4%	2.7%	3.3%	1.8%	1.2%	2.4%	1.0%
6:00	7.3%	6.9%	6.2%	3.7%	4.2%	3.9%	5.4%	5.2%	5.2%	1.9%	3.1%	2.0%
7:00	8.8%	6.6%	8.9%	5.0%	4.6%	6.1%	7.1%	5.5%	6.8%	2.7%	3.9%	2.9%
8:00	7.8%	7.1%	7.3%	4.7%	5.3%	5.6%	6.4%	6.0%	6.3%	3.6%	4.9%	3.7%
9:00	6.3%	7.3%	5.5%	4.4%	6.0%	4.7%	5.6%	6.7%	5.5%	4.7%	5.6%	4.7%
10:00	5.4%	7.2%	5.1%	4.6%	6.4%	4.8%	5.1%	6.8%	5.3%	5.6%	6.0%	5.7%
11:00	5.2%	7.0%	5.3%	5.1%	6.6%	5.2%	5.2%	6.8%	5.7%	6.2%	6.4%	6.5%
12:00	5.3%	6.8%	5.4%	5.5%	6.6%	5.5%	5.4%	6.7%	5.7%	6.7%	6.5%	7.1%
13:00	5.4%	6.8%	5.5%	5.8%	6.6%	5.6%	5.6%	6.8%	5.9%	7.0%	6.4%	7.1%
14:00	5.5%	6.5%	5.9%	6.6%	6.7%	6.3%	6.0%	6.6%	6.1%	7.2%	6.4%	7.1%
15:00	5.5%	5.9%	6.5%	7.5%	6.6%	7.7%	6.5%	6.3%	6.6%	7.1%	6.2%	7.2%
16:00	5.6%	5.0%	6.8%	8.2%	6.0%	8.7%	6.9%	5.5%	6.8%	7.0%	5.9%	7.2%
17:00	5.7%	3.9%	6.7%	8.3%	5.2%	8.7%	7.0%	4.5%	6.6%	6.8%	5.6%	6.9%
18:00	5.0%	3.4%	5.4%	6.5%	4.5%	6.4%	5.9%	3.9%	5.7%	6.2%	5.0%	6.2%
19:00	4.0%	2.8%	4.0%	5.0%	3.6%	4.6%	4.6%	3.3%	4.6%	5.3%	4.4%	5.2%
20:00	3.2%	2.2%	3.1%	4.1%	3.0%	3.6%	3.6%	2.7%	3.7%	4.5%	3.8%	4.2%
21:00	2.9%	1.9%	2.9%	3.6%	2.6%	3.4%	3.2%	2.4%	3.4%	4.0%	3.2%	3.8%
22:00	2.3%	1.6%	2.4%	2.8%	2.2%	2.8%	2.4%	2.0%	2.8%	3.4%	2.8%	3.3%
23:00	1.5%	1.3%	1.7%	2.0%	2.0%	2.1%	1.7%	1.7%	2.0%	2.5%	2.3%	2.5%

Table 3-4. Non-Freeway Daily Traffic Percentage by Hour of Day

Hour of Day	AM Peak			PM Peak			AM-PM Peak			Midday Peak (Weekend)		
	All Vehicle	Truck	*UMR*	All Vehicle	Truck	*UMR*	All Vehicle	Truck	*UMR*	All Vehicle	Truck	*UMR*
0:00	0.4%	0.6%	0.7%	0.8%	0.6%	1.0%	0.7%	0.3%	1.1%	2.0%	1.7%	2.0%
1:00	0.3%	0.5%	0.5%	0.5%	0.4%	0.6%	0.4%	0.2%	0.7%	1.3%	1.0%	1.4%
2:00	0.3%	0.6%	0.3%	0.4%	0.4%	0.4%	0.3%	0.1%	0.7%	1.0%	0.8%	0.9%
3:00	0.4%	0.8%	0.3%	0.3%	0.4%	0.3%	0.2%	0.1%	0.6%	0.8%	0.8%	0.6%
4:00	1.0%	1.1%	0.6%	0.3%	0.8%	0.4%	0.4%	0.2%	1.2%	0.6%	0.9%	0.5%
5:00	3.7%	2.7%	1.7%	1.0%	1.9%	1.0%	1.4%	1.5%	3.1%	1.0%	2.0%	0.8%
6:00	8.8%	5.5%	4.8%	2.3%	3.3%	2.8%	4.0%	5.4%	5.3%	1.6%	3.0%	1.6%
7:00	11.8%	7.5%	7.7%	4.3%	5.3%	5.0%	7.1%	9.8%	6.3%	2.5%	4.6%	2.4%
8:00	8.7%	7.8%	6.6%	5.2%	7.9%	5.0%	7.0%	9.0%	5.5%	3.5%	5.9%	3.4%
9:00	6.0%	7.6%	5.3%	4.6%	7.8%	4.7%	5.6%	6.6%	5.2%	4.8%	7.0%	4.7%
10:00	5.4%	8.0%	5.3%	4.3%	7.6%	5.1%	5.3%	6.0%	5.0%	5.8%	7.4%	5.9%
11:00	5.3%	8.0%	5.8%	5.0%	7.9%	5.9%	5.5%	5.9%	5.5%	6.2%	7.4%	6.9%
12:00	5.4%	7.5%	6.3%	5.8%	7.8%	6.5%	6.0%	6.0%	5.7%	7.2%	7.3%	7.6%
13:00	5.1%	7.5%	6.2%	6.0%	7.7%	6.4%	6.0%	7.0%	5.7%	7.5%	6.9%	7.6%
14:00	5.3%	7.4%	6.4%	6.3%	7.6%	6.8%	6.2%	6.3%	5.8%	7.5%	6.7%	7.6%
15:00	5.3%	6.5%	6.8%	7.7%	7.7%	7.9%	6.9%	6.8%	6.1%	7.3%	5.9%	7.6%
16:00	5.5%	5.3%	6.9%	9.5%	7.5%	8.8%	7.8%	8.4%	6.4%	7.1%	5.7%	7.4%
17:00	6.0%	5.0%	6.8%	10.8%	6.2%	8.8%	8.0%	8.2%	6.5%	6.7%	5.7%	6.9%
18:00	4.9%	3.0%	5.5%	8.3%	4.4%	6.4%	6.5%	5.0%	6.0%	6.2%	4.7%	6.0%
19:00	3.3%	2.1%	4.4%	5.4%	2.5%	5.0%	4.5%	2.6%	5.0%	5.3%	3.9%	5.1%
20:00	2.6%	1.8%	3.5%	4.0%	1.6%	4.1%	3.6%	1.4%	4.4%	4.5%	3.4%	4.2%
21:00	2.0%	1.2%	3.0%	3.2%	1.3%	3.5%	3.1%	1.2%	4.3%	3.7%	2.8%	3.7%
22:00	1.5%	1.0%	2.3%	2.3%	1.0%	2.5%	2.2%	1.3%	3.4%	3.1%	2.4%	3.0%
23:00	0.9%	0.8%	1.5%	1.6%	0.8%	1.9%	1.3%	0.4%	2.4%	2.4%	1.9%	2.3%

CHAPTER 4
RECOMMENDED METHODOLOGY IMPROVEMENTS TO *UMR* PUBLIC TRANSPORTATION METHODOLOGY

INTRODUCTION

For the past several years, TTI's *Urban Mobility Report*, the preeminent research initiative to quantify trends in urban travel congestion, has included an analysis of the impact that the presence of public transportation has on reducing congestion relative to the levels that might exist in the absence of public transit service. This hypothetical scenario is intended to provide one measure of one of the benefits of public transportation service (i.e., reducing congestion in urban areas).

The issue of assessing the congestion impact of public transportation is a conceptual or hypothetical question to some extent, as there are no serious proposals under discussion that would suggest public transportation services would no longer exist in congested urban areas. However, such an assessment provides insight on the value of transit and perhaps weighs in on future transit investments. The congestion consequence of public transit services is only one of the impacts of public transportation. Congestion reduction is among the goals cited for investment in public transportation, and in select markets, the group travel nature of public transit minimizes the land area or travel-way area required to accommodate a given number of people and thus, everything else held constant, can result in less congestion.

One could frame a discussion of the issue of the impact of transit on urban congestion in a number of different ways, each of which could represent a legitimate question and each of which would require a different type of methodology to more fully explore. Three possible different questions are presented below. *The third question is the one being addressed in this research initiative.*

1. In the absence of transit, how would land-use patterns be different, and what is the congestion consequence?
2. If public resources directed to public transit were instead directed to roadway capacity, how would congestion be different?
3. If transit were discontinued and land-use patterns remained the same, what would be the impact on roadway congestion?

Transportation in general, including public transportation, is known to influence land-use location decisions for businesses and individuals. Thus, in the long run, the presence or absence of transportation capacity would influence development patterns and the subsequent level and geographic distribution of travel demand. Therefore, the full consequence of not having transportation capacity would not realistically be known in the short term, as land-use responses are long-range impacts. Scenarios that look at near-term impacts of removing public transit are interesting impact assessment exercises but are not realistic in the long term, as travel behaviors and land-use development patterns may be markedly different in the absence of public transportation—particularly in situations where public transportation carries a significant share of travel.

Similarly, this research does not purport to look at the net impact that might result if resources currently invested in public transportation were instead deployed on alternative modes. While this is a legitimate policy question, there is no such serious proposal on the table, and such an analysis was beyond the scope of this work.

What this analysis does is support an impact assessment analysis carried out by the Texas A&M Transportation Institute in an effort to determine a conceptual estimate of the congestion consequence should public transportation no longer be available. Implicit in that process has been the assumption that in the absence of public transportation, much of the demand would be accommodated by personal auto travel in the same geography. The assumptions are implicitly hypothetical; however, they are based on the best available data and understanding of travel behavior.

The *UMR* estimates the effect of public transit on the roadway system for each urbanized area (UZA) in terms of several performance measures, including person hours of delay saved, gallons of fuel saved, and congestion cost saved. To get the performance measures for each UZA, the *UMR* uses three overall steps:

1. Determine the amount of average weekday VMT during peak periods under base conditions (i.e., with public transit service) for each functional class (freeways vs. arterials) and for each of five congestion levels: uncongested, moderate, heavy, severe, and extreme.
2. Estimate transit's net impact on roadway traffic in terms of changes in VMT during weekday peak periods for each functional class and each congestion level.
3. Add transit's net impact on VMT to the base VMT for each functional class and each congestion level.

If public transit were to be discontinued for a meaningful period of time (long enough that travelers would resume their normal activity/travel participation), there would be two opposite effects: roadway-based transit vehicles would be removed from the traffic stream, but prior transit travelers would shift to other means of travel, including some of them making new roadway vehicle trips.

- Roadway traffic reductions comprised of transit vehicles represent the debit side of transit's net impact on roadway traffic. Only roadway-based modes of transit in mixed traffic are relevant for this debit side.
- Travel previously accommodated by transit accounts for the credit side of transit's net impact on roadway traffic. Transit accommodates people who might otherwise use private passenger vehicles. All modes of transit are relevant for this credit side.

In general, the effect on the credit side can have many dimensions, and these different dimensions can occur in different timeframes:

- Short term—mode shifts by transit riders to other modes, including private-motorized modes.
- Medium term—changes in vehicle ownership and changes in location for residence, employment, or other activities.
- Long term—changes in land use.

To estimate the change in VMT in a post-transit environment, the counterfactual evaluation by the *UMR* estimates only the short-term effect of mode shifts by transit riders to private passenger vehicles.

Through the 2012 report year, the *UMR* did not consider the debit side of transit's net impact on roadway traffic. In addition, the *UMR* assumed on the credit side that every person mile previously made by public transit would have been made in a private passenger vehicle either as a driver or a passenger.

As a result of the methods described in this chapter, starting in the 2013 report year, the *UMR* will not only consider the debit side but also account for the fact that many transit riders in a post-transit environment might choose other options for travel, including not making a trip previously made by transit.

The following describes how the *UMR* estimates the net change in VMT in a post-transit environment through a four-step process:

- Preparing transit service and consumption data.
- Estimating post-transit removed VMT (debit side).
- Estimating post-transit returned VMT (credit side).
- Estimating net post-transit VMT change (credit side – debit side).

PREPARING TRANSIT SERVICE AND CONSUMPTION DATA

The *UMR* primarily uses annual data on transit service and consumption for estimating transit's net effect on roadway VMT. The National Transit Database (NTD) is the source of these service and consumption data. Specifically, the estimation uses data on the amount of average weekday daily vehicle miles (VMs) by roadway-based transit modes in mixed traffic and passenger-miles traveled (PMT).

The *UMR* for every current year reflects estimated conditions during the previous year. For example, the *2013 UMR* reflects 2012 conditions. But the NTD annual data on service and consumption for 2012 are not yet released to the public when the *2013 UMR* is being developed. However, the NTD also contains monthly data on measures of service and consumption, and the 2012 monthly data have already been released when the *2013 UMR* is developed. Specifically, the relevant monthly service data are vehicle revenue miles (VRM), and the relevant monthly consumption data are unlinked passenger trips (UPT). As a result, the monthly data can be used to estimate growth rates from 2011 to 2012, which can be applied to the 2011 annual data to get the 2012 VM and PMT data.

Average weekday daily VM and PMT for 2012 are prepared for every combination of agency, mode, and type of service (i.e., directly operated vs. purchased) contained in one of the publicly released tables for the 2011 annual NTD data, Table 19—Transit Operating Statistics: Service Supplied and Consumed. The Federal Transit Administration (FTA) releases its annual NTD data in a series of tables including Table 19. While agencies are required to report data on average daily VM and PMT annually, these data are not released directly. Indirectly, however, an online tool, Integrated National Transit Database Analysis System (INTDAS), available at http://www.ftis.org/intdas.html, provides average daily data.

For most of the agency–mode–type-of-service combinations in Table 19, average weekday daily PMT and VM can be obtained from INTDAS for 2011. This section describes the steps for estimating 2011 average weekday daily PMT and VM for those agency–mode–type-of-service combinations with missing data from INTDAS. In addition, this section describes the steps for estimating 2012 average weekday daily PMT and VM using the 2011 data.

Preparing 2011 VM and PMT Data

Estimating the missing average weekday daily PMT for 2011 uses 2011 average weekday daily UPT. In addition, estimating the missing data also uses averages within UZAs. The steps for associating transit agencies to UZAs and deriving complete data for average weekday daily UPT are described first, followed by the steps for PMT and VM data.

Associating Agencies to Urbanized Areas

For some cases of missing information in INTDAS, estimating 2011 service and consumption data uses averages for all agencies within a UZA or for all agencies within the same size category of UZAs. For this purpose, each transit agency in Table 19 must be associated with a UZA. Some agencies serve multiple UZAs, and several agencies may serve a single UZA. Publicly released NTD data only allow associating each agency to its primary UZA.

Deriving 2011 Average Weekday UPT

Average weekday UPT for 2011 is used in deriving 2011 average weekday PMT when the latter is not directly available in INTDAS for some cases. The following lists the cases when average weekday UPT is not readily available and how it is estimated:

1. The 2011 annual UPT is available in Table 19—divide the annual UPT by 300.
2. The 2011 annual UPT is not available in Table 19—multiply the number of vehicles operated in maximum service (VOMS) for any agency–mode–type-of-service combination by an average weekday UPT per VOMS. VOMS is always available in Table 19.
    a. The agency–mode–type-of-service combination from Table 19 is present in the INTDAS data—the average UPT per VOMS is for the same combination within the UZA size category of that agency.
    b. The agency–mode–type-of-service combination from Table 19 is not present in the INTDAS data—the average UPT per VOMS is for the same combination of mode and type of service for all UZAs.
    c. The combination of mode and type of service from Table 19 is not present in the INTDAS data—the average UPT per VOMS is for the UZA size category of that agency for all modes and types of service combined.

Steps for Deriving Average Weekday PMT for 2011

The following lists the cases for when average weekday PMT for 2011 for any agency–mode–type-of-service combination is not available from INTDAS and how it is estimated:

1. The 2011 annual PMT is available from Table 19—divide total annual PMT by 300.
2. The 2011 annual PMT is not available from Table 19—multiply the average weekday UPT for the agency–mode–type-of-service combination by a corresponding average passenger trip length (APTL).
    a. The agency–mode–type-of-service combination from Table 19 is present in the INTDAS data—use the APTL for the same combination of mode and type of service within the UZA size category of that agency.
    b. The agency–mode–type-of-service combination from Table 19 is not present in the INTDAS data—use the APTL for the same combination of mode and type of service for all UZAs.
    c. The combination of mode and type of service is not present in the INTDAS data—use the APTL for the UZA size category of that agency for all modes and types of service combined.

Deriving 2011 Average Weekday VM

The following lists the cases for when average weekday VM for 2011 for any agency–mode–type-of-service combination is not available from INTDAS and how it is estimated:

1. The 2011 annual VM is available from Table 19—divide the annual VM by 300.
2. The 2011 annual VM is not available from Table 19—multiply VOMS for the agency–mode–type-of-service combination by an average weekday VM per VOMS.
    a. The agency–mode–type-of-service combination from Table 19 is present in the INTDAS data—use the average VM per VOMS for the same combination of mode and type of service within the UZA size category of that agency.
    b. The agency–mode–type-of-service combination from Table 19 is not present in the INTDAS data—use the average VM per VOMS for the same combination of mode and type of service for all UZAs.
    c. The combination of mode and type of service is not present in the INTDAS data—use the average VM per VOMS for the UZA size category of that agency for all modes and types of service combined.

The 2011 VM data, both directly from INTDAS and derived above, are needed only for roadway-based transit modes operating in mixed traffic. Table 4-1 lists the roadway-based modes in the NTD. For later use to estimate post-transit removed VMT, these modes are grouped into three categories: large buses with frequent stops, medium buses with infrequent stops, and small vehicles with infrequent stops.

Table 4-1. Roadway-Based Transit Modes and Grouping

Modes	Groups
• CB: Commuter bus • JT: Jitney • MB: Bus • PB: Público • RB: Bus rapid transit • TB: Trolleybus	Large buses with frequent stops
• DR: Demand response	Medium buses with infrequent stops
• DT: Demand response—Taxi • VP: Vanpool	Small vehicles with infrequent stops

To include only mixed-traffic VM data for roadway-based modes, the total VM data both directly from INTDAS and derived above are multiplied by the share of directional route miles that are not on exclusive rights-of-way during 2011. The directional route miles of a mode represent the mileage in each direction of roadways over which transit vehicles travel while in revenue service. The right-of-way is considered exclusive for a roadway-based mode when it is reserved at all times for use by transit vehicles of this mode. For each fixed-route mode, transit agencies are required to report both the total directional route miles and the directional route miles on exclusive rights-of-way. The data on directional route miles by type of right-of-way are extracted from INTDAS.

Preparing 2012 VM and PMT Data

Preparing 2012 data involves deriving 2011–2012 growth rates using monthly data and applying them to the 2011 data.

Deriving 2011–2012 Growth Rates in UPT and VRM

The growth rates are derived using the monthly data on UPT and VRM from the Excel file at http://www.ntdprogram.gov/ntdprogram/pubs/MonthlyData/May_2013_Raw_Database.xls. The annual total UPT and VRM for each fiscal year for each agency are determined by taking into account the ending month of the fiscal year of that agency. The growth rate for any agency–mode–type-of-service combination is estimated only when the monthly data are available for every month of the two fiscal years.

Deriving 2012 Average Weekday PMT and VM

The steps for deriving the 2012 average weekday PMT and VM are as follows:

1. PMT—For any given agency–mode–type-of-service combination, apply the corresponding 2011–2012 UPT growth rate to the 2011 average weekday PMT.
2. VM—For any given agency–mode–type-of-service combination, apply the corresponding 2011–2012 VRM growth rate to the 2011 average weekday VM.
3. If a growth rate for an agency–mode–type-of-service combination is not available from the monthly data, the growth rate used depends on the circumstances:

a. The same agency–mode–type-of-service combination is present among the derived growth rates—use the growth rate for the same combination of mode and type of service within the UZA size category of that agency.
b. The same agency–mode–type-of-service combination is not present among the derived growth rates—use the growth rate for the same combination of mode and type of service for all UZAs.

ESTIMATING POST-TRANSIT RETURNED VMT

Post-transit returned VMT refers to the vehicle travel that would have been made by transit riders in a post-transit environment to replace the passenger miles they actually have traveled by transit. It needs to be estimated for weekday peak periods by functional class (freeways vs. arterials) for every agency–mode–type-of-service combination for all transit modes. This section first describes the basic steps to estimating post-transit returned VMT from the average daily PMT data already prepared, followed by descriptions of additional pieces of information used in the basic steps.

Basic Steps

The basic steps for estimating post-transit returned VMT from the average daily PMT data already prepared are as follows:

1. Estimate average weekday peak PMT by applying a set of peak shares to the already-prepared average weekday PMT. Exhibit B-14 of the *2012 UMR* presented these peak shares by mode for 15 individual transit agencies *(2)*. For each mode, averages were also made available for each size category of UZAs.
2. Convert the average weekday peak PMT to total post-transit returned VMT by applying a mode shift factor and a circuity factor. A mode shift factor accounts for the fact that not all transit riders would return to private passenger vehicles in a post-transit environment for the passenger miles they have actually made on public transit. A circuity factor accounts for the probability that travel between a given pair of origin and destination may be longer in distance by transit than by private passenger vehicle. In applying these factors, changes in destination between travel by transit and travel by private passenger vehicle are not considered. Details about mode shift and circuity factors are discussed later.
3. Disaggregate total post-transit returned VMT by functional class between freeways and arterials. The first step is to separate the post-transit returned VMT for road-based transit modes between freeways and arterials. Details about the distribution by functional class are discussed later. The second step is to assign the total post-transit returned VMT to freeways or arterials as follows:
    a. Freeways: commuter rail and the freeway portion of the total post-transit returned VMT for road-based modes.
    b. Arterials: other non-road-based transit modes and the arterial portion of total post-transit returned VMT for road-based modes.
4. Disaggregate the post-transit returned VMT for each functional class by level of base congestion: uncongested, moderate, heavy, severe, and extreme. Ideally, the distribution for disaggregating the total post-transit returned VMT for each functional class should

reflect the fact that transit travel is likely to be more concentrated on more congested parts of a roadway network than travel by private passenger vehicle in a given UZA. Until better data are available, the *UMR* currently disaggregates post-transit returned VMT by congestion level for a given functional class according to the distribution of based roadway VMT.

Mode Shift Factors

A mode shift factor represents the ratio of transit passenger miles to private vehicle miles displaced by transit before circuity is considered. In general, mode shift factors may be estimated from different methods (*8*). One approach is to estimate mode shift factors from responses to an alternative mode question as part of transit on-board surveys. Such a question typically includes drive alone, auto ride, taxi, etc. as alternative modes. For a given distribution of alternative modes, the corresponding mode shift factor for an agency can be estimated as (% Drive Alone) + (% Auto Ride) / 2.5 + (% Taxi).

APTA published two reports between 2004 and 2007 that summarized data on alternative modes from on-boarding surveys conducted by individual agencies. The first report (*9*) separated between rail and roadway modes but did not disaggregate the summary data by UZA size. The mode shift factor was 53 percent for rail and 37 percent for roadway modes. The second report (*10*) not only separated between rail and bus modes but also disaggregated by category of agency size (small, medium, large, and large suburban). The mode shift factor was 39 percent for small agencies, 42 percent for medium agencies, 47 percent for large agencies, and 52 percent for large suburban agencies. However, these categories of agency size cannot be matched with the categories of UZA size used by the *UMR*.

While the summary data on alternative modes in these reports were based on a large number of transit on-board surveys from a range of transit agencies and UZAs, the data were not available for individual modes, agencies, or UZAs.

The mode shift factors for commuter rail for the *2013 UMR* were derived with the summary data from two on-board surveys with different UZAs. For other modes, the mode shift factors were derived with the summary data from 60 on-board surveys across 44 different UZAs. For these other modes, average mode shift factors were derived for each size category of UZAs for those UZAs without any on-board data available. PMT data were used as weights when aggregating on-board data from more than one agency.

A large number of documents reporting on-board survey results were obtained. Some of these came from transit agencies in Florida and had already been available to CUTR. Most of these documents were searched and accessed on the Internet. These documents were screened to select those with data on alternative modes. As more and newer data become available, these estimates can be refined.

Circuity Factors

The theoretically shortest distance from Point A to Point B on the surface of the earth is called the "great-circle distance." The distance via any mode of transportation will always be equal or greater than the great circle distance. For a given mode, the ratio of its travel distance to the great circle distance is called its circuity ratio. For the current purpose, the ratio of a transit mode's circuity ratio to the circuity ratio of driving defines the circuity factor of this transit mode.

Differences in circuity across modes result in differences in distance traveled for a given pair of origin and destination. The importance of circular factors has long been recognized, especially when comparing the relative energy efficiency of different modes of transportation (*11*). The importance of circular factors is equally relevant for comparing the relative rate of emissions or for comparing the relative effect on roadway conditions.

The problem is that the circuity factor for any mode is difficult to measure. A few studies have measured circuity factors for non-transit modes. Fricker (*12*), for example, measured it for carpooling relative to driving alone for 206 individual carpoolers; he derived a value of 1.07, which is smaller than the 1.15 that had been assumed in the literature. A literature search, however, found no studies on measuring distance-based circuity factors for any transit mode. One difficulty in isolating the effect of a single transit mode is that transit travel frequently involves more than one transit mode and both transit and non-transit modes.

While there is no empirical evidence, transit distance-based circuity factors likely vary by mode, particularly between modes with exclusive rights-of-way and modes in mixed roadway traffic. In addition, larger metropolitan areas tend to have more dense transit networks and more frequent transit services than smaller areas. As a result, larger metropolitan areas should have more direct transit travel for a given transit mode.

This lack of actually measured circuity factors, however, has not prevented specific values from being used in the literature. In the landmark study of the relative energy efficiency of urban transportation modes, for example, the Congressional Budget Office (*11*) assumed a value of 1.20 for vanpool, 1.40 for demand responsiveness, 1.10 for express bus, and 1.30 for commuter rail. Delucchi (*13*), on the other hand, adjusted these values downward, particularly for rail modes, in comparing the relative emission rates of different transit and other modes.

Without any evidence on the distance-based transit circuity factors, the approach taken in the *2013 UMR* is to set default values that vary across UZA size but not by mode. Table 4-2 shows these default values.

Table 4-2. Default Transit Circuity Factors by UZA Size

UZA Size				Total
Small	Medium	Large	Very	
1.15	1.11	1.08	1.05	1.10

Distribution of VRM by Functional Class

The distribution of VRM by functional class is used to disaggregate VM between freeways and arterials for roadway-based transit modes. The distribution of VRM by functional class has been derived by combining the General Transit Feed Specification (GTFS) database of transit networks and schedules for individual transit agencies with the functional classification information for the service area contained in FHWA's National Highway Planning Network. The GTFS defines a common format for public transit schedules and associated geographic information. Transit agencies can use the GTFS specification to provide their schedules and geographic information to Google Maps® and other Google® applications that show transit information. The National Highway Planning Network is a comprehensive geospatial network database of the nation's major highway system. Such a distribution has been derived for 81 individual transit agencies from 67 different UZAs as well as for each of the four size categories of UZAs.

ESTIMATING POST-TRANSIT REMOVED VMT

Post-transit removed VMT refers to the vehicle travel that actually has been made by roadway-based transit vehicles operating in mixed traffic conditions that would not be made in a post-transit environment. Post-transit removed VMT needs to be estimated for weekday peak periods by functional class (freeways vs. arterials) for every agency–mode–type-of-service combination. This section first describes the basic steps to estimating post-transit removed VMT from the average daily VM data already prepared, followed by descriptions of additional pieces of information used in the basic steps.

Basic Steps

The basic steps for estimating post-transit removed VMT from the average daily VM data already prepared are:

1. Estimate average weekday peak VM by applying a set of peak shares to the already-prepared total average weekday VM. Details about these peak shares are discussed later.
2. Disaggregate the average weekday peak VM by functional class in terms of freeways and arterials. The disaggregation is based on shares of roadway-based VRM between freeways and arterials. Details about these VRM shares by functional class are discussed later.
3. Disaggregate the average weekday peak VM for each functional class across the five congestion levels: uncongested, moderate, heavy, severe, and extreme. Ideally, the distribution for disaggregating the total post-transit removed VMT for each functional class should reflect the fact that transit service is likely to be more concentrated on more congested parts of a roadway network than travel by private passenger vehicles in a given UZA. Until better data are available, the *UMR* currently disaggregates post-transit removed VMT by congestion level for a given functional class according to the distribution of base roadway VMT.
4. Estimate post-transit removed VMT by converting the average weekday peak VM for each functional class and each level of base congestion from Step 3 to passenger-car-equivalent VMT. The conversion is based on pre-established passenger-car equivalency

(PCE) values. Transit vehicles operating in mixed traffic may consume the equivalent of more than one private vehicle worth of roadway capacity due to their physical size, characteristics of transit operations, and roadway features. A particular PCE value represents the number of private passenger vehicles displaced by a single transit vehicle under specified roadway, traffic, and control conditions. Details on these PCE values and related contributing factors are discussed later.

Peak Share of VM

The peak share for getting the average weekday peak VM has been derived from adjusting the peak shares for boardings shown in Exhibit B-14 of the *2012 UMR* by a factor reflecting differences in the degree of peaking between VRM and boardings. Each size category of UZAs has its own adjustment factor.

The NTD contains data on weekday rail car revenue miles for each weekday period—AM peak, midday, PM peak, and night—for commuter rail, heavy rail, and light rail but not for any other modes. Individual transit agencies define these periods according to their local conditions and report to the NTD. Using NTD data for 2007–2010 (2011 data are not available), the adjustment factor for each size category of UZAs is calculated as the ratio of the peak share for revenue passenger car miles over the peak share for boardings for these three rail modes combined.

PCE Values

To determine default PCE values, a brief scan of the literature was conducted to understand what research exists that may have quantified PCEs through simulation, measurement, or other methods. This scan resulted in four basic conclusions:

1. PCE values depend on many factors about transit vehicles and operations and the roadway network. In the first two columns, Table 4-3 lists these factors summarized from the scan.
2. The literature does not provide the PCE values for the range of conditions at the UZA level.
3. Using the limited information from the literature, reasonable assumptions can be made on default PCE values for this range of conditions.
4. Additional research or simulation would be required to obtain more robust PCE values for this range of conditions.

Table 4-3. PCE Factors and Dimensions

PCE Factors		PCE Dimensions			
Category of Individual Factors	**Individual Factors**	**Type of Transit Vehicle**	**Size of Urbanized Areas**	**Roadway Functional Class**	**Congestion Level**
Transit vehicles and operations	Large size of transit vehicles	X			
	Slow acceleration/deceleration	X		X	X
	Long dwell time		X	X	X
	High frequency			X	X
	Bike-on-bus policy			X	X
	High handicap volume			X	X
	Lack of bus bays			X	X
Roadway network	Roadway upgrade and length	X			
	Narrow roadways		X		X
	Large share of large vehicles in traffic	X	X		
	Dense intersections on arterials		X	X	
	Roadway congestion				X

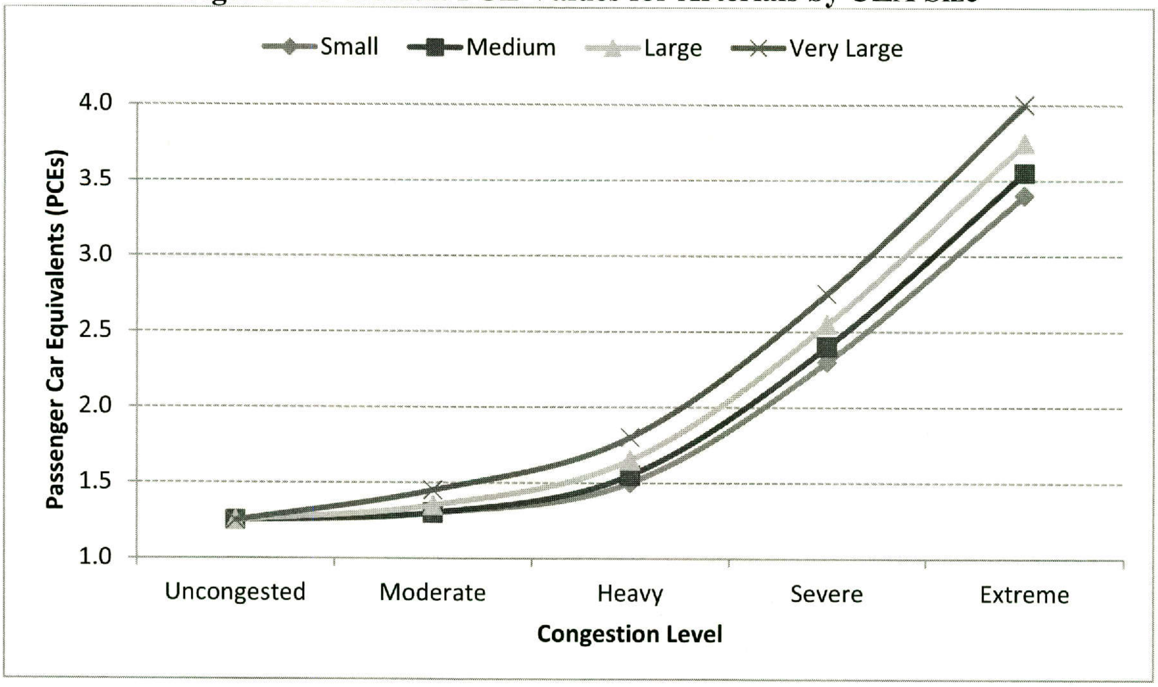
Table 4-4 represents the estimated default PCEs that vary across four dimensions: UZA size, roadway functional class, congestion level, and type of transit vehicle. Each of these factors is hypothesized to contribute to the impact of transit vehicle traffic on overall roadway congestion. For reference, recall that Table 4-1 defines each type of transit vehicle in terms of modes used in the NTD.

Table 4-4. Default PCEs by Four Dimensions

Functional Class	**Congestion Level**	**Type of Transit Vehicle**					
		Large Buses by UZA Size (fixed-route and jitney)				**Medium Buses (demand response)**	**Small Vehicles (vanpools & taxis**
		Small	**Medium**	**Large**	**Very Large**		
Freeways	Uncongested	1.50	1.50	1.50	1.50	1.25	1.00
	Moderate	1.7	1.7	1.7	1.7	1.40	1.00
	Heavy	1.9	1.9	1.9	1.9	1.60	1.00
	Severe	2.1	2.1	2.1	2.1	1.80	1.00
	Extreme	2.4	2.4	2.4	2.4	2.00	1.00
Arterials	Uncongested	1.25	1.25	1.25	1.25	1.25	1.00
	Moderate	1.30	1.30	1.35	1.45	1.35	1.00
	Heavy	1.50	1.55	1.65	1.80	1.50	1.00
	Severe	2.30	2.40	2.55	2.75	1.75	1.00
	Extreme	3.40	3.55	3.75	4.00	2.25	1.00

Figure 4-1 shows the default PCE values by congestion level and UZA size for arterials to illustrate a visual on how they differ.

Figure 4-1. Default PCE Values for Arterials by UZA Size



These default PCE values are set as follows:

- Small vehicles (taxis for demand response service and vanpools)—These transit vehicles are considered to be equivalent to an average private passenger vehicle. These small transit vehicles are much smaller than other transit vehicles and rarely stop for passenger pickups and drop-offs.
- Large buses on arterials (fixed-route and jitney)—These PCE values are set relative to the minimum value of 1.25 for uncongested conditions and 4.0 for extreme congestion conditions.
    - Under uncongested conditions, the effect of large buses is likely to be small but may not be negligible. For example, they take longer to accelerate at traffic lights. In addition, they may block regular traffic when the light is green at an intersection and they happen to stop for passenger pickups and drop-offs, for either a far-side or a near-side stop. To capture these effects, a value of 1.25 is used.
    - Parry and Small (*14*) assumed a preferred PCE value of 4.0 for Washington, D.C. and Los Angeles for the areas served by the Washington Metropolitan Area Transit Authority (WMATA) and the Los Angeles County Metropolitan Transit Authority (MTA) in their study of whether urban transit subsidies should be reduced.
    - Parry and Small (*14*) also used a range of PCE values from 2.0 to 8.0 for a sensitivity analysis, but the high value of 8.0 is not chosen for the *UMR* because it may be true for some localized highly extreme conditions but is unlikely to be representative for an entire UZA. According to the 1985 *Highway Capacity Manual* (*15*), as cited by the Victoria Transport Policy Institute (*16*), the bus PCE is about 4.4 for the following relatively extreme condition—for buses operating

on city streets without bus bays where they must stop regularly at the curb for passengers.

- Medium buses (demand response services)—These PCE values are set relative to those for large buses by taking into account both their smaller sizes and less frequent stops.
- Large buses on freeways—These PCE values are set relative to the minimum value of 1.50 for uncongested conditions and 2.40 for extreme congestion conditions. The PCE value of 2.40 is based on empirical data and microscopic traffic simulations for multilane freeways with upgrades under 2 percent during congestion (*17*). As shown in Table 5 of (*17*), the PCE value of 1.5 for uncongested conditions is from the 2000 *Highway Capacity Manual* for freeway sections with upgrades under 2 percent (*18*). These PCE values are assumed to be the same across the UZA sizes primarily because freeways are largely similar across all UZAs and buses do not stop on freeways anywhere.

While these default PCE values are not specific to variations in each of the 13 individual factors that potentially may impact PCE values, the influences of these individual factors are likely to be captured by the four dimensions in Table 4-3. The following discusses the reasons for varying the PCEs by these factors:

- Type of transit vehicle—The three different types of transit vehicles differ not only in size but, more importantly, in how frequently they pick up and drop off passengers.
- Roadway functional class—Transit vehicles on arterials frequently stop for passenger pickups or drop-offs, but they do not stop on freeways. The PCE values depend largely on the size and weight of transit vehicles on freeways but also depend on the effects of these passenger pickups and drop-offs on arterials.
- Congestion level—The extent to which the roadway is congested can highly impact the PCEs of transit vehicles because removing transit service from a roadway network that has adequate capacity would not impact roadway performance much. Many of the characteristics of transit operations contribute to roadway congestion. At the same time, the congestion effect of these characteristics of transit operations is likely to be proportionally much greater with more severe congestion.
- UZA size—For a given congestion level (other than uncongested conditions), the hypothesis is that the impact of each bus mile on roadway capacity is greater in larger UZAs. These hypothesized differential impacts result from differences in transit operations and roadway networks across different size categories of UZAs. For example:
    - Larger UZAs are likely to have denser intersections and narrower roadways.
    - Transit services in larger UZAs are likely to have longer dwell time due to higher demand.
    - Larger UZAs are likely to have larger shares of large vehicles (i.e., buses) in traffic. While the higher frequency of transit service in larger UZAs is already captured in the amount of bus miles, larger shares of large buses can have additional effects on roadway traffic.
    - Larger UZAs may be less likely to have bus bays on their transit routes.

ESTIMATING NET POST-TRANSIT VMT CHANGE

Once the post-transit returned VMT and post-transit removed VMT have been estimated for each agency–mode–type-of-service combination, it takes two simple steps to calculate the net post-transit VMT change for individual UZAs:

1. Subtract post-transit removed VMT from post-transit returned VMT for each agency–mode–type-of-service combination.
2. Aggregate the net post-transit VMT change for these individual combinations to individual UZAs by the primary UZA of each agency.

IMPLEMENTATION OF METHODOLOGY IMPROVEMENTS

The methodology outlined in the above sections can be executed through application of an Excel spreadsheet tool that was developed as part of this overall effort. This spreadsheet workbook includes both necessary formulas for executing the above methodological improvements as well as several comprehensive data sets necessary to execute these calculations for the *2013 Urban Mobility Report*. It is intended to be used iteratively with the *UMR* data sets that characterize urban area roadway volume and congestion levels for the respective urban areas.

As each subsequent report update occurs, the respective data sets can be reviewed and updated as data are available to reflect the most current conditions. Specifically, information about transit service levels can be updated annually and other estimates of post transit travel behavior can be updated as additional survey or other information becomes available.

FUTURE IMPROVEMENTS

By incorporating the methods described in this chapter, the *2013 UMR* will include a number of improvements to the approach used in earlier years for estimating the effect of public transit on roadway VMT. There is no doubt that these improvements are analytically important for more accurate estimates of the effect of public transit on roadway traffic conditions. These improvements are significant with regard to the magnitude and direction of the estimated effect of public transit on roadway traffic conditions. Further improvements, however, are still desirable. Some of these are feasible in the short term, while others require more time.

Improvements

The new approach for the *2013 UMR* makes several improvements to the approaches from earlier years. These include:

- Explicitly accounting for the miles traveled by roadway-based transit vehicles operating in mixed traffic conditions.
- More accurately accounting for the potential shift to private passenger vehicles in a post-transit environment by transit riders for the passenger miles they have actually traveled by transit.
    - Using average daily weekday PMT from NTD rather than average daily weekday equivalent converted from annual total PMT by dividing it with 300 days.

- Disaggregating PMT for roadway-based transit modes to functional classes by the distribution of vehicle revenue miles for these transit modes rather than by the distribution of base roadway traffic.
- Using mode shift factors from on-board surveys rather than assuming every passenger mile traveled on transit would be shifted to private passenger vehicles in a post-transit environment.
- Accounting for path circuity rather than assuming the same path of travel between transit and roadway for a given origin-destination pair.

Further Improvements in the Short Term

In the short term, further improvements should focus on the support information used in estimating net post-transit VMT change from average weekday daily service and consumption data from the National Transit Database. The following are potential candidates for such further improvements for estimating post-transit returned VMT and post-transit removed VMT, respectively. Another potential improvement is to account for transit access by private passenger vehicles.

These improvements would refine the process and perhaps add to accuracy in the case of specific metropolitan areas whose conditions are different from the norm. The overall impact of these changes is felt to be modest—particularly in the context of the magnitude of changes between the methods prescribed here and those used in previous *UMR* analyses.

Post-transit returned VMT

Suggested post-transit returned VMT improvements include the following:

- Obtain values specific to agencies, modes, and types of service for more agencies and more UZAs.
- Estimate values through comparing the distances traveled by transit and private passenger vehicles via their respective shortest paths between the actual pair of origin and destination for each of the transit trips actually made and randomly selected from the 2009 National Household Travel Survey (NHTS). While the 2009 NHTS is inadequate for estimating values specific to all UZAs, the sample should be large enough to allow estimating values for a range of conditions.
- Obtain values specific to agencies, modes, and types of service for more agencies and more UZAs. One way to cover more agencies and UZAs would be to use the transit on-board survey data that the APTA has assembled from individual transit agencies for its report on profiles and transit passengers (*9*) and for the transit performance monitoring system (*10*).
- Obtain values specific to agencies for more agencies and UZAs by matching agency schedule and network data in the GTFS format with roadway network data. This means obtaining GTFS databases for more agencies and more UZAs and improving geographic information system (GIS) techniques to match roadway network data with the transit network data. In addition, obtain such values to reflect differences in passenger volume across functional classes by using boarding data for trip-specific electronic fareboxes or using load data from automatic passenger counters.

- Obtain distributions that reflect the fact that transit PMT is more concentrated on more congested parts of a roadway network in a given UZA.

Post-transit removed VMT

Suggested post-transit removed VMT improvements include the following.

- Obtain values specific to VM by using transit schedule and network data in the GTFS format, and obtain such values specific to agencies, modes, and types of service for most agencies and UZAs for which GTFS data are available.
- Obtain values specific to agencies for more agencies and UZAs by matching agency schedule and network data in the GTFS format with roadway network data. This means obtaining GTFS databases for more agencies and more UZAs and improving GIS techniques to match roadway network data with the transit network data.
- Obtain distributions that reflect the fact that transit roadway-based transit service is more concentrated on more congested parts of a roadway network in a given UZA.
- Conduct simulations at least at the corridor level to assess the effect of roadway-based transit vehicles on roadway traffic conditions for a range of conditions on transit vehicles, transit service, roadway characteristics, base roadway conditions, etc.
- Explore the prospect that rail and exclusive guideway facilities that are not fully grade separated (roadway grade crossings) would have sufficient impact on cross-traffic delays so as to merit some inclusion of that effect into the overall analysis.

Access VMT

In terms of transit modes used by commuters with relatively long commutes, such as commuter rail, some of the commuters access the service by private passenger vehicles either as a driver or as a passenger. In a post-transit environment, such access VMT would not be made. The significance of access VMT varies across modes and UZAs. It may either be considered separately or be considered as part of the circuity factor used.

Further Improvements in the Longer Term

Further improvements in the longer term should focus on using both temporally and spatially detailed data available from technologies already in application to estimate post-transit removed VMT, post-transit returned VMT, and net post-transit VMT change that are similarly detailed both temporally and spatially. These temporally and spatially detailed data for individual agencies and UZAs can come from automatic vehicle location, automatic passenger counters, GTFS databases of transit schedules and networks, and GIS databases of roadway networks.

Given the overall conceptual nature of the post-transit congestion impact analysis, these potential future changes, while desirable, would not be expected to offer significant value as it relates to policy discussions surrounding the role of transit in reducing congestion.

CHAPTER 5
CONCLUSIONS AND FUTURE WORK

This research report documents the findings of a research effort to investigate two aspects of possible improvement for methods in the *Urban Mobility Report.* First, researchers investigated the possibility of creating new time-of-day distributions for trucks (in contrast to distributions currently used in the *UMR* for all vehicles). Second, researchers teamed with transit researchers at the University of South Florida CUTR to investigate possible updates to the methodology used in the *UMR* to estimate transit benefits.

TRUCK VOLUME DISTRIBUTIONS

Researchers collected vehicle classification data from Georgia, Texas, Washington, and Colorado. While there were ultimately only 36 sites used to investigate potentially new truck distribution graphs, the results generally indicate that trucks have a different time-of-day distribution than a distribution created from all vehicles together. The following are highlights of the findings documented in this report:

- Weekday has a higher proportion of trucks than weekend, and freeway has a higher proportion of trucks than non-freeway (Table 3-1).
- In general, truck distribution profiles do not follow the patterns of all-vehicle profiles (Figures 3-1 and 3-2).
- The non-freeway truck distribution for the AM-PM peak profile shows that trucks are in with the peak periods of the all-vehicle distributions (Figure 3-3 and Figure 3-7). While this is based upon only three samples and requires more research, it is hypothesized that this could be indicative of deliveries being made during peak periods.
- On weekends, the truck distributions have a similar form as all vehicles, but the truck volumes begin to form sooner (Figure 3-4 and Figure 3-8).
- For morning-peaking distributions for weekdays, the newly developed truck distributions show a typical midday peak pattern during the regular work hours, and freeway trucks start forming about an hour earlier than they do on non-freeway roads (Figure 3-5). Similarly, along afternoon-peaking roadways, the truck distributions show a smooth midday peak for freeway but a plateau between 8 AM and 4 PM (Figure 3-6).

The results strongly suggest that the distribution for trucks is different than all vehicles. However, because the sample size of these findings is relatively low, researchers hope to investigate these findings on larger samples prior to making methodological changes in the *UMR*.

PUBLIC TRANSPORTATION BENEFITS METHODOLOGY CHANGES

As part of this research, TTI researchers collaborated with public transit experts at the USF CUTR to assist in the development of suggested methodological changes to improve the public transportation benefits methodology used in the *UMR.*

Chapter 4 provides documentation of CUTR's recommended improvements for the *2013 UMR.* TTI researchers will look to incorporate these changes into the *2013 UMR.* The proposed approaches presented in Chapter 4 provide several improvements to the transit benefits methodology in the *UMR*, including:

- Explicitly accounting for the miles traveled by roadway-based transit vehicles operating in mixed traffic conditions.
- More accurately accounting for the potential shift to private passenger vehicles in a post-transit environment by transit riders for the passenger miles they have actually traveled by transit. This is facilitated by:
    - Using average daily weekday PMT from NTD rather than average daily weekday equivalent converted from annual total PMT by dividing it with 300 days.
    - Disaggregating PMT for roadway-based transit modes to functional classes by the distribution of vehicle revenue miles for these transit modes rather than by the distribution of base roadway traffic.
    - Using mode shift factors from on-board surveys rather than assuming every passenger mile traveled on transit would be shifted to private passenger vehicles in a post-transit environment.
    - Accounting for path circuity rather than assuming the same path of travel between transit and roadway for a given origin-destination pair.

Chapter 4 also documents future improvement opportunities for the short term and long term. Researchers will investigate these methodological improvements as resources allow for future versions of the *UMR*.

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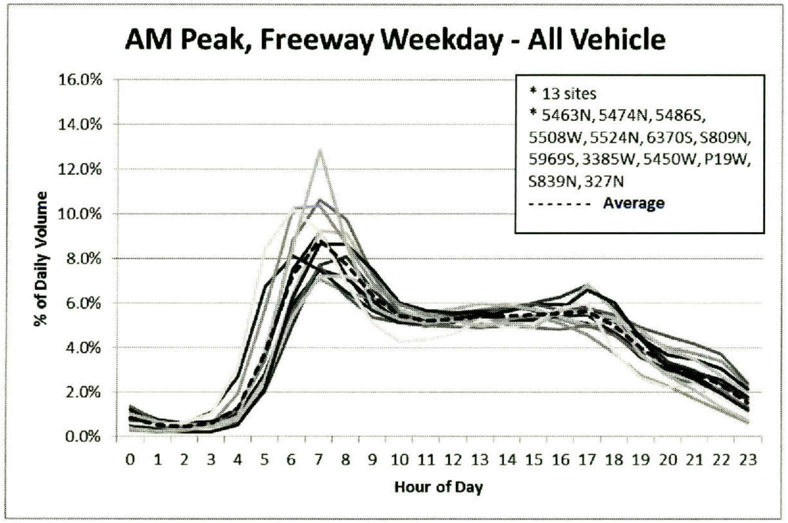
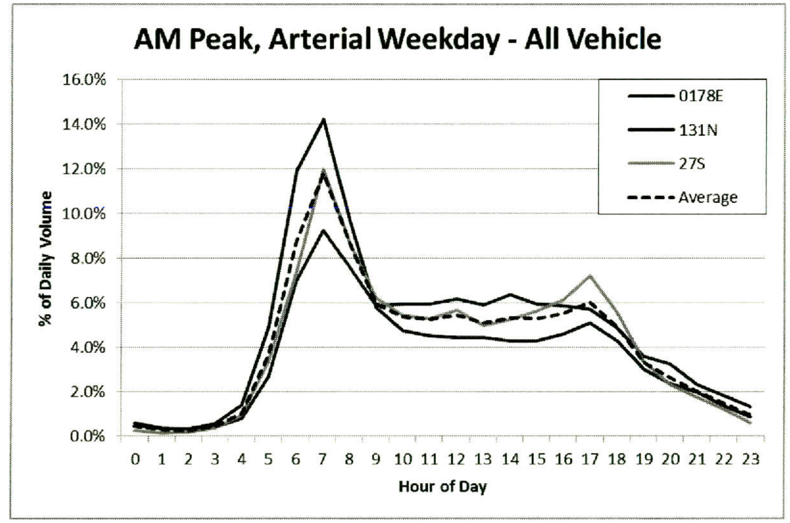
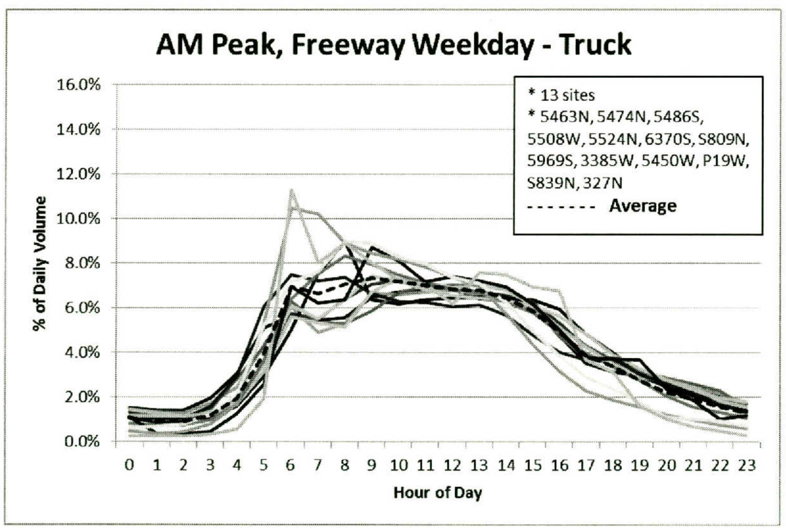
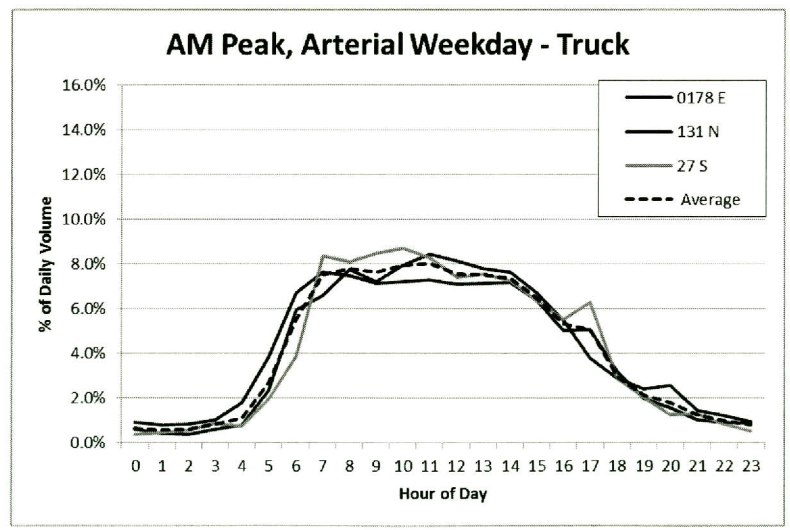
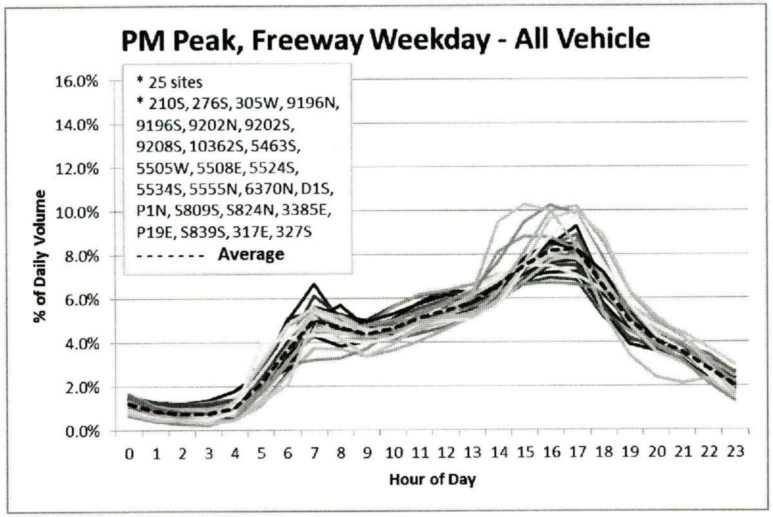
APPENDIX
PERCENTAGE OF DAILY VOLUME DISTRIBUTIONS

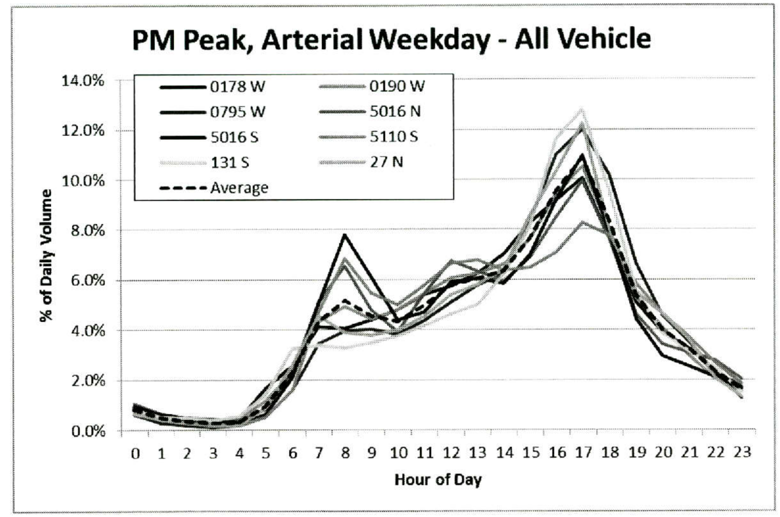


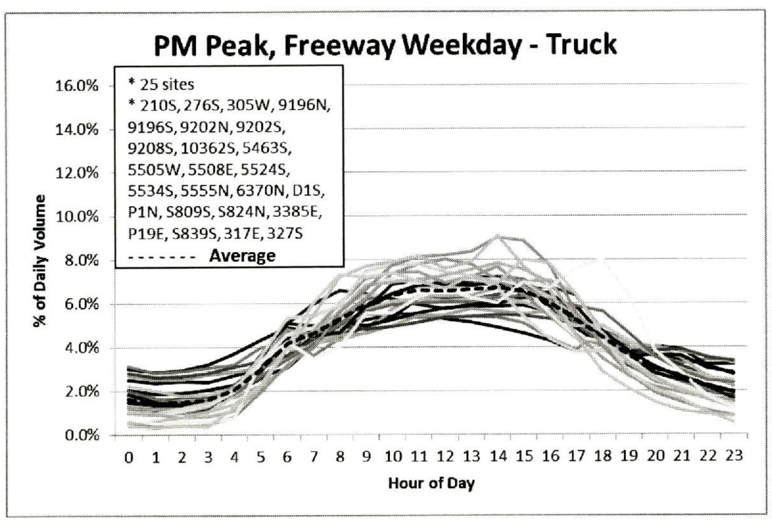


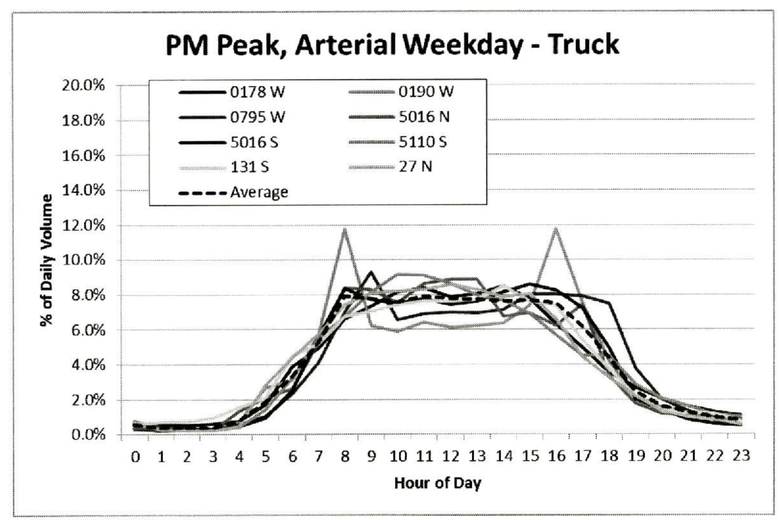


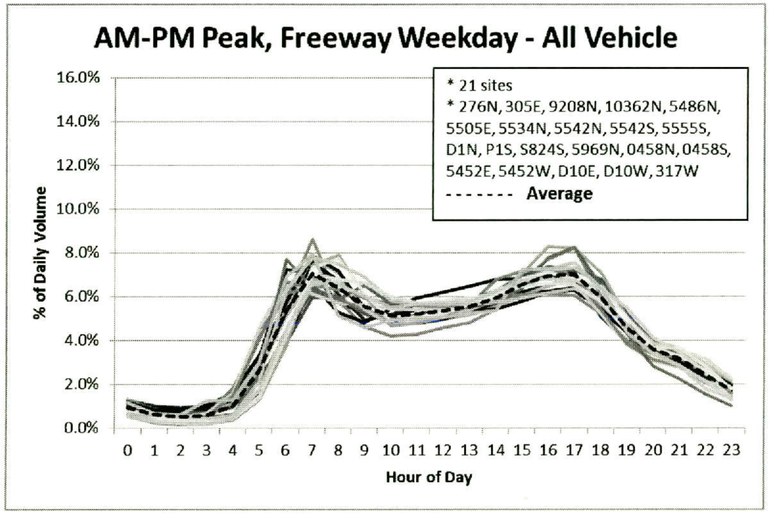


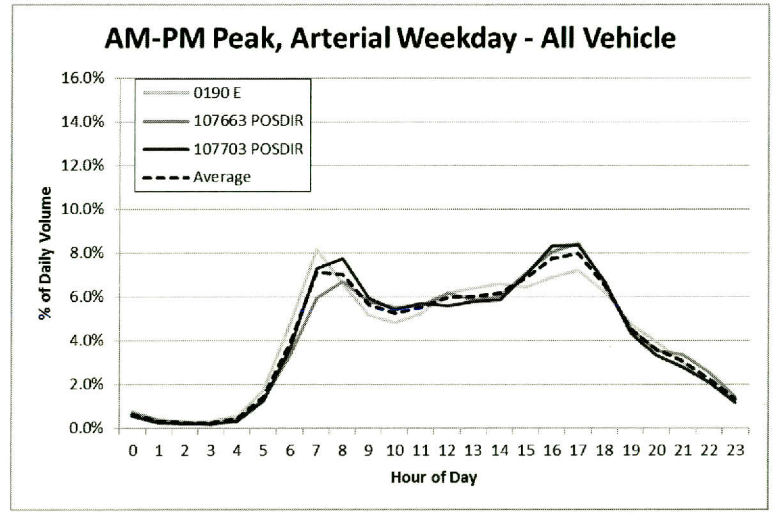

PM Peak, Freeway Weekday - All Vehicle
* 25 sites
* 210S, 276S, 305W, 9196N, 9196S, 9202N, 9202S, 9208S, 10362S, 5463S, 5505W, 5508E, 5524S, 5534S, 5555N, 6370N, D1S, P1N, S809S, S824N, 3385E, P19E, S839S, 317E, 327S
Average
% of Daily Volume
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour of Day

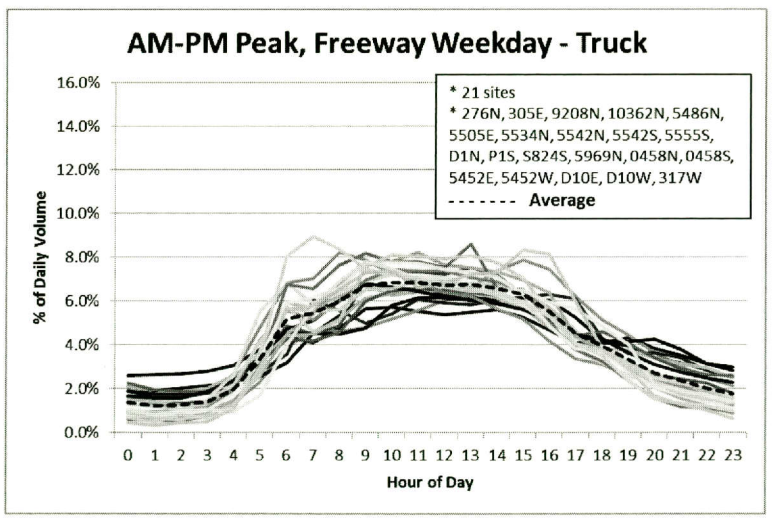

PM Peak, Arterial Weekday - All Vehicle
0178 W
0190 W
0795 W
5016 N
5016 S
5110 S
131 S
27 N
Average
% of Daily Volume
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour of Day

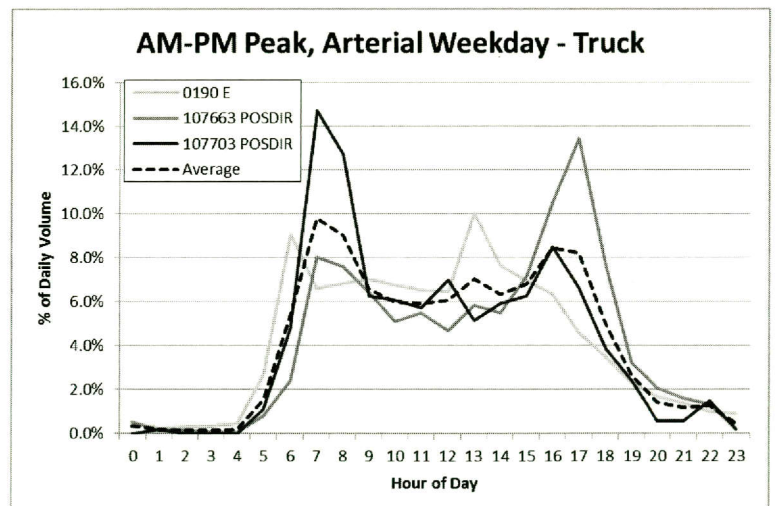

PM Peak, Freeway Weekday - Truck
* 25 sites
* 210S, 276S, 305W, 9196N, 9196S, 9202N, 9202S, 9208S, 10362S, 5463S, 5505W, 5508E, 5524S, 5534S, 5555N, 6370N, D1S, P1N, S809S, S824N, 3385E, P19E, S839S, 317E, 327S
Average
% of Daily Volume
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour of Day


PM Peak, Arterial Weekday - Truck
0178 W
0190 W
0795 W
5016 N
5016 S
5110 S
131 S
27 N
Average
% of Daily Volume
20.0%
18.0%
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour of Day


AM-PM Peak, Freeway Weekday - All Vehicle
* 21 sites
* 276N, 305E, 9208N, 10362N, 5486N, 5505E, 5534N, 5542N, 5542S, 5555S, D1N, P1S, S824S, 5969N, 0458N, 0458S, 5452E, 5452W, D10E, D10W, 317W
------- Average
% of Daily Volume
Hour of Day


AM-PM Peak, Arterial Weekday - All Vehicle
0190 E
107663 POSDIR
107703 POSDIR
Average
% of Daily Volume
Hour of Day


AM-PM Peak, Freeway Weekday - Truck
* 21 sites
* 276N, 305E, 9208N, 10362N, 5486N, 5505E, 5534N, 5542N, 5542S, 5555S, D1N, P1S, S824S, 5969N, 0458N, 0458S, 5452E, 5452W, D10E, D10W, 317W
------- Average
% of Daily Volume
Hour of Day


AM-PM Peak, Arterial Weekday - Truck
0190 E
107663 POSDIR
107703 POSDIR
Average
% of Daily Volume
Hour of Day