RESEARCH & DEVELOPMENT

DRAFT

Planning-Level Extensions to NCDOT Freeway Analysis Tools

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16. Abstract

This project developed extensions to the freeway work zone analysis methodology used by NCDOT, and updated the associated software tool. Through the course of this project, necessary data were collected to develop default traffic volume profiles for different freeways across the state. These default demand profiles, along with the proposed methodology to assign them to each analysis, enhance the user's ability to perform work zone evaluations in North Carolina more quickly and accurately. The project team also embedded new methodologies to quantify the impact of work zones based on the recently-completed national NCHRP 03-107project. The new extensions to the work zone analysis methodology are implemented in the new Java based FREEVAL-WZ software tool. FREEVAL-WZ is fully customized to fit the needs of NCDOT to generate standard reports for each work zone analysis. A comprehensive user's guide is also developed, and serves as the main reference to guide users through the software tool.

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Executive Summary

Conducting a full operational analysis of freeway facilities is a challenging undertaking, as most available methods either lack the necessary detail for specific geometry and demand patterns, or are very data and cost-intensive to implement. For the past few years, NCDOT has been using a customized software application for conducting in-house analyses of freeway facilities, with a special emphasis on work zones. The analysis methodology and associated software tool, FREEVAL-WZ, were deliverables from a prior NCDOT research effort (2010-08). The methodology is founded on the analytical method for evaluating freeway facilities in the Highway Capacity Manual 2010, but has been enhanced to incorporate work-zone analysis details, as well as various state-specific default values for application in North Carolina. While that prior research accomplished its objectives and produced a tool that is used by NCDOT analysts today, several critical extension needs to the methodology have been identified by NCDOT staff through the use and application of the tool in day-to-day practice.

The particular focus of this project was on implementing a series of planning-level analysis extensions to the methodology. Planning-level freeway (work zone) analyses are oftentimes performed in a “data poor” analysis context, where the available data is limited to basic freeway geometry characteristics, and daily traffic demand patterns. Detailed peak-hour volume estimates are oftentimes not available at the early stages in a project. Further, in a planning-level application for work zones, a key decision of interest is when to close lanes and for how long, which ultimately calls for a full-day (24-hour) analysis context. Finally, customized output reports are needed to present key performance metrics in a standardized and readily usable format.

The main products of this research are new empirical results on default traffic volume distributions and methods to support 24-hour freeway analysis, to allow customized application for different geographic regions in North Carolina, and to provide additional demand distributions for general freeway and freeway work zone analysis. These empirically-based results are integrated in a significantly enhanced FREEVAL-WZ tool that enables the analyst to perform a planning-level assessment of freeway facilities and freeway work zones in a 24-hour context, with consideration of region-specific traffic demand patterns.

The products of this research assist day-to-day freeway work zone analyses performed by NCDOT through providing additional default values and customization of the FREEVAL-WZ tool and methodology. The project addressed critical needs and limitations of the tool, and led to a more usable and reliable product to support NCDOT in-house analysis activities.

The results of this research will help analysts in the NCDOT Safety and Mobility Division to explore the operational performance of freeway facilities in a planning-level context, by conducting additional freeway work zone research, and by significantly enhancing the capability of the existing FREEVAL-WZ tool. The research further benefits analyses with and without work zones by enabling 24-hour analysis, improved volume estimation, and enhanced usability, including specifically-targeted output reports for different groups within NCDOT. As such, the primary users of the research products within NCDOT include the work zone group, as well as congestion management.

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1 Introduction

The evaluation of the operational performance of freeway facilities, and the assessment of operational impacts of work zones on freeways, are important focus areas for the Safety and Mobility Division within NCDOT. NCDOT analysts currently apply the FREEVAL-WZ tool, which was developed through a prior research effort completed in 2011 *(11)*, and which builds on the freeway facilities method in the Highway Capacity Manual 2010 *(3)*. The tool provides NCDOT with an in-house software system that can be used to quickly and efficiently estimate the impacts of various work zone strategies, and compare alternatives for the purpose of making informed decisions for work zone traffic control and staging. However, some limitations and critical additions were identified at the conclusion of that prior project, but were deemed to be beyond the scope of the original research effort. In addition, NCDOT staff have identified several shortcomings and areas of required enhancements for the methodology and tool, now that FREEVAL-WZ has been used in day-to-day operations for a few years. This report summarizes research findings and products from a follow-up NCDOT project (2015-09) that was specifically targeted at addressing these shortcomings, and enhancing the NC-specific default values, as well as associated software implementation.

1.1 Research Objectives

The objectives of this project are to

(1) Develop traffic volume distributions by freeway facility type and time of day for North Carolina freeways;
(2) Enhance the FREEVAL-WZ tool through additional planning-level enhancements, including a 24-hour analysis and customized output features such as automatic PDF reports; and
(3) Improve the user-friendliness, reliability and computational performance of the FREEVAL-WZ tool.

1.2 Project Scope

Through this project, the ITRE team has implemented a series of planning-level analysis extensions to the FREEVAL-WZ work zone analysis methodology and software. Planning-level freeway (work zone) analyses are oftentimes performed in a "data poor" analysis context, where the available data are limited to basic freeway geometry characteristics and daily traffic demand patterns. Detailed peak-hour volume estimates are oftentimes not available at the early stages in a project. Further, in a planning-level application for work zones, a key decision of interest is when to close lanes and for how long, which ultimately calls for a full-day, 24 hour analysis context. Finally, customized output reports are needed to present key performance metrics in a standardized and readily usable format.

The specific areas of methodological extensions that have been addressed in this project include:

1. Expanding the FREEVAL-WZ tool to enable a 24-hour analysis (96 consecutive fifteen-minute time periods), which is of critical importance for supporting work zone staging decisions, as well

as evaluating the whole-day performance of a freeway facility in general congestion management applications;

2. Developing additional default traffic volume distributions, which can be used to generate automatic inputs in the methodology. These added k-factor profiles represent extensions to the method to cover a broader geographic region across the state, and enable streamlined analysis of key corridors in the state in a data poor environment;
3. Developing and enabling k-factor profiles for “high-demand” conditions (e.g. 85th percentile) in addition to average distributions currently included in the tool. These will be used to support sensitivity analyses of expected impacts;
4. Enhancing user-friendliness of the tool based on a few years of experience of in-house use at NCDOT. This includes enhancing the reliability and robustness of the tool, to specifically target common analysis issues identified by NCDOT staff;
5. Customizing the output features and reports of the tool to specifically address the needs of NCDOT, including delay, queue, and user cost performance measures;
6. Developing a comprehensive user’s guide for the updated FREEVAL-WZ software tool.

1.3 Background

The desire to improve work zone analysis is based on the NCDOT 'Work Zone Safety and Mobility Policy', which intends to "support the systematic consideration and management of work zone impacts related to safety, mobility, operations, and training" and emphasizes the importance of "minimizing the effects of work zones/activities on the surrounding transportation network"*(1)*. The North Carolina policy is partially motivated by the FHWA 'Rule on Work Zone Safety and Mobility' aiming to "better address the work zone issues of today and the future" *(2)*.

Through the NCDOT policy, the scope of this research effort is concentrated on "significant" work zones, which are expected to have a high impact on the traveling public and are oftentimes located on freeway facilities. As such, the FREEVAL tool is ideally suited for analysis, since it is fundamentally based on the HCM 2010 freeway facilities methodology *(3)*. The tool has been effectively used in national level research to model the effects of recurring freeway bottlenecks *(4)* and was found to be significantly more efficient when compared to simulation-based analysis tools. The reliability version of the FREEVAL considers non-recurring congestion sources such as weather and incident’s impact which enables a comprehensive assessment of the freeway facilities *(5, 6)*.

Other existing deterministic tools for work zone evaluation, include QUEWZ-98 *(7)*, representing the previous state-of-the-practice at NCDOT, which evaluates the performance of a freeway segment with and without a lane closure and provides estimates of queues and user cost from the work zone, based primarily on 1998 Texas data. Alternatively, another spreadsheet-based tool, Quickzone *(8)*, offers greater flexibility than QUEWZ by allowing a network-level analysis. However, it requires significant resources to set up the network, and lacks the operational detail of the effect of weaving segments and ramps. Both tools have been applied in research to model work zone impacts *(9)*. Other analysis tools investigated in technical assistance report *(10)* all require high levels of data input, user training and are expensive. The investigated simulation-based tools include CORSIM, VISSIM, AIMSUN, PARAMICS, and DYNASMART-P.

In summary, FREEVAL was identified as the tool most appropriate for in-house analysis needs of NCDOT, as well as providing broader application to other sections in the Traffic Management Unit, including congestion management. With the proposed customization, FREEVAL-WZ combines the efficiency of a quick planning-level analysis with the potential for conducting a detailed operational evaluation of freeway operations with and without a work zone.

2 Developing Default Volume Distributions

This section of the report presents findings and results of a 24-hour traffic volume profile analysis for North Carolina freeways to be used in the updated Freeway-WZ tool. The traffic volume data were collected with the help from the NCDOT Traffic Survey Unit, as well as the Traffic.com sensor database. The project team has developed standardized freeway traffic volume profiles separated by weekday and weekend. For the weekday volume profiles, the team further divided them into several specific categories after developing an identification method that considers the shape of volume profiles. Special effects such as weather, seasonality, or geographical differences were also considered in the analysis.

2.1 Study Objectives

One of three objectives proposed in the original proposal is 'to develop traffic volume distributions by freeway facility type and time of day for North Carolina freeways'. Two 24-hr freeway traffic volume profiles were provided in the previous project (2010-08: Corridor-Based Forecasts of Work-Zone Impacts for Freeways) separated by urban and rural areas as shown in Exhibit 1.

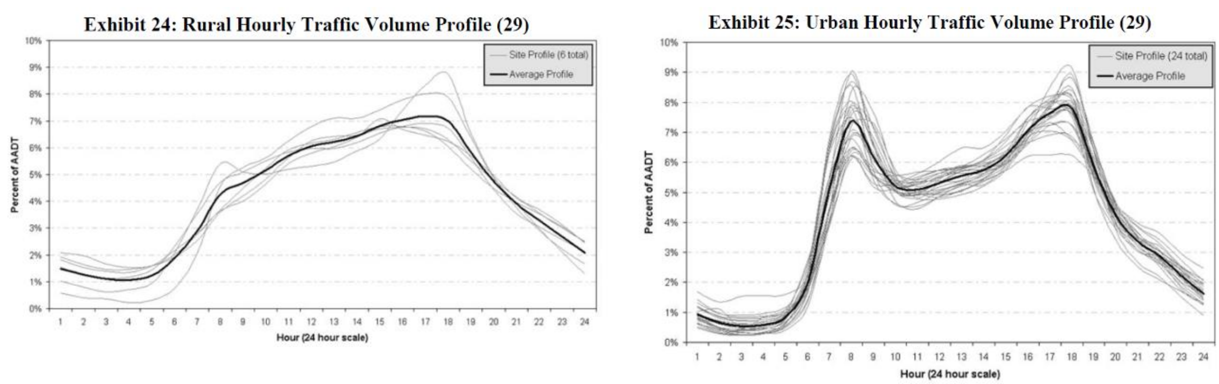


Exhibit 1: NC Freeway Traffic Volume Profiles from the Previous Study (left: rural, right: urban)

The total number of volume profiles analyzed in the previous study was 30 (6: rural, 24: urban) and they were all from weekday data. The volume profile data in the previous study had several weaknesses including: 1) being more than 10-years old, 2) providing only two categories: urban and rural, 3) lacking analysis of weather, seasonal, or geographical effects, 4) not supporting weekend analysis, and 5) not being sensitive to directionality of travel to accurately reflect day-to-day commuting patterns. Therefore, the research team aimed to provide new freeway traffic volume profiles for NCDOT to be used in the updated FREEVAL-WZ tool, giving more confidence and flexibility in applying volume profiles for freeway (work zone) analysis.

Specific to this task and objective, the research team investigated following items:

1. Volume profile identification and application method for NC freeways,

2. Analyses results of weekends data, and
3. Analyses results of seasonal, geographical, and weather effect to volume profiles.

2.2 Analysis Scope and Limitations

The volume profile analysis was based on freeway traffic volume data collected with the help from NCDOT and sensor database in NC as shown below:

1. Permanent station data
   - 52 volume profiles from 26 stations
   - 24-hour volume data for a whole year
   - 2013 data were used whenever available; if the 2013 data were unavailable, then the latest available one year of data was used
2. Temporary station data
   - 144 volume profiles from 73 stations
   - 24-hour volume data for a week
   - The latest data if more than two dataset (having different time frame) are available for any station

2.3 Data Collection

The team collected traffic volume and weather data from various sources. In case of the traffic volume data, the team obtained data from NCDOT and the Traffic.com sensor database. NCDOT provided freeway traffic volume data separated by permanent and temporary stations across state. Many of the stations had up-to-date volume data with a small number of exceptions. The Traffic.com sensor database provides up-to-date volume data in the RTP (Research Triangle Park) area. The team selected specific sensors of interests in collecting and analyzing traffic volume profiles.

A map showing all permanent and temporary data collection locations is shown in Exhibit 2 below. The exhibit illustrates the broad geographic coverage of the available data, covering most freeways in the state of North Carolina.

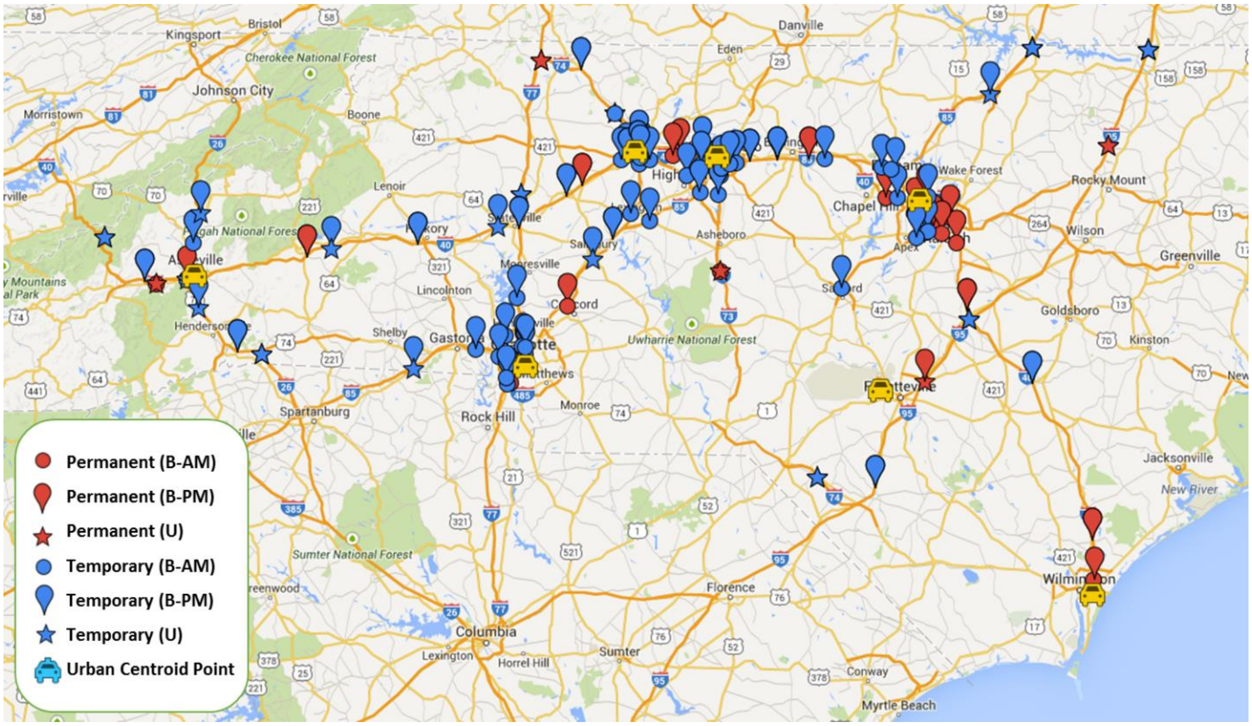


Exhibit 2: Geographical Distribution of Permanent and Temporary Traffic Count Stations

2.3.1 Permanent Station Data

Exhibit 3 presents a list of permanent count stations used in the analysis, including code name, site/stations number, route number location, county, and available date of traffic volume data. The code was provided separated by ‘a’ for stations having current data available and ‘b’ for stations that are not presently online (but provided data up to a few years ago). There were nine more stations but they were excluded in the data collection and analysis since they have data either only before the year of 2000 or in a duplicate location with more up-to-date data. It is also noteworthy to state that the ’a10’ (I-440, West of US 70) data was not collected and analyzed from the NCDOT data because the team could collect identical data from the Traffic.com sensor database (‘s’ stations).

Since each station had bi-directional volume data, either east-to-west or north-to-south, a total of 52 volume profiles were collected from 26 permanent stations. Each volume profile presented average hourly volume level for 24-hour in the year of data collection.

Exhibit 3: Freeway Traffic Data from Permanent Stations

Code	ATR Site #	Route #	Location	County	Data Collection Year
b1	A0001	I-40/ I-85	West of SR 1928 (Jimmie Kerr Rd)	Alamance	2000
a1	A1001	I-240	West of NC 191 (Brevard Rd)	Buncombe	2013
a2	A1003	I-40	East of SR 1200 (Wiggins Rd)	Buncombe	2013
a3	A1101	I-40	West of SR 1734 (Carolina St)	Burke	2013
a4	A2502	I-95	North of I-295/US 13	Cumberland	2013
b2	A2901	I-40	East of SR 1410 (Farmington Rd)	Davie	2009
a5	A4012	I-40 Bus	West of I-40 & I-40 Bus Split	Guilford	2013
a6	A4013	I-40	East of NC 66	Forsyth	2013
a7	A5001	I-40	West of NC 242	Johnston	2013
b3	A5901	I-85	West of US 29	Mecklenburg	2002
a8	A5903	I-277	South of US 29 (Graham St)	Mecklenburg	2013
b4	A5910	I-485	East of I-77	Mecklenburg	2005
a9	A6303	I-95	South of NC 33	Nash	2013
b5	A6407	I-40	West of NC 132 (College Rd)	New Hanover	2005
b6	A6501	I-95	North of NC 48	Northampton	2006
a10[1]	A9108	I-440	West of US 70 (Glenwood Ave.)	Wake	2013
b7	A9201	I-85	North of US 1	Warren	2007
a11	W8501	I-77	South of NC 89 (West Pine St)	Surry	2013
a12	W7001	I-40	West of NC 210	Pender	2013
a13	W7501	I-73/ I-74	North of New Hope Church Rd	Randolph	2013
s1	284.5	I-40	0.22 Mile West of Aviation Pkwy	Wake	2013
s2	274.8	I-40	0.85 Mile West of Fayetteville Rd	Durham	2013
s3	6.0	I-540	0.68 Mile West of Leesville Rd	Wake	2013
s4	9.8	I-440	0.29 Mile East of Wake Forest Rd	Wake	2013
s5	2.1	I-440	0.33 Mile West of Western Blvd	Wake	2013
s6	304.1	I-40	0.76 Mile West of E Garner Rd	Wake	2013
s7	297.3	I-40/440	0.72 Mile North of US-70	Wake	2013

[1] *The data were not collected, instead s1~s7 were collected and analyzed.*

2.3.2 Temporary Station Data

The project team also collected and analyzed traffic volume data from 73 temporary stations. A total dataset of 144 volume profiles was created from 11,308-hour of raw data provided by the NCDOT. Exhibit 4 presents the temporary stations with the date of data collection and the location of each station.

Exhibit 4: Freeway Traffic Data from Temporary Stations

Header ID	Date	Location
413	May 17, 2013	I 26 NORTH of LONG SHOALS RD (EXIT 37)
414	May 16, 2013	I 40 EAST OF NEWFOUND RD (Exit 33)
415	May 16, 2013	I 26 NORTH OF SR 1142 (EXIT 59)
416	May 09, 2013	US 1 S OF WALNUT ST (EXIT 101)
417	June 12, 2013	I 73 SOUTH OF SR 2137 (Exit 3)
418	May 13, 2013	I-85 W OF NC 147 (EXIT 172)
419	May 28, 2013	I-95 N OF I-40 (EXIT 81)
420	May 15, 2013	I-40 E OF NC 55 (EXIT 278)
421	May 28, 2013	I-40 E OF I-440 (EXIT 293)
422	May 13, 2013	I-85 N OF US 501 (EXIT 176)
423	May 13, 2013	I-85 N OF NC 157 (WITHIN EXIT 175)
424	September 11, 2013	I-40-85 W OF UNIVERSITY DR (EXIT 140)
425	September 11, 2013	I-40/85 E OF MEBANE OAKS RD (EXIT 154)
426	September 12, 2013	I-85 S OF US 64 (EXIT 96)
427	September 11, 2013	I-85 E OF US220 (EXIT 122)
428	September 17, 2013	US 220 N OF I-85 (Exit 78)
429	September 17, 2013	I 73/US 220 S OF PINEVIEW RD (EXIT 79)
430	September 17, 2013	US 52 N OF US 64 (EXIT 89)
431	September 25, 2013	I-73 S OF SR 1541 WENDOVER AVE (EXIT 102)
432	September 17, 2013	US 52 N OF S MAIN ST (EXIT 123)
433	September 17, 2013	I 40 BUS E OF MLK JR DR (Exit 6B)
434	September 18, 2013	US 52 S OF CLEMONSVILLE RD (Exit 105)
435	September 10, 2013	US 52 S OF AKRON DR (EXIT 112)
436	September 25, 2013	I 40 BUS E OF SR 3173 SILAS CREEK PKY (Exit 2)
437	September 25, 2013	I 40 W OF US 421 INTERCHANGE (Exit 188)
438	September 19, 2013	I 40 E OF NC 150 INTERCHANG (EXIT 192)
439	September 19, 2013	I 40 E OF US 311 (Exit 196)
440	September 25, 2013	I 40-85 E OF SR 3045 MT HOPE CHURCH RD (Exit 132)
441	September 19, 2013	I 40 E OF SR 3153 HANES MALL BLVD (Exit 190)
442	October 03, 2013	I-73/US 220 S OF NC 62 (Exit 89)
443	October 03, 2013	I-85 S OF NC 150 (Exit 84)
444	October 09, 2013	I-40 BUS E OF SR 1725 WITHIN EXIT 5C
445	October 09, 2013	I-74 E OF NC 68 (EXIT 67)
446	October 09, 2013	I-85 BUS S OF I-40 (EXIT 219)
447	October 09, 2013	I-85 BUS S OF I-40 (EXIT 219)
448	October 15, 2013	I-40 E OF SR 3037 (EXIT 224)
449	October 08, 2013	I-85 N OF US 601 (EXIT 75)
450	October 24, 2013	I-40 E OF NC 191 (EXIT 47)
451	October 23, 2013	I-26 N OF US 19-23 BUS (EXIT 18)
452	October 23, 2013	I-40 W OF SR 1124 (EXIT 121)
453	October 25, 2013	I-26 E OF NC 280 (EXIT 40)
454	October 22, 2013	I-40 W OF SR 1753 (EXIT 146)
455	November 06, 2013	I-485 E OF NC 16 (EXIT 16)
456	November 20, 2013	US 29 WITHIN 16th ST EXIT
457	November 06, 2013	I-85 S OF NC 216 (EXIT 2)
458	November 20, 2013	US 52 N OF SR 4315 (EXIT 108A)
459	November 05, 2013	I-77 N OF US 21 (EXIT 28)

Header ID	Date	Location
460	November 05, 2013	I-40 W OF US 64 (EXIT 168)
461	November 20, 2013	US 52 S OF I-74 (EXIT 140)
462	October 23, 2013	I-40 E OF SR 1129 (EXIT 94)
463	November 20, 2013	US 29 N OF I-40 (EXIT 223)
464	November 06, 2013	I-485 S OF US 29 (EXIT 9)
465	November 07, 2013	I-77 S OF SR 1128 (EXIT 1)
466	November 07, 2013	I-485 E OF NC 49 (EXIT 1)
467	November 05, 2013	I-77 N OF I-85 (EXIT 13)
468	October 03, 2013	I-85 N OF US 311 (EX113)
469	November 20, 2013	I-95 N OF NC 48 (EXIT 180)
470	November 21, 2013	I-74 E OF US 74 (EXIT 194)
471	November 21, 2013	I-95 S OF US 301 (EXIT 22)
472	November 21, 2013	I-40 W OF US 117 (EXIT 355)
473	November 20, 2013	I-85 N OF NC 39 (EXIT 214)
474	November 20, 2013	I-85 N OF US 1-401 (EXIT 233)
475	October 22, 2013	I-77 N OF SR 1890 (EXIT 59)
476	October 22, 2013	I-77 S OF US 70 (EXIT 49)
477	October 23, 2013	I-26 N OF US 19-23 (EXIT 9)
478	October 25, 2013	I-26 S OF NC 108 (EXIT 67)
479	November 22, 2013	US 1 N OF US 64 (EXIT 98)
480	November 06, 2013	I-85 N OF NC 7 (EXIT 23)
481	November 07, 2013	I-85 E OF SR 2691 (EXIT 39)
482	October 24, 2013	I-40 W OF COLD SPRINGS ROAD (EXIT 7)
483	December 11, 2013	US 1 N OF US 15-501 (EXIT 71)
484	October 03, 2013	I-40/84 W OF UNIV DR (EX140)
485	May 08, 2013	I-540 W OF LEESVILLE RD (EXIT 7)

2.4 Volume Data Analysis

The team analyzed permanent stations volume data first to examine any distinct characteristic of the 24-hour volume of each station. The data were separated by weekday and weekend, since it was intuitive that each had different volume profiles. Next, the team continued the volume data analysis on the basis of seasonal and weather differences for several representative locations.

2.4.1 Weekday Data

In the previous freeway traffic volume profile development, the study separated rural and urban areas first, and then presented volume profiles for each category. However, the previous work did not offer additional criteria for separating the volume data. Moreover, for locations that are in-between urban and rural area, subjective judgment was needed to identify the site as either urban or rural. As shown in Exhibit 1, that difference of urban versus rural would then trigger a huge difference in traffic volume distribution based on an arbitrary distinction without much guidance. Considering these limitations of the urban and rural separation, the research team approached data analysis by first examining the shape of the traffic volume distribution, and then tried to understand geographical and other effects for the purpose of binning the volume profiles into categories.

After analyzing 1-year of weekday volume data for each 52 volume datasets and for clear weather conditions (all rain and snow events were removed from the data), the team came up with three different volume profiles:

1. Unimodal,
2. Bimodal-AM peak, and
3. Bimodal-PM peak.

Exhibit 5 presents these three distinctive volume profiles, showing individual (thin lines) and average (thick line) distribution obtained from the data provided by NCDOT.

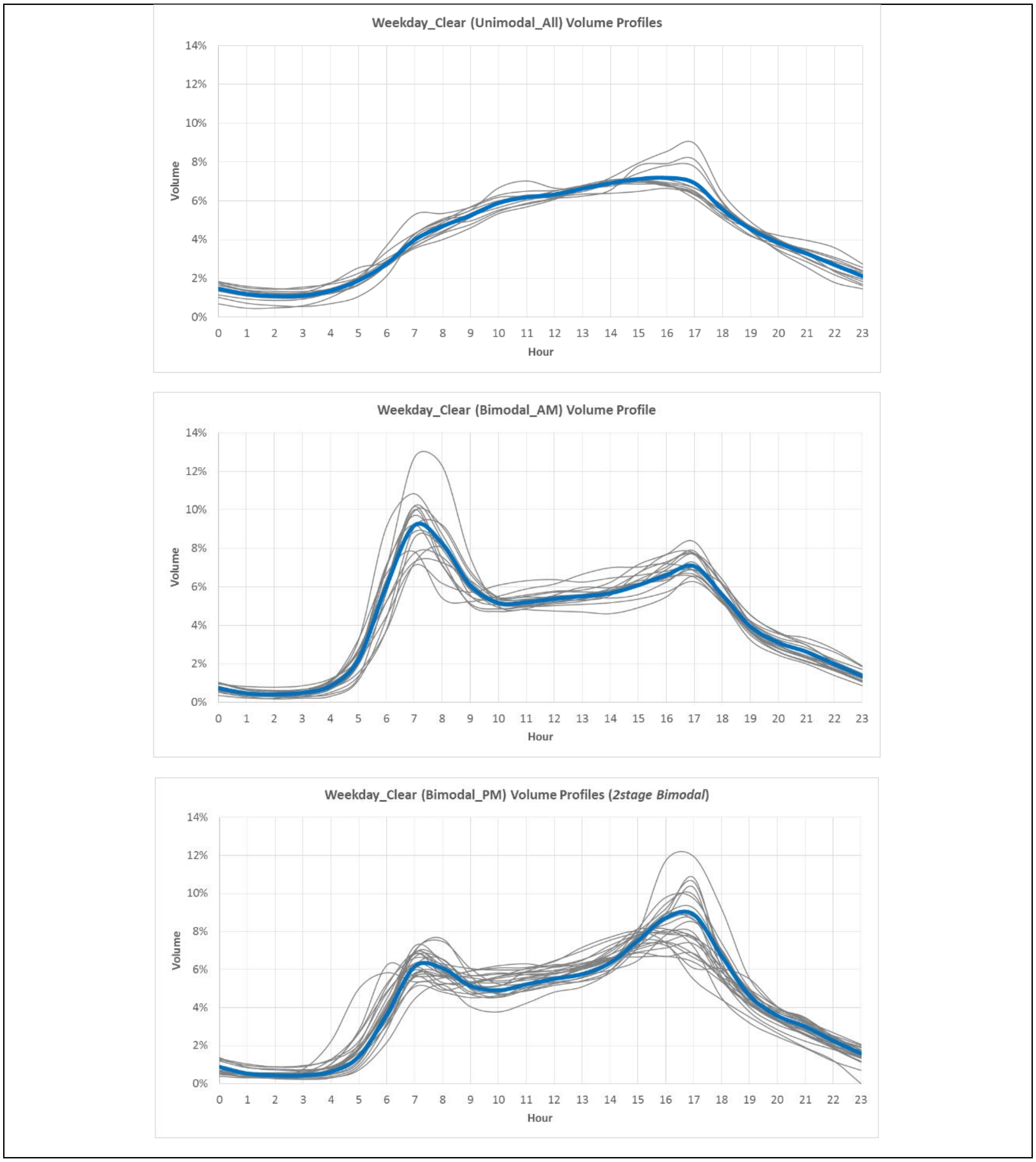


Exhibit 5: Three Volume Profiles (top to bottom: unimodal, bimodal-AM peak, bimodal-PM peak)

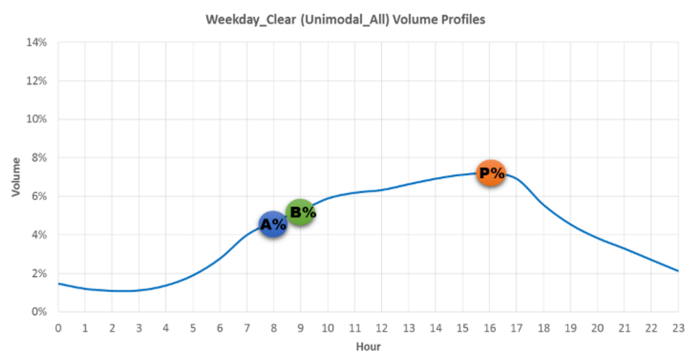
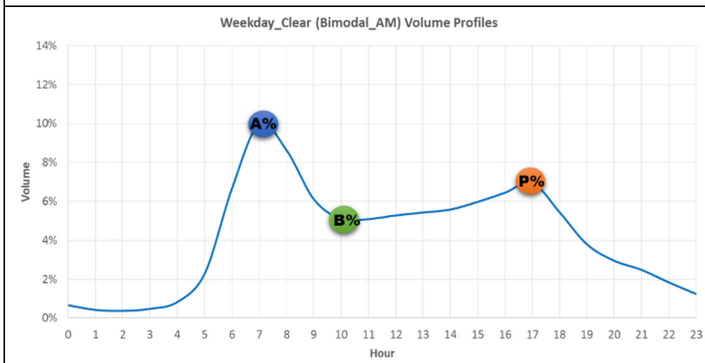
As shown in Exhibit 5, the unimodal profile looks very similar to the 'rural' profile used in the previous research. On the other hand, the bimodal datasets show volume profiles that are substantially different from the prior "urban" profile, by introducing peak directionality into the volume profile. In the bimodal volume profiles, they are separated into either AM peak or PM peak volume profile. The distinction largely depends on whether the directional freeway segment (all freeway analyses in the HCM are directional) is positioned towards an urban area and employment center (AM Peak), or away from the urban core towards residential areas in urban fringe areas (PM Peak).

In an effort to provide more specific guidance, the team developed a quantifiable method for identifying the three volume profiles, as explained below with four basic steps:

- **Step 1: Define AM peak, PM peak, and between peak times**
  - AM peak: volume data collected between 6 AM ~ 8 AM
  - PM peak: volume data collected between 4 PM ~ 6 PM
  - Between peak: volume data collected between 9 AM ~ 3 PM
- **Step 2: Estimate volume percentage of the peaks identified in Step 1**
  - AM peak: the highest percentage (A %)
  - PM peak: the highest percentage (P %)
  - Between peak: the lowest percentage (B %)
- **Step 3: Define unimodal and bimodal volume profiles**
  - If B % > A % + 0.3 % and P % > A %, then *unimodal*
  - Otherwise, bimodal
- **Step 4: Define bimodal volume profiles separately**
  - If A % > P %, then *bimodal-AM peak*
  - If P % > A %, then *bimodal-PM peak*

The application of the volume profile identification method is presented in Exhibit 6 illustrating examples of the unimodal and bimodal-AM peak cases.

Exhibit 6: Volume Profile Identification Method Application (Unimodal and Bimodal-AM peak)

Volume Profile Diagram	Step	Identification Process
	1	AM peak: 6~8 AM PM peak: 4~6 PM Between peak: 9 AM~3 PM
	2	A %: 4.7 % (8 AM) P %: 7.2 % (4 PM) B %: 5.2 % (9 AM)
	3	*<u>Unimodal</u>* – since B % is greater than A % by 0.3 % and P % is greater than A %
	4	Not applicable
	1	AM peak: 6~8 AM PM peak: 4~6 PM Between peak: 9 AM~3 PM
	2	A %: 10.0 % (7 AM) P %: 7.0 % (5 PM) B %: 5.1 % (10 AM)
	3	Bimodal – since B % is not greater than A % by 0.3 %
	4	*<u>Bimodal-AM peak</u>* – since A % is greater than P %

The team applied the four-step volume profile identification method to all 52 freeway traffic volume data collected. The results of the volume profile application is presented in Exhibit 7. That analysis found that the bimodal case is observed more frequently than the unimodal volume profile. The bimodal-PM peak case was most frequently observed among the collected data. The reason the AM Peak and PM peak numbers are not the same, is that several stations exhibited a unimodal profile in one direction, but the bi-modal PM peak profile in the opposite direction.

Exhibit 7: Weekday Volume Profile Application Results

Volume Profile	Number of Volume Profiles
Unimodal	11
Bimodal-AM peak	16
Bimodal-PM peak	25
Total	52

As a next step, the team analyzed each volume profiles with respect to the variation of volume percentage focused at each peak time. For instance, in the case of the unimodal distribution, the highest average volume percentage was observed at 4 PM. Thus, the team identified the maximum, the 75th percentile, average, 25th percentile, and minimum volumes at that time. After that, each volume profile was selected following to the peak time volume so that it would add up to 100 % for each profile. Exhibit 8, Exhibit 9, and Exhibit 10 present 24-hr volume percentages of each category focused at the peak time for unimodal, bimodal-AM, and bimodal-PM, separately.

Exhibit 8: Unimodal Volume Profile Analysis Result

(Unit: %)

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Minimum	1.83	1.59	1.48	1.46	1.78	2.27	3.03	3.82	4.44	5.14	5.93	6.23	6.21	6.35	6.39	6.49	6.64	6.35	5.48	4.71	3.97	3.39	2.75	2.29
25th Percentile	1.79	1.52	1.44	1.55	1.70	2.04	2.72	3.55	4.00	4.60	5.34	5.68	6.07	6.60	6.98	6.97	6.80	6.36	5.17	4.61	4.22	3.96	3.58	2.74
Average	1.47	1.20	1.09	1.11	1.37	1.89	2.76	3.99	4.69	5.25	5.89	6.18	6.33	6.63	6.91	7.12	7.18	6.91	5.55	4.54	3.83	3.28	2.70	2.12
75th Percentile	1.73	1.35	1.22	1.23	1.48	2.04	2.91	3.64	4.32	4.78	5.45	5.87	6.14	6.61	7.06	7.15	7.10	6.67	5.77	4.69	3.95	3.47	2.99	2.40
Maximum	1.02	0.72	0.60	0.55	0.70	1.07	2.13	4.14	4.79	4.97	5.52	5.82	6.13	6.58	7.19	7.95	8.54	8.96	6.39	4.92	4.01	3.28	2.35	1.69

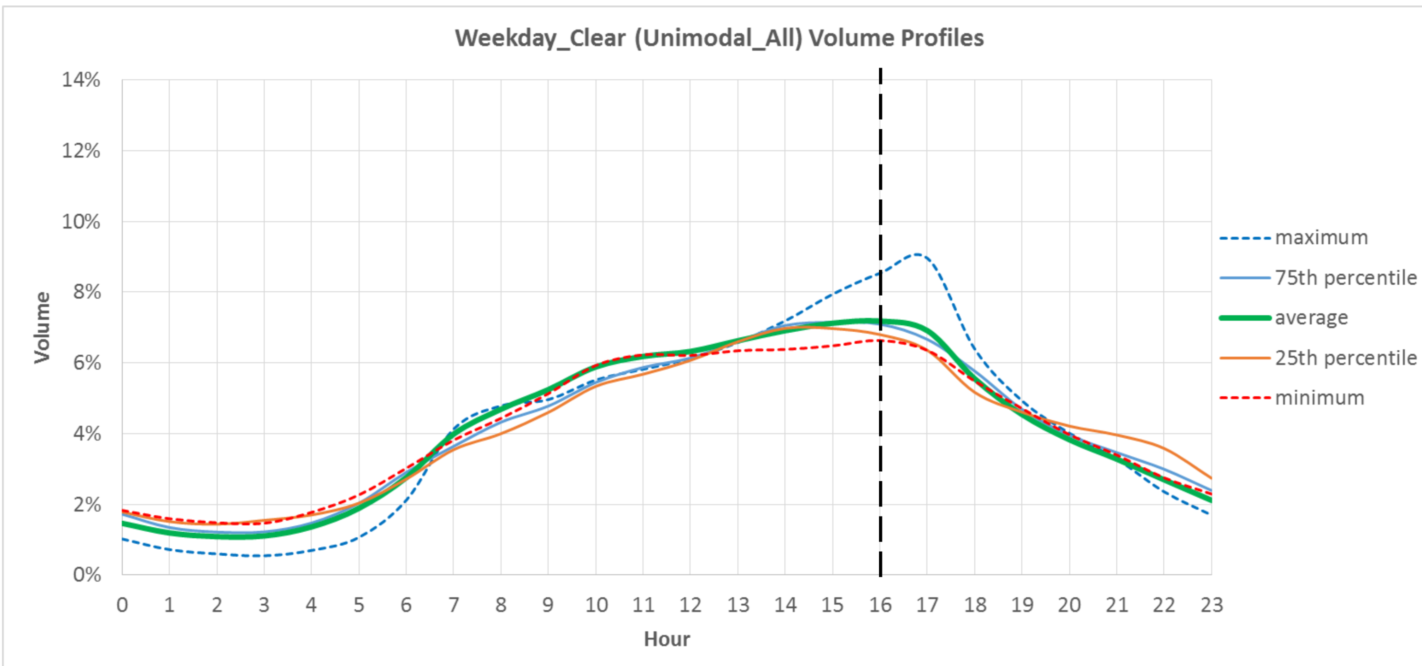


Exhibit 9: Bimodal-AM Peak Volume Profile Analysis Result

(Unit: %)

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Minimum	0.95	0.82	0.78	0.86	1.22	2.20	4.45	7.11	6.18	5.72	6.08	6.31	6.37	6.25	6.45	6.59	6.81	6.98	5.47	3.84	2.93	2.36	1.89	1.37
25th Percentile	1.00	0.68	0.58	0.50	0.73	1.94	5.22	7.74	7.54	5.91	5.10	5.00	5.21	5.48	5.75	6.10	6.72	6.89	6.16	4.54	3.65	3.10	2.62	1.85
Average	0.74	0.47	0.41	0.50	0.84	2.20	6.01	9.18	8.25	6.08	5.17	5.20	5.38	5.51	5.67	6.08	6.61	7.07	5.59	3.95	3.10	2.63	1.99	1.37
75th Percentile	0.76	0.54	0.34	0.33	0.42	1.28	5.68	10.00	7.14	5.51	5.33	5.47	5.42	5.31	5.55	6.71	7.29	7.67	6.11	4.21	3.22	2.57	1.84	1.31
Maximum	0.36	0.22	0.21	0.45	0.88	2.46	6.93	12.70	12.27	7.53	5.02	4.82	4.74	4.69	4.60	4.91	5.47	6.56	5.21	3.24	2.45	2.00	1.40	0.87

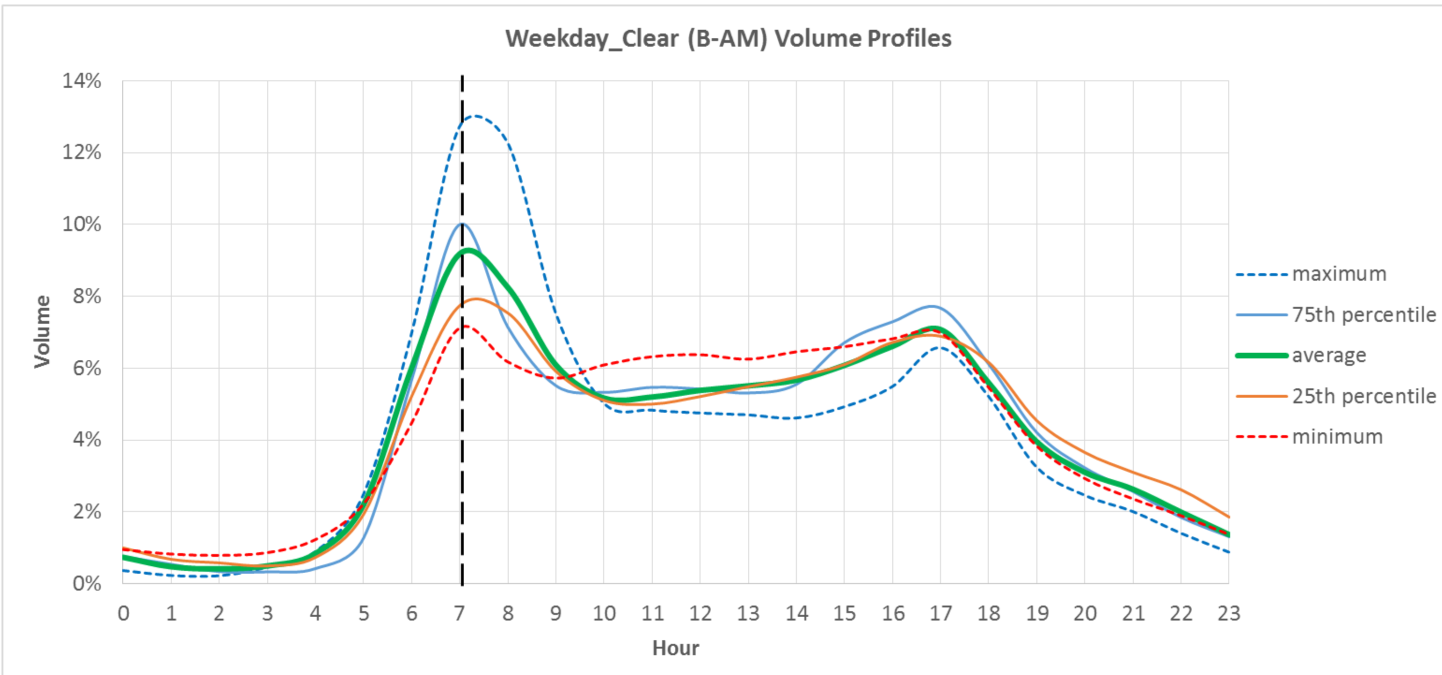


Exhibit 10: Bimodal-PM Peak Volume Profile Analysis Result

(Unit: %)

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Minimum	0.93	0.55	0.47	0.36	0.48	1.12	3.73	6.65	6.53	5.32	5.12	5.91	6.26	6.16	6.47	7.31	7.27	6.08	6.06	5.51	4.05	3.39	2.51	1.78
25th Percentile	0.39	0.31	0.39	0.57	1.27	2.69	5.25	6.60	6.29	6.05	5.98	6.03	6.46	6.98	7.54	7.93	8.14	7.19	4.52	3.19	2.48	1.87	1.18	0.70
Average	0.85	0.55	0.47	0.49	0.75	1.70	3.98	6.18	5.88	5.26	5.19	5.46	5.71	5.99	6.57	7.48	8.29	8.37	6.26	4.52	3.51	2.89	2.15	1.52
75th Percentile	0.64	0.34	0.28	0.23	0.30	0.84	2.81	6.16	6.55	4.97	4.55	5.23	5.79	6.01	6.52	7.71	8.96	9.23	6.96	4.81	3.93	3.48	2.33	1.38
Maximum	0.89	0.40	0.27	0.23	0.32	0.72	2.17	4.45	5.19	4.05	3.77	4.23	4.81	5.09	5.93	7.91	11.72	11.94	9.20	5.54	4.02	3.28	2.31	1.57

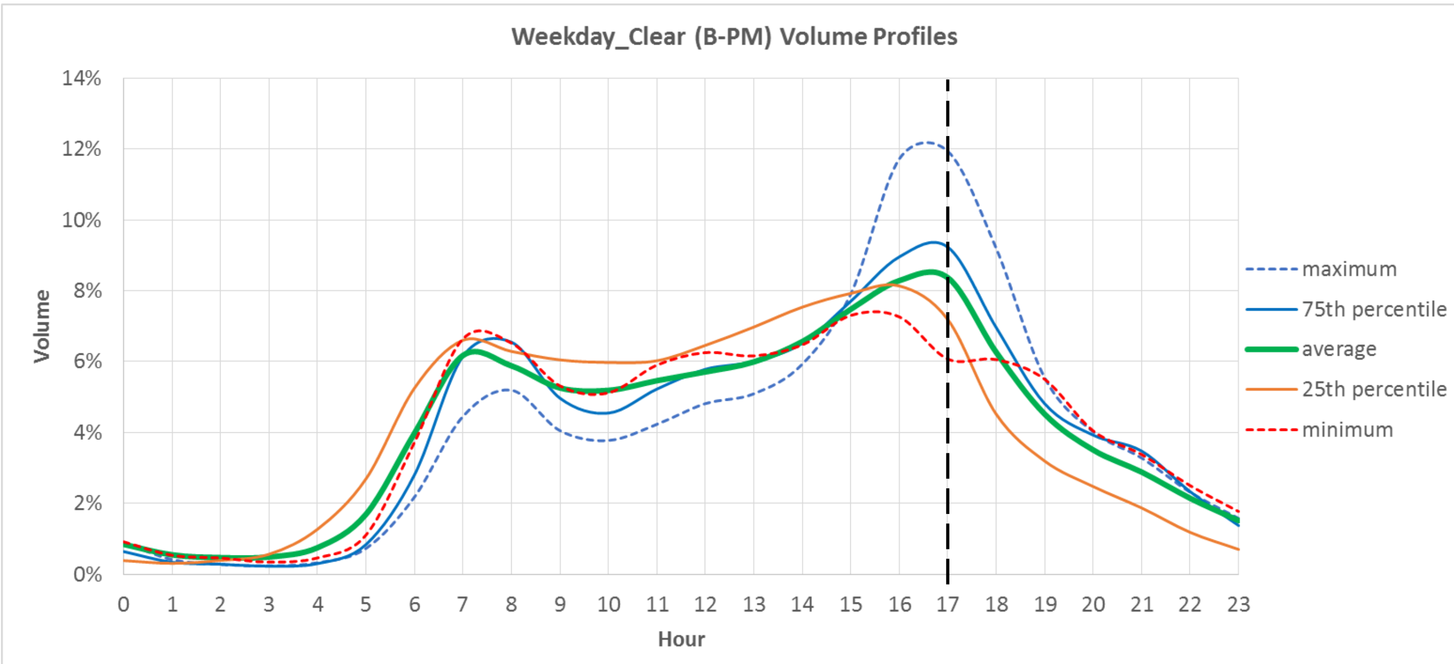


Exhibit 11 shows all the permanent and temporary combined stations separated by their volume profiles, bimodal-AM, bimodal-PM, or unimodal. The urban centroid point (UCP) is explained in the following section.

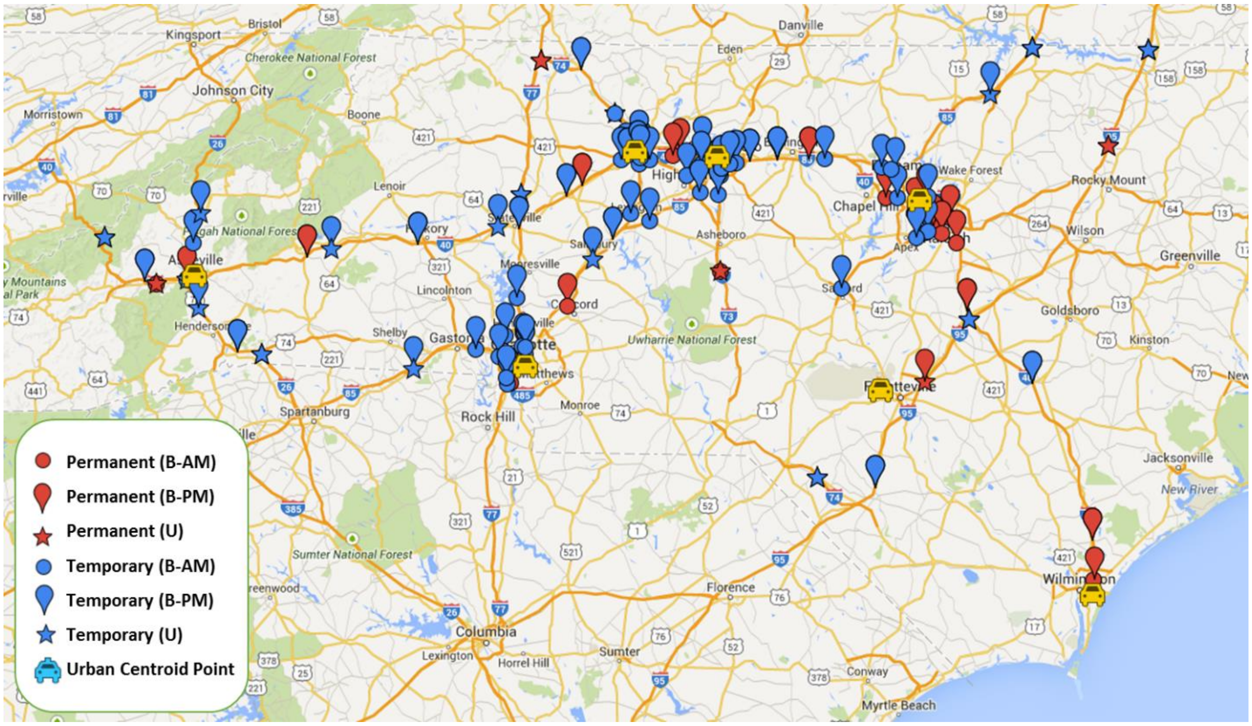


Exhibit 11: Geographical Distribution of Permanent and Temporary Traffic Count Stations

As seen in Exhibit 11, a majority of traffic count stations are located on major freeways and cities. Especially, Charlotte, Greensboro, Winston-Salem, Raleigh, Durham, and Chapel Hill area have more stations than any other area. It was also noticeable that unimodal (star shape icon) stations are commonly located in rural areas.

2.4.2 Weekend Data

The research team has also analyzed weekend volume profiles (including holidays) for clear weather conditions (rain and snow events removed). Exhibit 12 depicts the volume profile analysis results for weekend, including holidays, for all sensor stations.

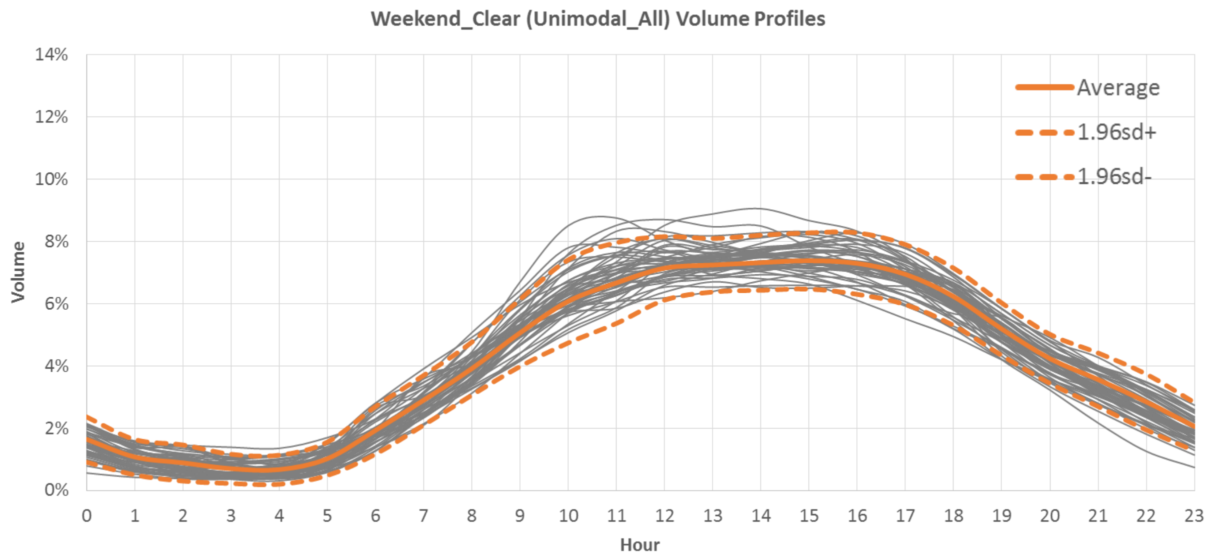


Exhibit 12: Weekend Volume Profiles Analysis Result

In Exhibit 12, the average of the data with ±1.96 standard deviations is presented to show the 95th percentile confidence level in the data. It is quite different result compared to weekday data since there is only one type (unimodal) of data regardless of geographical differences of data collection sites.

The team also went one step further in the analysis to see whether there is any distinctive difference between Saturday and Sunday data. The entire weekend data were thus divided into two groups, separated by Saturday to Sunday, to explore if any differences are observed. The results of the analysis are shown in Exhibit 13.

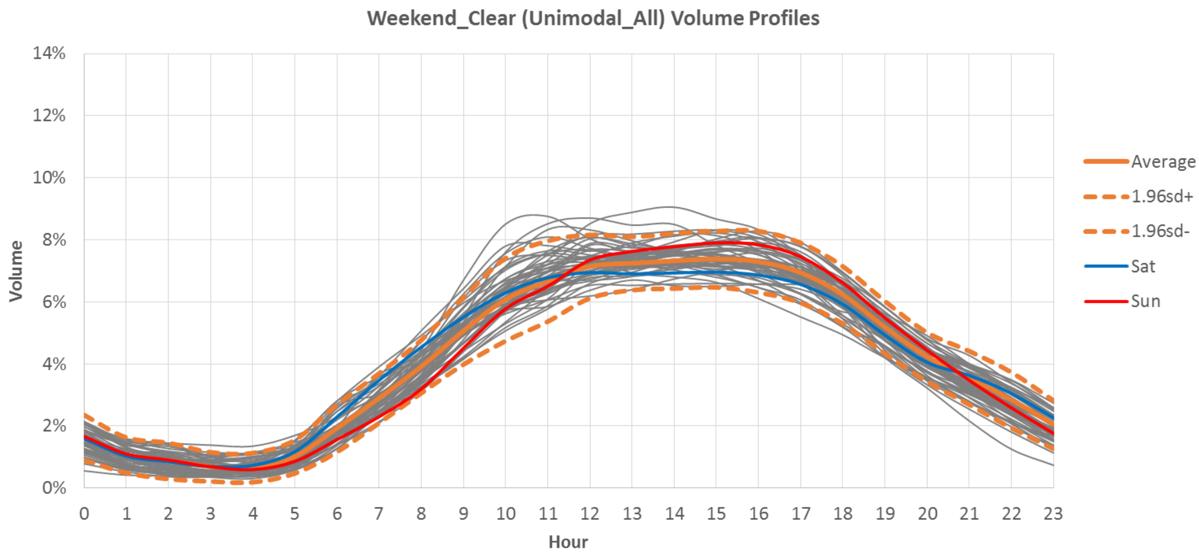


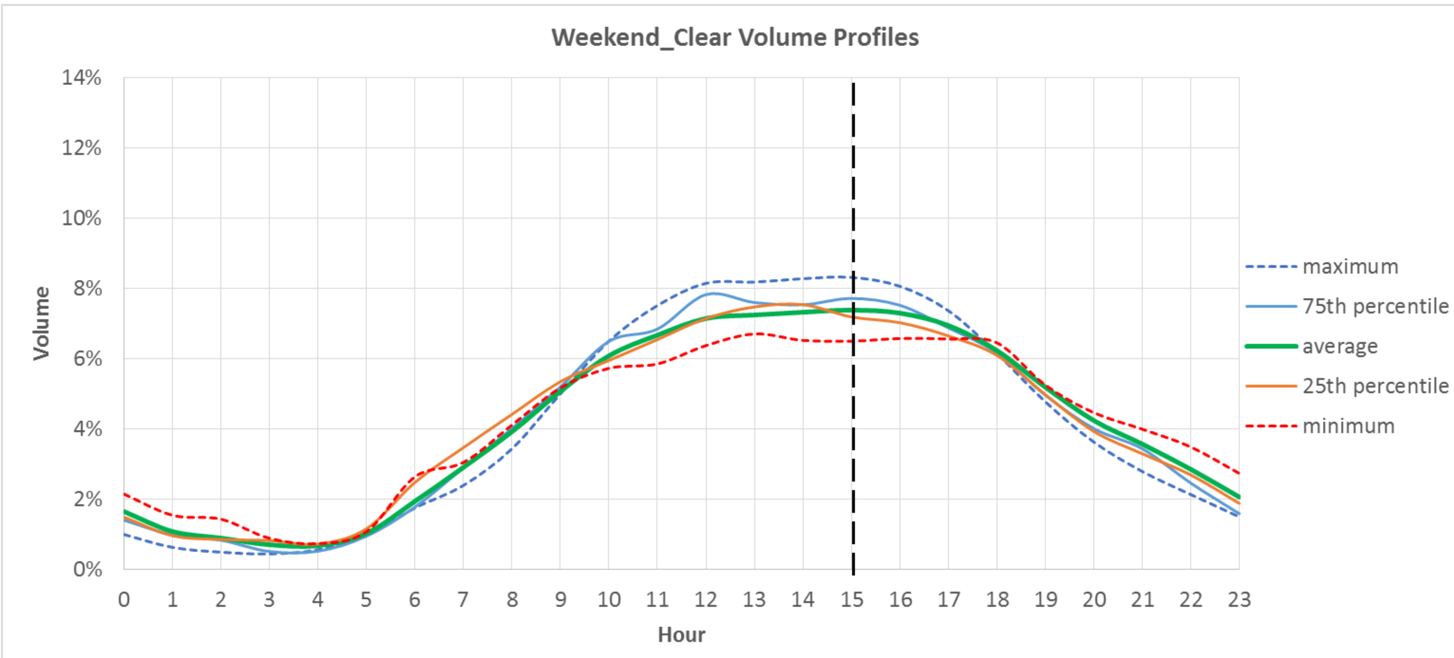
Exhibit 13: Saturday and Sunday Data Analysis Result

In Exhibit 13 the average value of each Saturday and Sunday data are presented with the overall weekend's average and the 95th percentile confidence level data. It is observed in the diagram that Saturday traffic starts earlier than Sunday traffic, by around one hour, in the AM peak time, and Sunday traffic has higher volume distribution than Saturday traffic, around 1% point, in the PM peak. However, both the Saturday and Sunday average volume profile data are estimated inside of the 95th percentile confidence level of the combined weekend's data. This results give confidence to the research team to use a single/unified volume profile representing both Saturday and Sunday. As a result of the weekend volume data analysis, Exhibit 14 is presented separated by minimum, the 25th percentile, average, the 75th percentile, and maximum volume proportion at 3PM.

Exhibit 14: Weekend Volume Profile Analysis Result

(Unit: %)

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Minimum	2.15	1.55	1.43	0.89	0.74	1.08	2.64	3.05	4.11	5.17	5.73	5.85	6.37	6.70	6.52	6.50	6.57	6.56	6.45	5.25	4.46	3.99	3.49	2.74
25th Percentile	1.48	0.95	0.85	0.81	0.72	1.15	2.47	3.46	4.41	5.34	5.95	6.54	7.14	7.47	7.54	7.19	7.02	6.65	6.09	4.97	3.93	3.29	2.68	1.87
Average	1.64	1.07	0.89	0.70	0.67	1.02	1.93	2.90	3.92	5.07	6.08	6.67	7.14	7.24	7.32	7.38	7.30	6.94	6.23	5.19	4.23	3.56	2.85	2.05
75th Percentile	1.40	0.97	0.83	0.50	0.51	0.94	1.77	2.89	4.01	5.19	6.49	6.84	7.82	7.60	7.54	7.71	7.52	6.87	6.16	4.96	4.01	3.43	2.45	1.58
Maximum	1.00	0.63	0.49	0.44	0.56	0.96	1.75	2.39	3.44	5.00	6.50	7.51	8.14	8.18	8.28	8.31	8.06	7.37	6.15	4.77	3.63	2.79	2.13	1.50



2.4.3 Seasonal Effect

The project team examined data from two locations, Wilmington and Asheville, to analyze seasonal effects to the volume profiles. A seasonal effect on volume profiles was hypothesized for tourist areas, such as the beach in the summer and the mountains in the fall. For the beach area, the team analyzed data from station 'b5' in Wilmington, and for the mountain area, the team analyzed station 'a2' for the Asheville region. Both eastbound and westbound data were analyzed in both cases. Additionally, weekday and weekend data were analyzed separately since the team already confirmed that they had considerably different volume profiles.

First, the results of the beach area seasonal effect were analyzed, and are presented in Exhibit 15 and Exhibit 16 separated by eastbound and westbound data.

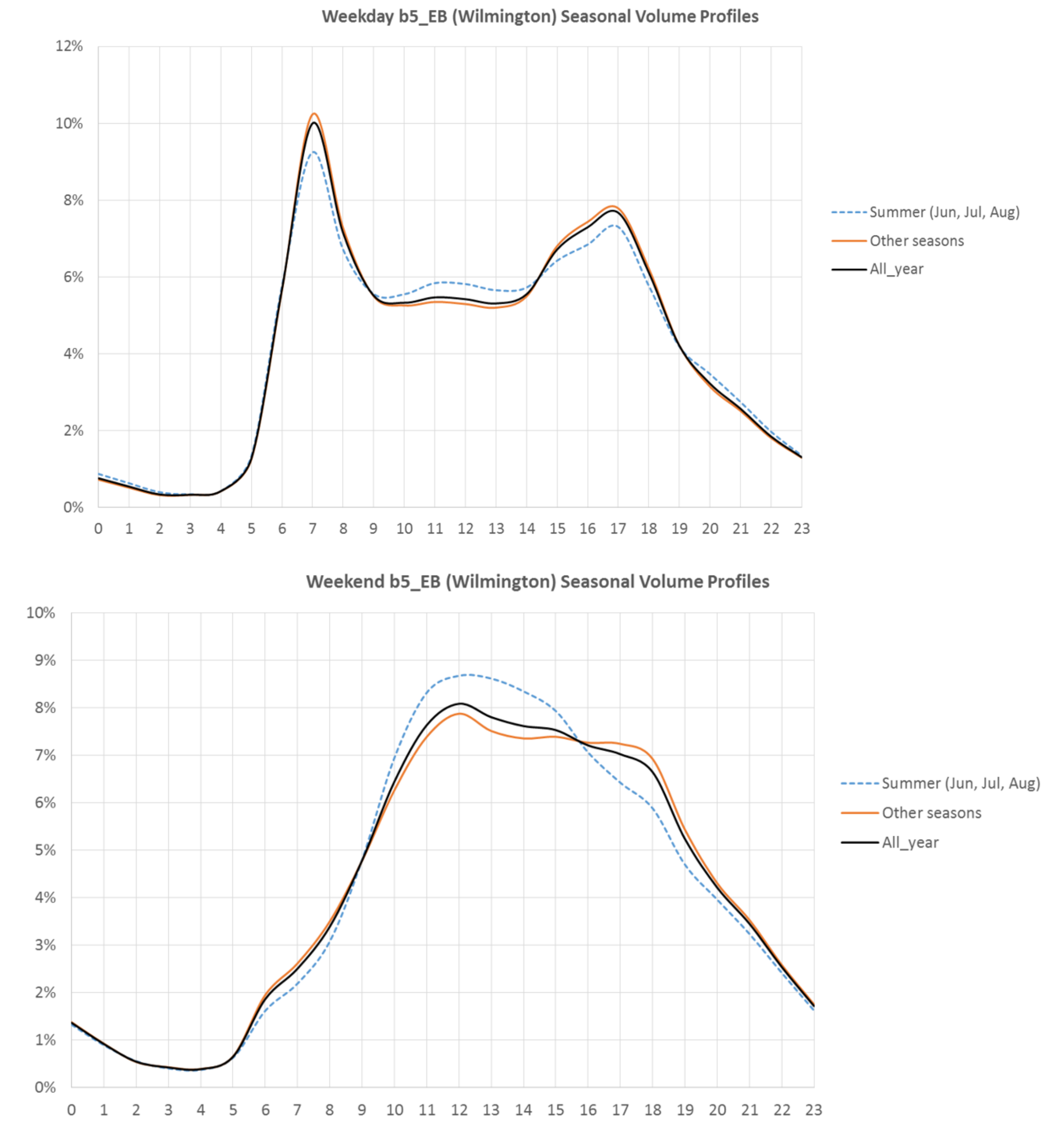


Exhibit 15: Beach Area (b5-eastbound) Volume Profile Analysis Results (top: weekday, bottom: weekend)

As seen in Exhibit 15, the eastbound volume profiles are presented in three groups: summer (June, July, and August) season, other seasons, and the whole year data. After seeing the volume profiles for each group, the team concluded that the summer season data also showed very consistent volume profiles compared to the other season, or the whole year of data, since weekday had bimodal-AM peak and weekend showed unimodal volume profiles consistently.

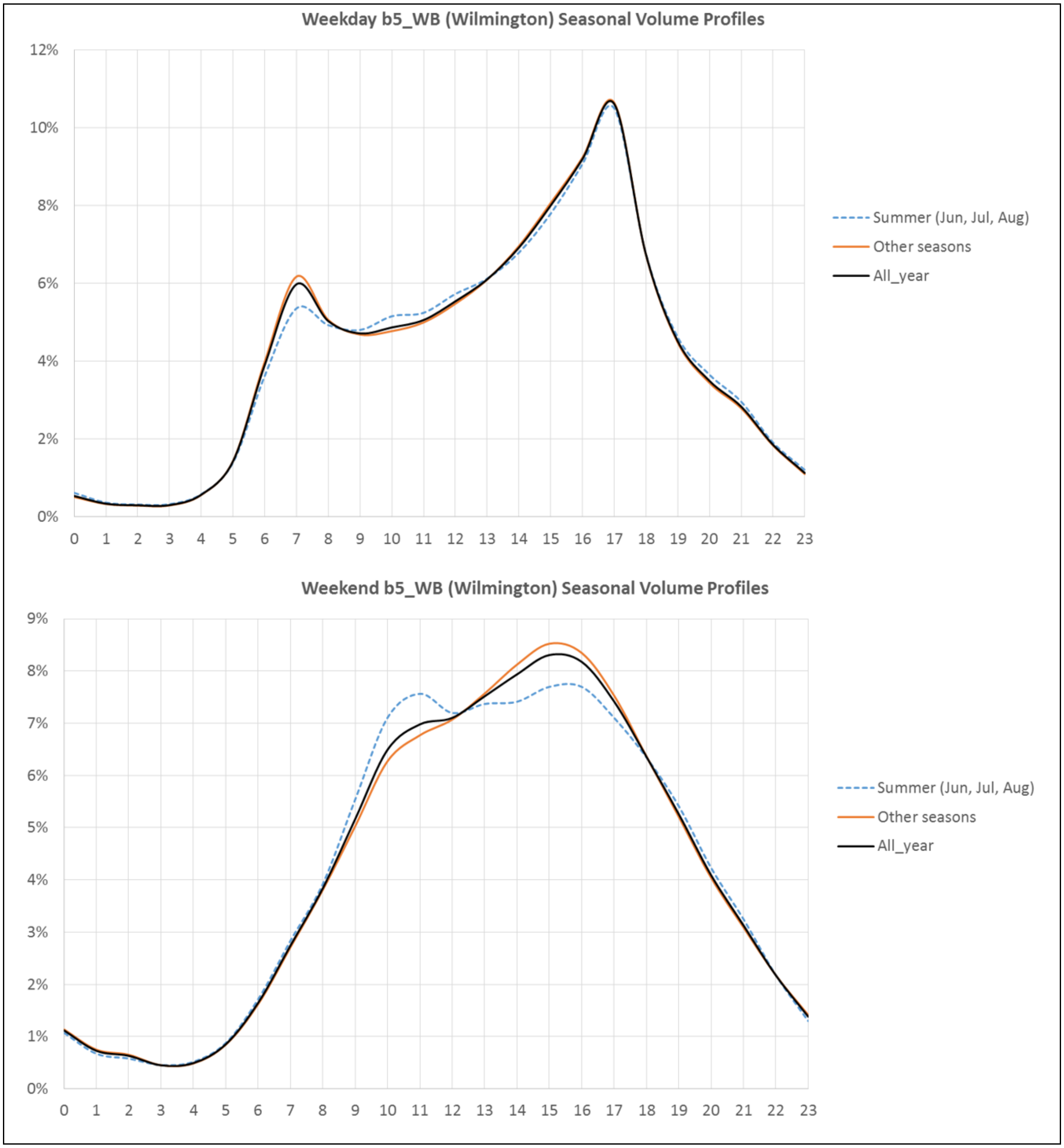
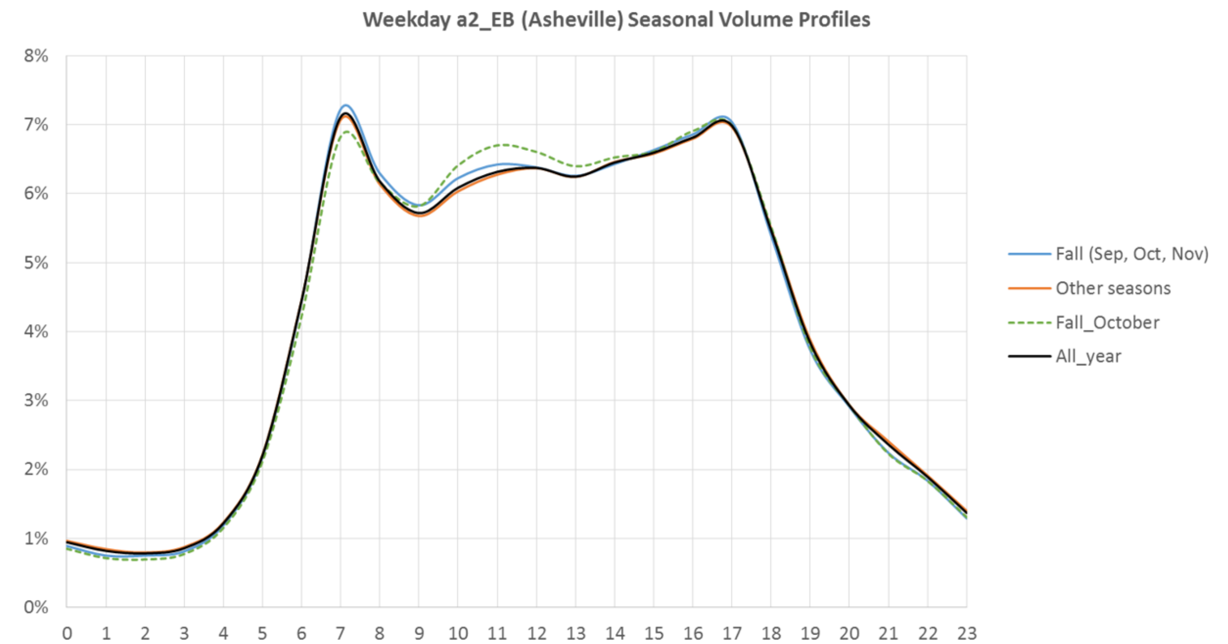


Exhibit 16: Beach Area (b5-westbound) Volume Profile Analysis Results (top: weekday, bottom: weekend)

In Exhibit 16, the westbound volume profiles shows results consistent with the eastbound data. The summer season data show slightly different variations compared to other season or the whole year data. But neither weekday nor weekend summer season data shows a significant difference to the established average profiles for the rest of the year.

In the next step, the project team analyzed a freeway in the North Carolina mountains, to explore seasonal effects on volume profiles related to the fall tourist season. The results are presented in Exhibit 17 and Exhibit 18 separated by eastbound and westbound data.



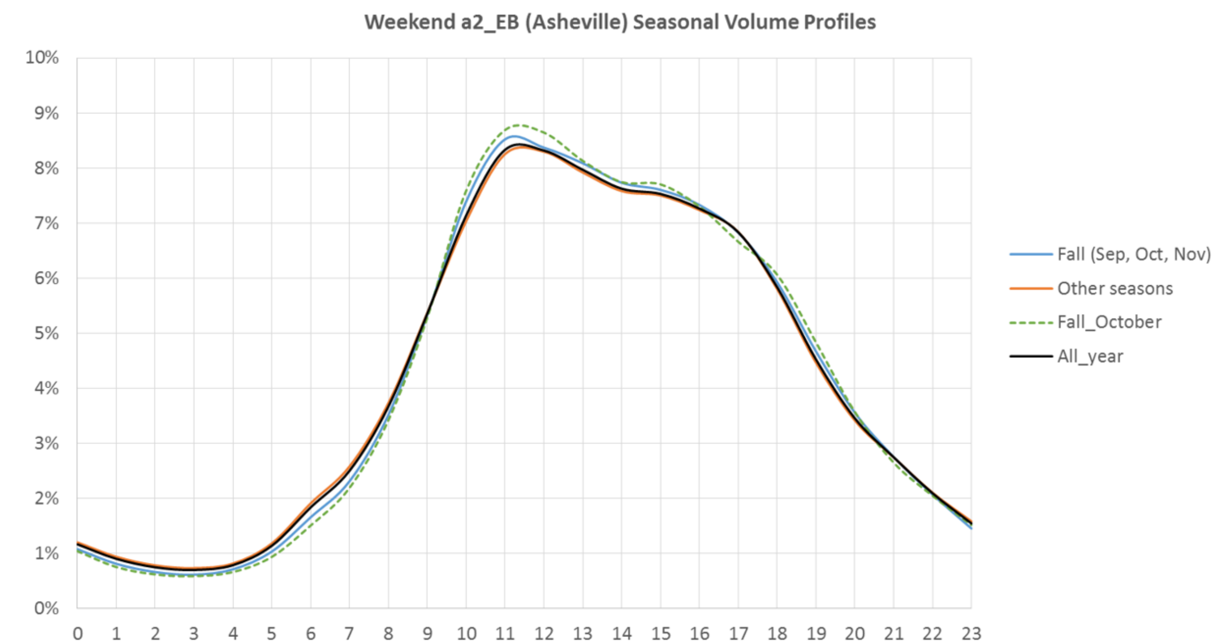


Exhibit 17: Mountain Area (a2-eastbound) Volume Profile Analysis Results (top: weekday, bottom: weekend)

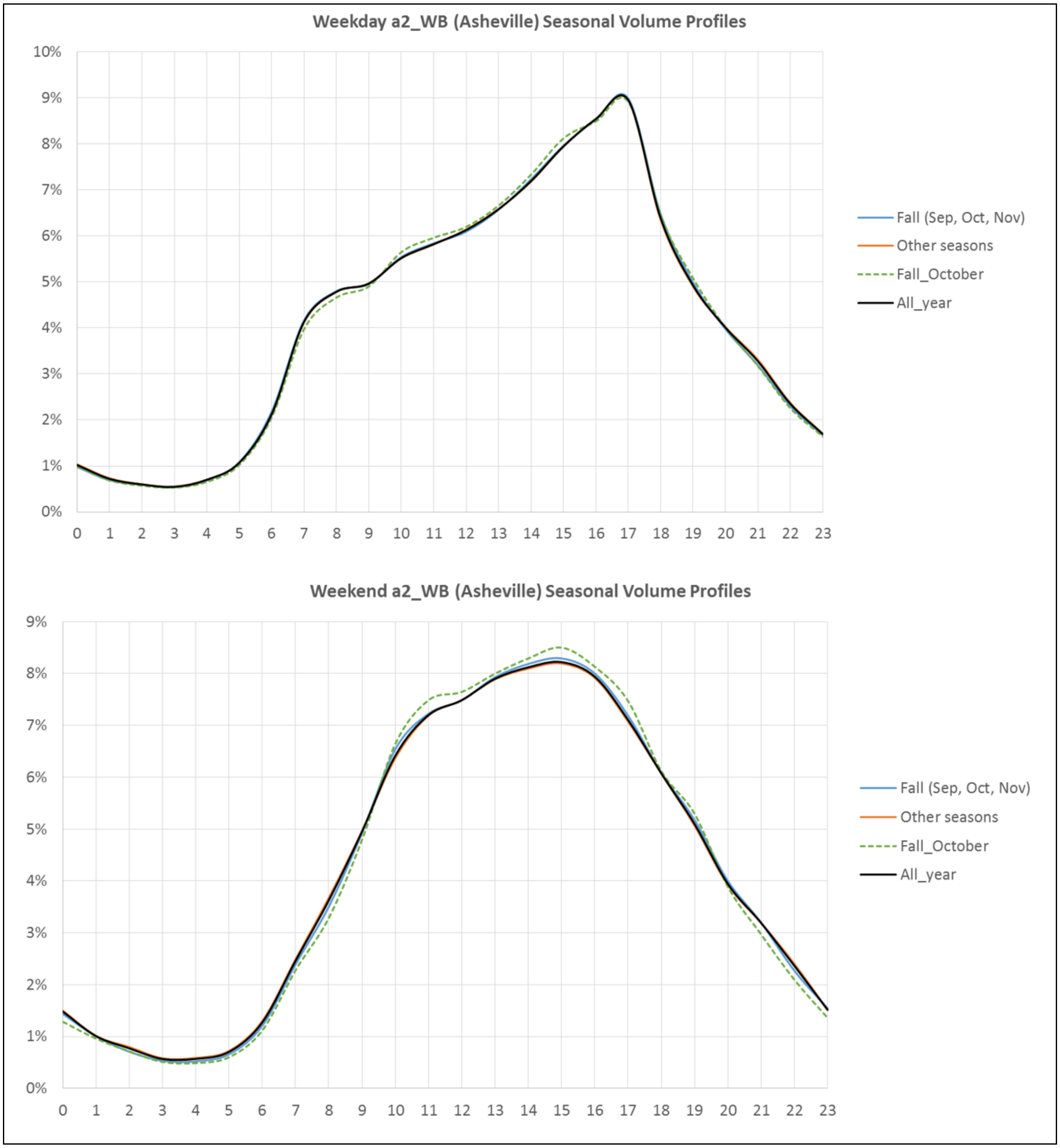


Exhibit 18: Mountain Area (a2-westbound) Volume Profile Analysis Results (top: weekday, bottom: weekend)

In Exhibit 17, the eastbound volume profiles are presented in four groups: fall (September, October, and November) season, other season, October, and the whole year data. The fall season was separated into two groups since October could be different considering the foliage related traffic. After seeing the volume profiles for each group, the team concluded that the fall season data showed very consistent volume profiles compared to the other season, October, or whole year data since weekday had bimodal-equal peak and weekend showed unimodal volume profiles consistently.

In Exhibit 18, the westbound volume profiles also shows consistent results with previous eastbound data. The fall season data show slightly different variations compared to other season, October, or the whole year data. Neither weekday nor weekend fall season data does not have different volume profiles in the analysis results.

The results of the seasonal data effect suggest that neither summer beach traffic nor fall tourist season in the mountains appear to have an impact on the daily distribution of traffic in the volume profiles. Note that this is not to say that there are no differences in traffic, as the average daily traffic (ADT) in those seasons may in fact be significantly higher than the AADT. However, these differences are accounted for through the standard seasonal adjustment factors used by NCDOT. The present analysis suggests that no separate volume profiles are needed to then separate the seasonally-adjusted ADT across the 24-hour analysis period.

2.4.4 Weather Effect

The team examined three representative volume profile data, unimodal, bimodal-AM peak, and bimodal-PM peak, to explore the effect of inclement weather on volume profiles. For each volume profile data, three different weather conditions were analyzed, including clear conditions, severe rain, and snow. Volume data measured under the condition of more than 1 inches of rain and more than 0.5 inches of snow for the subject day were classified as severe rain and snow, respectively. Since this is a planning-level analysis, no sensitivity for the time-of-day of the rain or snow event was included, even though the timing of these events arguably will be an important consideration for a more operational and detailed analysis.

First, the weather analysis results for unimodal volume profile are presented in Exhibit 19. The volume profile data collected near Ashville (sensor a2, westbound) were analyzed for the three weather conditions. The numbers in parentheses indicate the number of days for each weather condition. After analyzing the unimodal volume profile data, the team confirmed that there were no considerable changes to the daily volume distribution with consideration of these severe weather conditions.

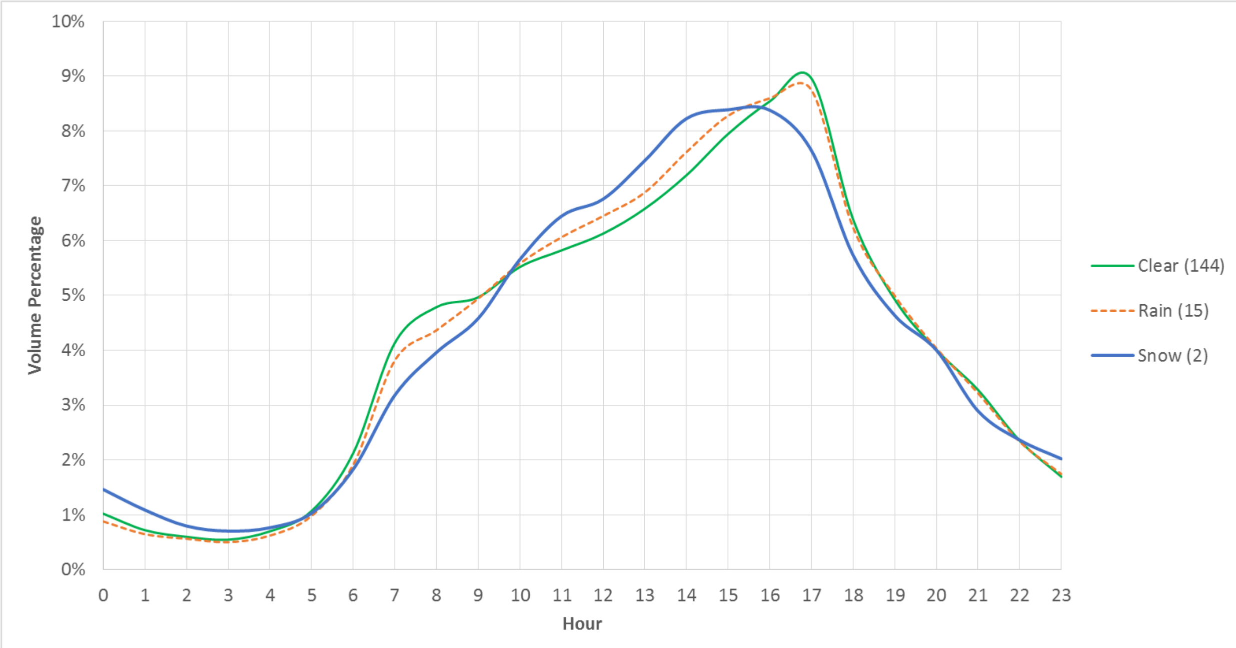


Exhibit 19: Weekday Unimodal Weather Effect (a2-WB)

Next, the team examined bimodal-AM and bimodal-PM volume data that were collected in the Raleigh area, as presented in Exhibit 20 and Exhibit 21, separately. The rain and snow weather condition data were collected under the same thresholds described above, classified as more than 1 inch of rain and more than 0.5 inches of snow, respectively. As seen in the results, even under the severe weather condition, the volume profile showed consistent characteristics to the clear-weather days, maintaining each respective volume profile.

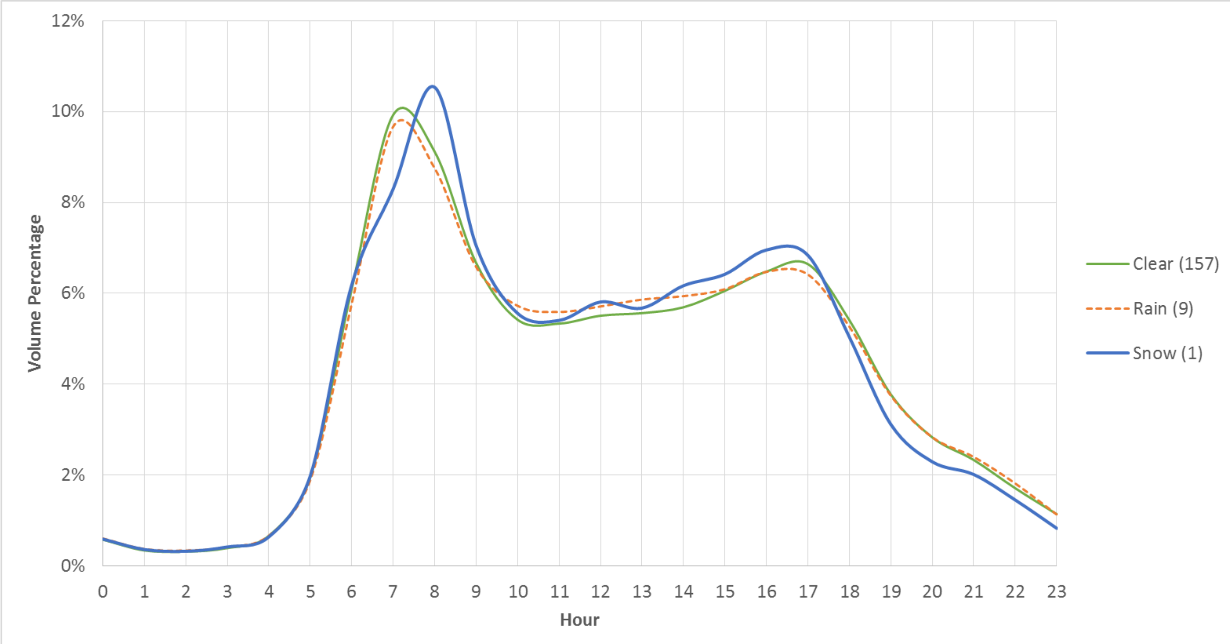


Exhibit 20: Weekday Bimodal-AM Weather Effect (s4-WB)

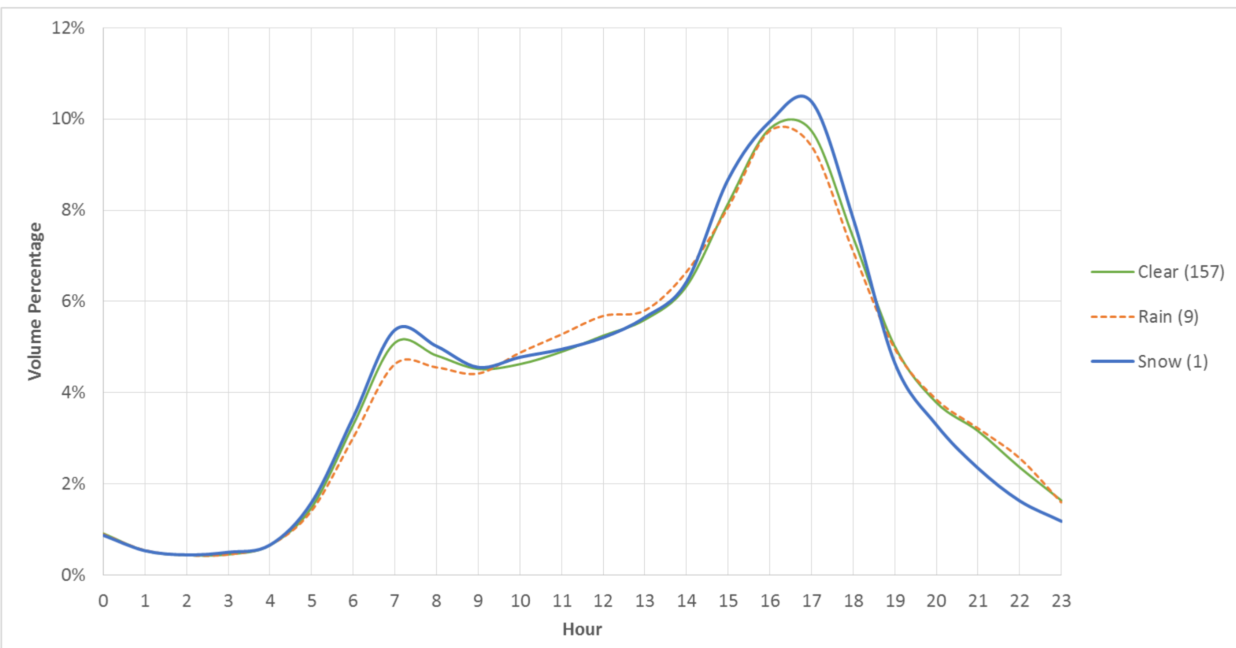


Exhibit 21: Weekday Bimodal-PM Weather Effect (s6-EB)

As a result of the weather effect analysis, the team confirmed that it should be okay not to explicitly consider weather effect in the application of daily volume profiles in the FREEVAL-WZ tool. The difference of hourly volume percentage under severe weather conditions relative to clear weather days did not show distinctive differences.

Of course, special severe events can impact the distribution of traffic, especially if for example a heavy snow event hits in early morning hours before the morning commute. But the analysis suggests that there is no generalizable pattern that can be applied across all inclement weather events. Instead, a custom volume profile may be needed to test specific scenarios, which is more within the scope of a detailed operational analysis though. It is also emphasized that this analysis strictly focused on the demand-side of FREEVAL inputs, which means the volume profiles. Any weather event as severe as the ones explore in this section are further expected to have significant impacts on the supply side, by reducing the available per-lane capacity. These capacity adjustment factors are implemented separately and defaults are available in the HCM based on national research.

2.5 Urban Centroid Point (UCP) Analysis

This section presents guidance for how to apply the various volume profiles to the analysis of a freeway facility in North Carolina. The method assumes that the analyst has chosen a segment for evaluation, and knows where it is located relative to major urban areas in the state. The methodology is sensitive to distinctions of urban vs. rural freeways (defined by the NCDOT municipal boundaries GIS layer), as well as the directionality of peaking characteristics. The latter is important for freeways in urban areas, where a directional facility that points towards an urban employment center is likely to have an AM peak focus, while the opposite direction is likely to have a PM peak focus

2.5.1 What is UCP?

The UCP (Urban Centroid Point) is a concept developed by the research team to explain the characteristic of volume profiles analyzed in the project. The UCP was selected based on US census 2013 population data, focusing on cities that have a population of more than 100,000 people.[1] The only exception was the UCP in Asheville, since even if the city has only 83,000 population, there were distinct peaking characteristics and many available traffic volume stations.

In the case of Raleigh, Durham, and Cary, they were combined as one metropolitan area (i.e. the Triangle), because they were clustered and it was inappropriate to separate these cities in the analysis. The city of High Point was combined with the City of Greensboro for the same reason. Overall, a total of 7 UCPs were created using the NCDOT Municipal Boundaries GIS dataset.[2] They were previously presented in Exhibit 11.

[1] http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk
[2] https://connect.ncdot.gov/resources/gis/pages/gis-data-layers.aspx

2.5.2 Volume Profile Criteria Based on UCP

The project team created two criteria regarding UCP and traffic volume profiles. The first is about location relative to the urban boundary, and the other is about directionality relative to the UCP, as listed below:

- 1st criterion: traffic stations that are located inside UCP boundary have bimodal volume profile, while stations outside the UCP boundary have unimodal (rural) profiles.
- 2nd criterion: inside the UCP boundary, stations on freeway segments headed inwards or towards the UCP have bimodal-AM peak, and stations headed outward or away from the UCP have bimodal-PM peak.

The first criterion defines a volume profile based on the distance of the analysis segment from the UCP. The criterion says that if any traffic station is located inside a predetermined boundary of the UCP, that it will have a bimodal volume profile, and that otherwise a unimodal volume profile is used. For instance, if the boundary is determined as a 20-mile radius of the UCP, all traffic stations that are located inside of the 40-mile diameter boundary (centered around the UCP), are expected to show bimodal volume profiles.

The second criterion distinguishes bimodal-AM and bimodal-PM based on the direction of the segment or facility under study with respect to the UCP. If any station is pointed towards the UCP, then it is expected that a majority of traffic uses the facility in the morning to head towards the UCP. The result is a bimodal-AM distribution. On the other hand, if any station is pointed away from the UCP, then a majority of traffic is expected to use the facility in the PM peak as people leave work and return to homes in the urban fringe. The result then is a bimodal-PM distribution. Because all freeway traffic stations are operated in pairs for both direction (either East/West or North/South), the second criterion is expected to tell which one has AM peak, and which one has PM peak.

The directionality criterion poses some challenges for urban loop freeways that are present in many major urban areas across the state. For those segments, the location relative to major radial routes (freeways or arterials) becomes the determining factor distinguishing AM versus PM peaking. For example, if Wade Avenue is taken as a major radial route into downtown Raleigh (and research triangle park), it is expected that traffic on the I-440 loop road points towards the Wade Avenue interchange in the morning, and away from it in the afternoon. In some cases, analyst judgment and local knowledge is needed to distinguish morning and afternoon peaking characteristics.

It is further noted that the original data used to develop the method remains available as facility-specific input for many freeways across the state. As such, the UCP estimation method really only applies to locations that are not covered by the available dataset.

2.5.3 Methodology

Exhibit 22 depicts the overall process of the UCP analysis starting from the location of UCPs.

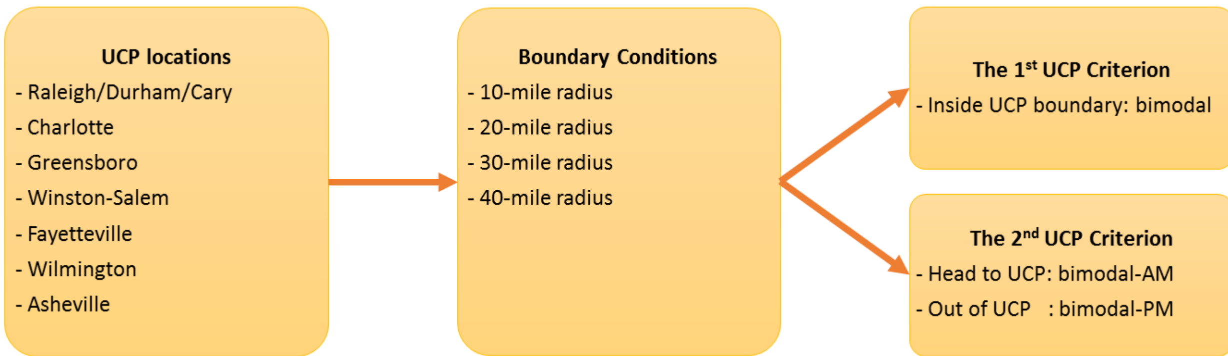


Exhibit 22: UCP Analysis Process

A total of 7 cites in NC were selected as having UCPs. After that, 4 levels of UCP boundaries were selected to test the two UCP criteria. According to the 1st UCP criterion, the team intends to examine whether any station that is located inside the UCP boundary has bimodal distribution or not. If the station shows either bimodal-AM or bimodal-PM, then it follows the 1st UCP criterion. However, if the station shows a unimodal volume profile, the station is regarded as not following the 1st UCP criterion.

In the 2nd UCP criterion the team examines the direction to the UCP and whether a station has a bimodal-AM or bimodal-PM volume profile. Exhibit 23 presents a simplified diagram of UCP criterion test having A1 and A2 traffic stations, east to west direction.

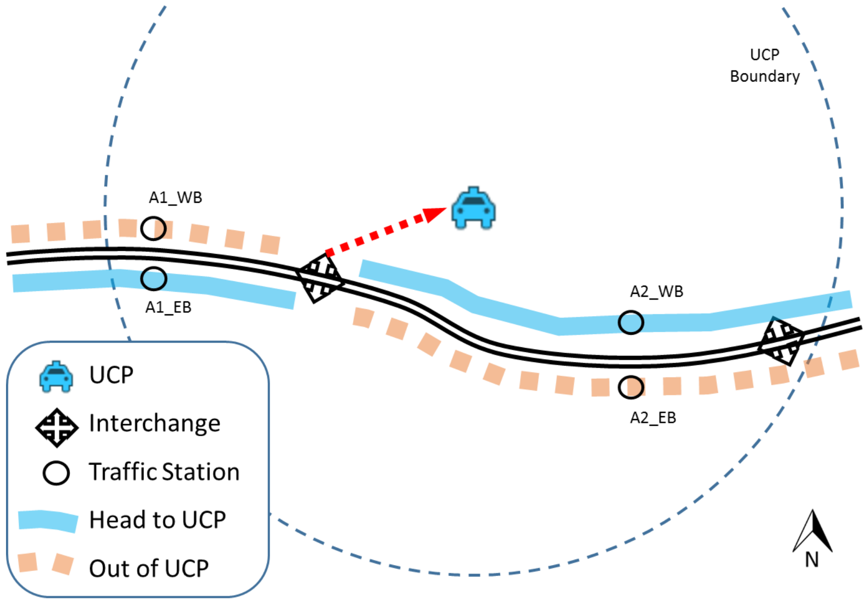
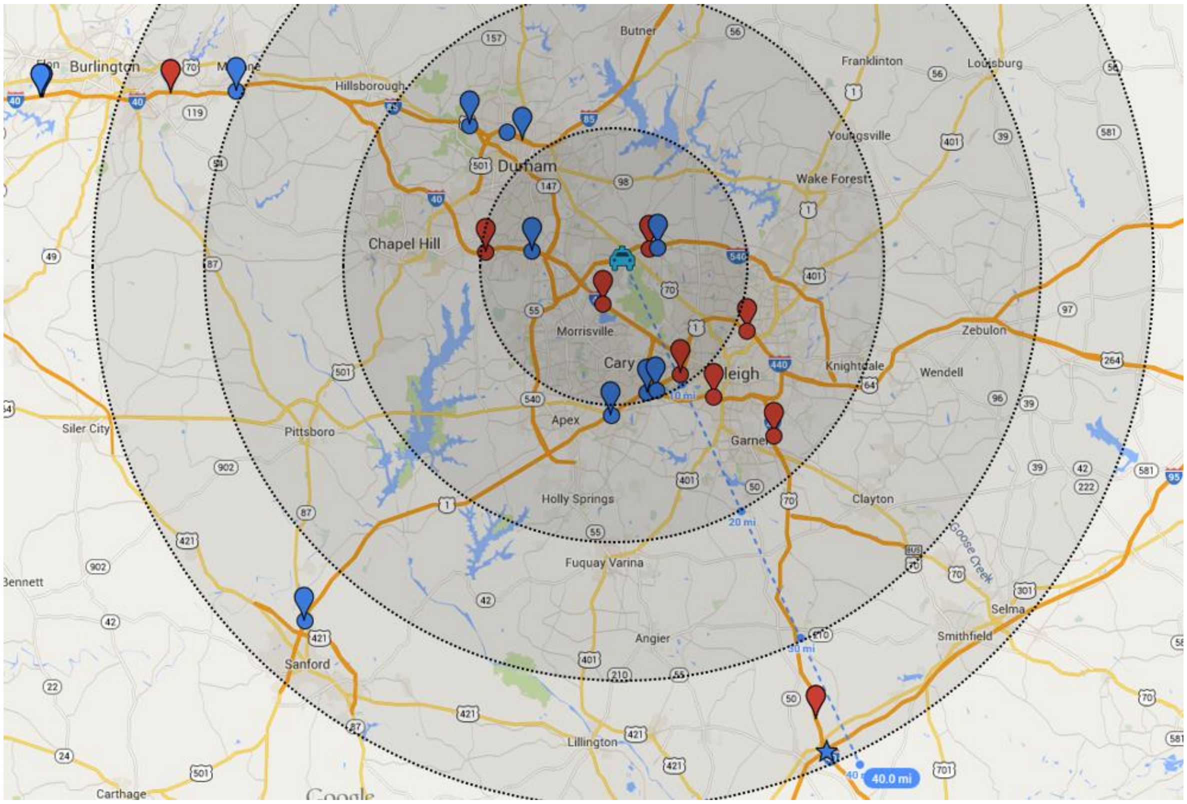


Exhibit 23: UCP Criteria Test

As seen in Exhibit 23, the team first identified the nearest interchange on freeways to/from the UCP. Having the interchange as a reference point, each side of freeway is divided into either 'head to UCP' or 'out of UCP'. Depending on the location of each traffic station, the station is expected to have either bimodal-AM peak or bimodal-PM peak following to the 2nd UCP criteria. If the station is located on the head to UCP side, then it should have bimodal-AM peak. On the other hand, if the station is located on the out of UCP side, the bimodal-PM peak is expected for its volume profile.

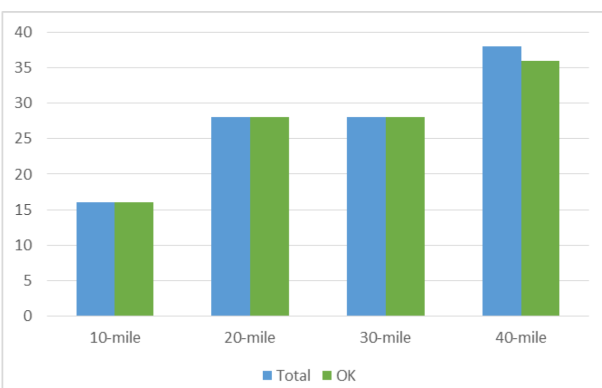
2.5.4 UCP Analysis Result

The seven UCP analysis results are presented in Exhibit 24 through Exhibit 30. Each analysis results depicts overall UCP map with different level of boundaries, city and population, and the two UCP criteria analysis result. The result also provides the percentage of 'UCP station' that follows each UCP criterion.



City	Population	Analysis		10-mile	20-mile	30-mile	40-mile
Raleigh, Durham, Cary	828,309	1st Criterion	Total Station	16	28	28	38
			UCP Station	16	28	28	36
			UCP Percentage	100%	100%	100%	95%
		2nd Criterion	Total Station	16	28	28	38
			UCP Station	16	28	28	34
			UCP Percentage	100%	100%	100%	89%

The 1st UCP Rule (Boundary)



The 2nd UCP Rule (Direction)

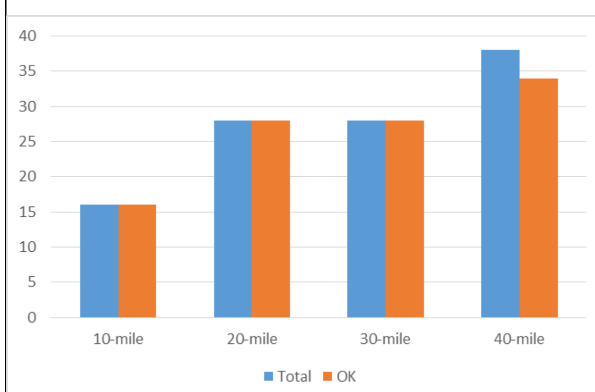
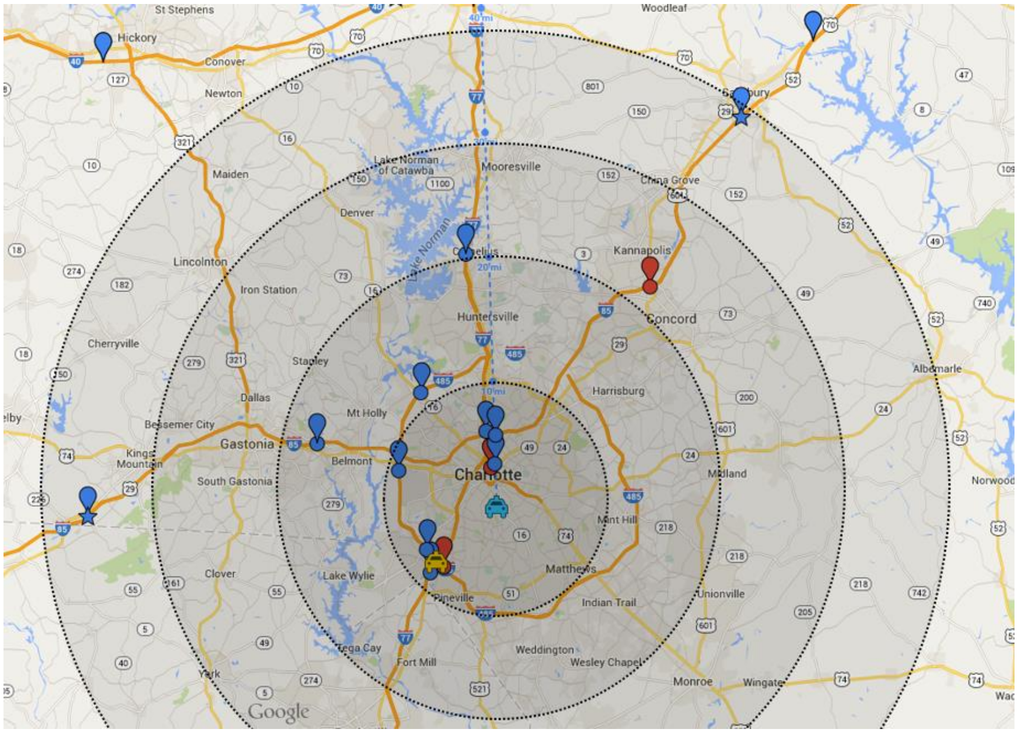
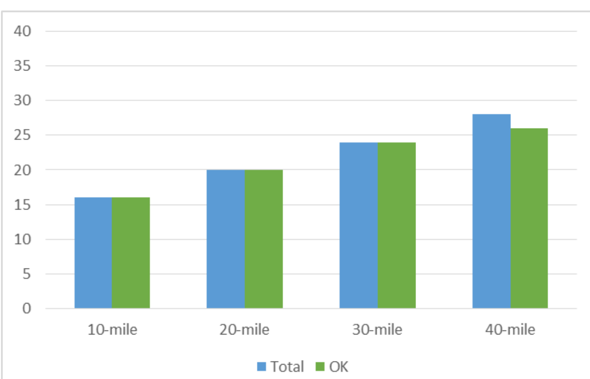


Exhibit 24: UCP Analysis Results of Raleigh, Durham, and Cary



City	Population	Analysis		10-mile	20-mile	30-mile	40-mile
Charlotte	792,862	1st Criterion	Total Station	16	20	24	28
			UCP Station	16	20	24	26
			UCP Percentage	100%	100%	100%	93%
		2nd Criterion	Total Station	16	20	24	28
			UCP Station	14	18	20	21
			UCP Percentage	88%	90%	83%	75%

The 1st UCP Rule (Boundary)



The 2nd UCP Rule (Direction)

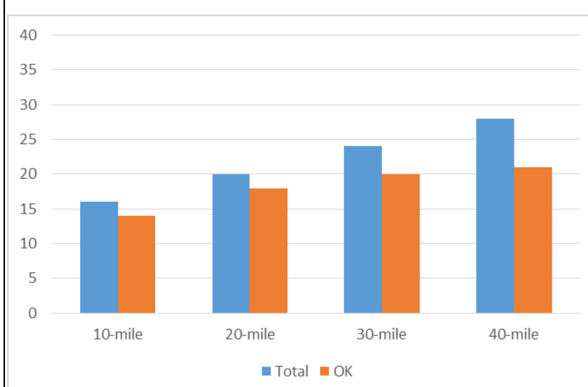
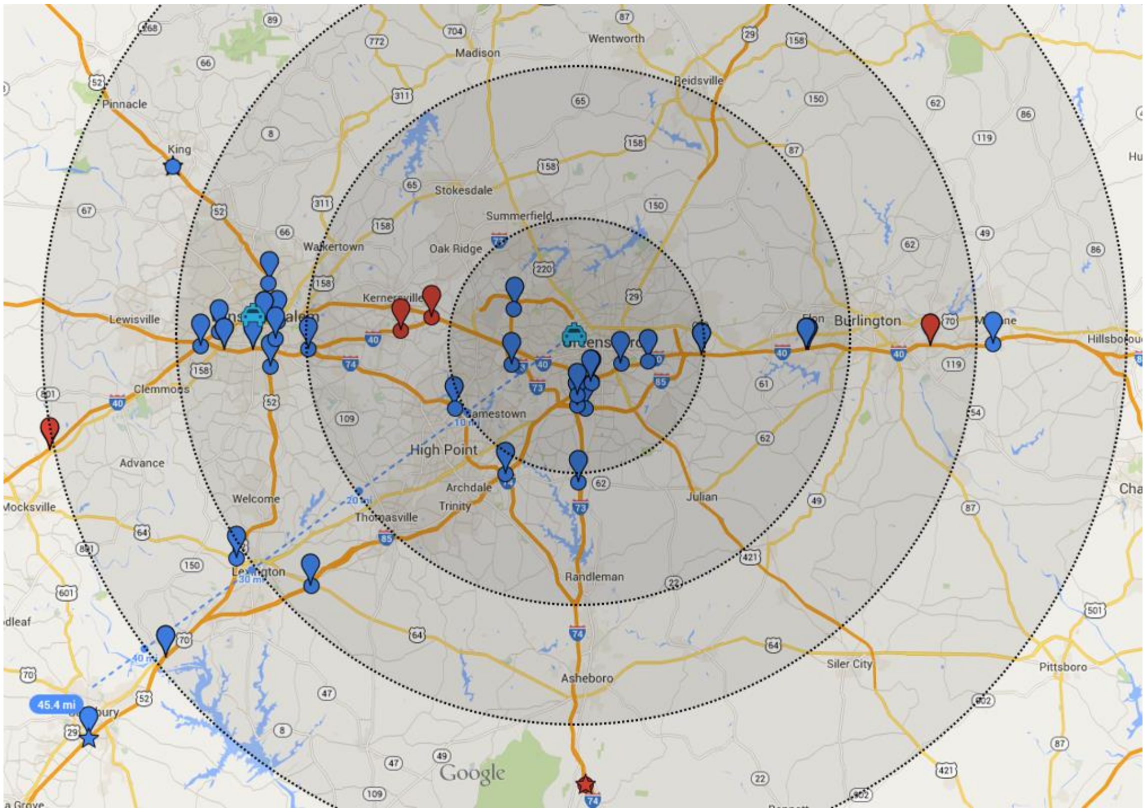
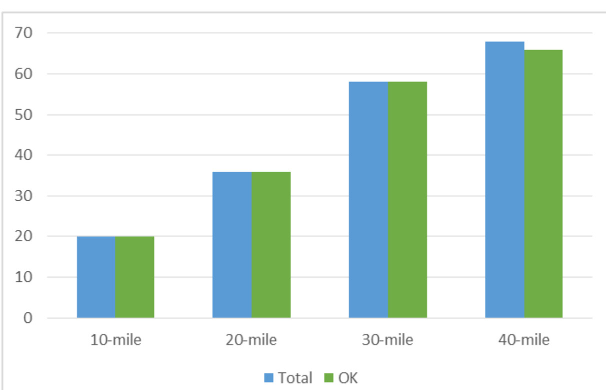


Exhibit 25: UCP Analysis Results of Charlotte



City	Population	Analysis		10-mile	20-mile	30-mile	40-mile
Greensboro	279,639	1st Criterion	Total Station	20	36	58	68
			UCP Station	20	36	58	66
			UCP Percentage	100%	100%	100%	97%
		2nd Criterion	Total Station	20	36	58	68
			UCP Station	17	29	43	46
			UCP Percentage	85%	81%	74%	68%

The 1st UCP Rule (Boundary)



The 2nd UCP Rule (Direction)

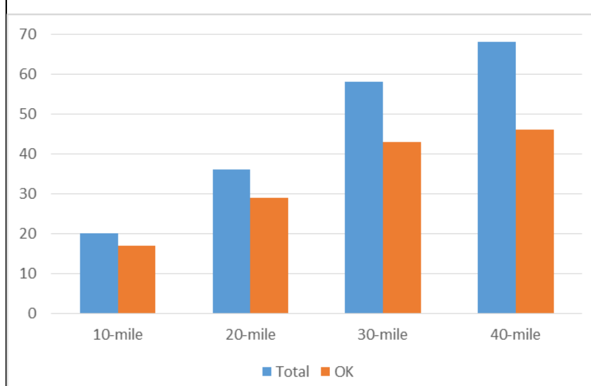
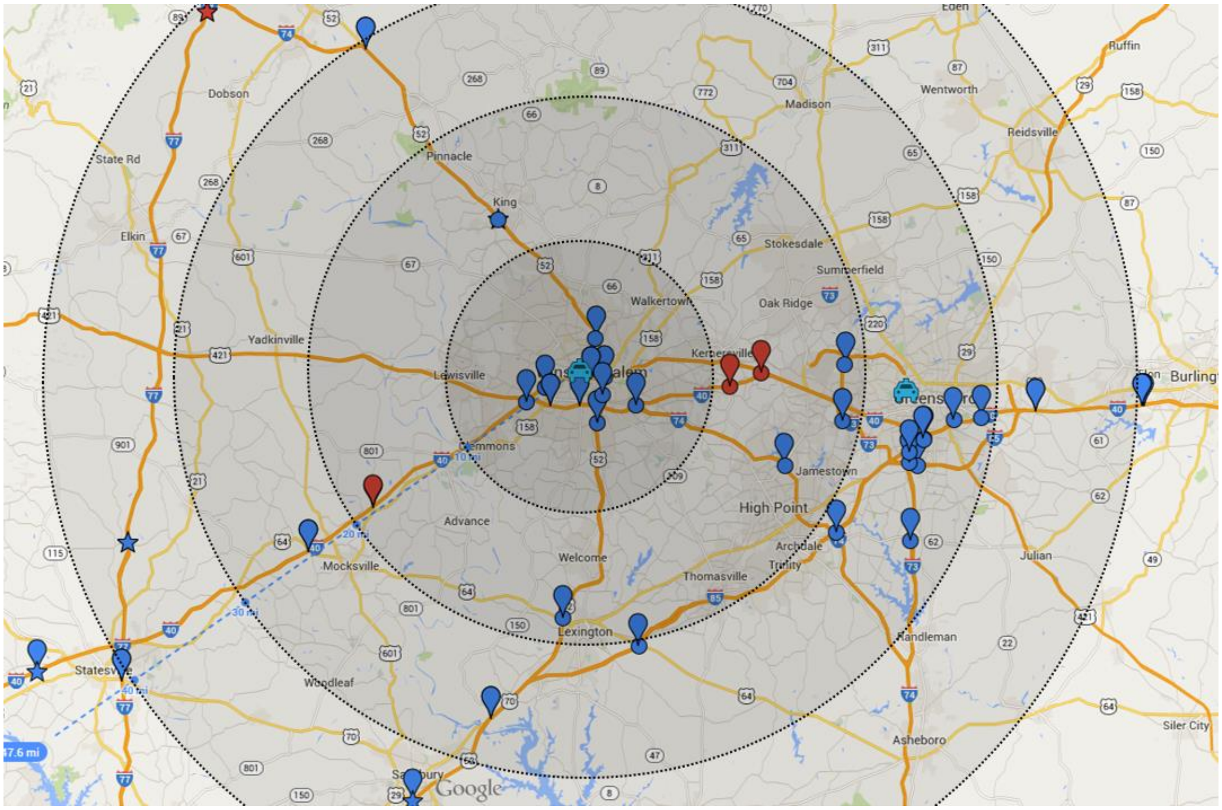
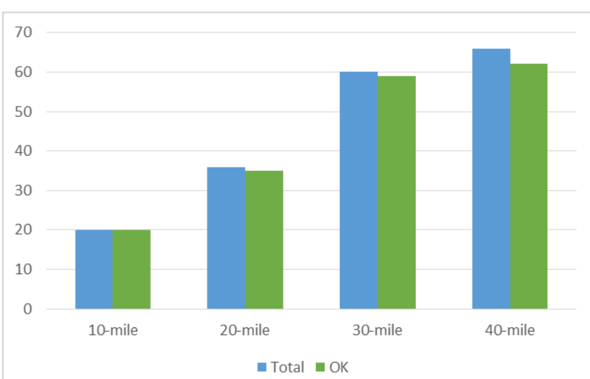


Exhibit 26: UCP Analysis Results of Greensboro



City	Population	Analysis		10-mile	20-mile	30-mile	40-mile
Winston-Salem	236,441	1st Criterion	Total Station	20	36	60	66
			UCP Station	20	35	59	62
			UCP Percentage	100%	97%	98%	94%
		2nd Criterion	Total Station	20	36	60	66
			UCP Station	15	25	39	40
			UCP Percentage	75%	69%	65%	61%

The 1st UCP Rule (Boundary)



The 2nd UCP Rule (Direction)

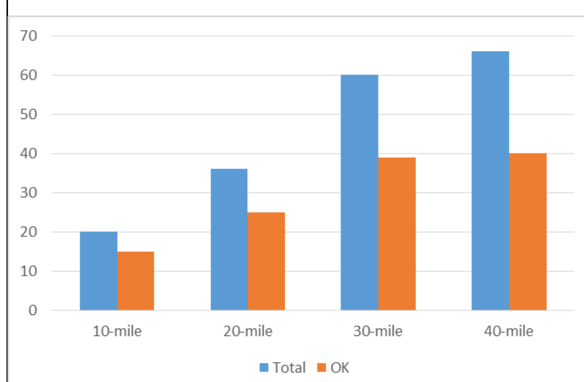
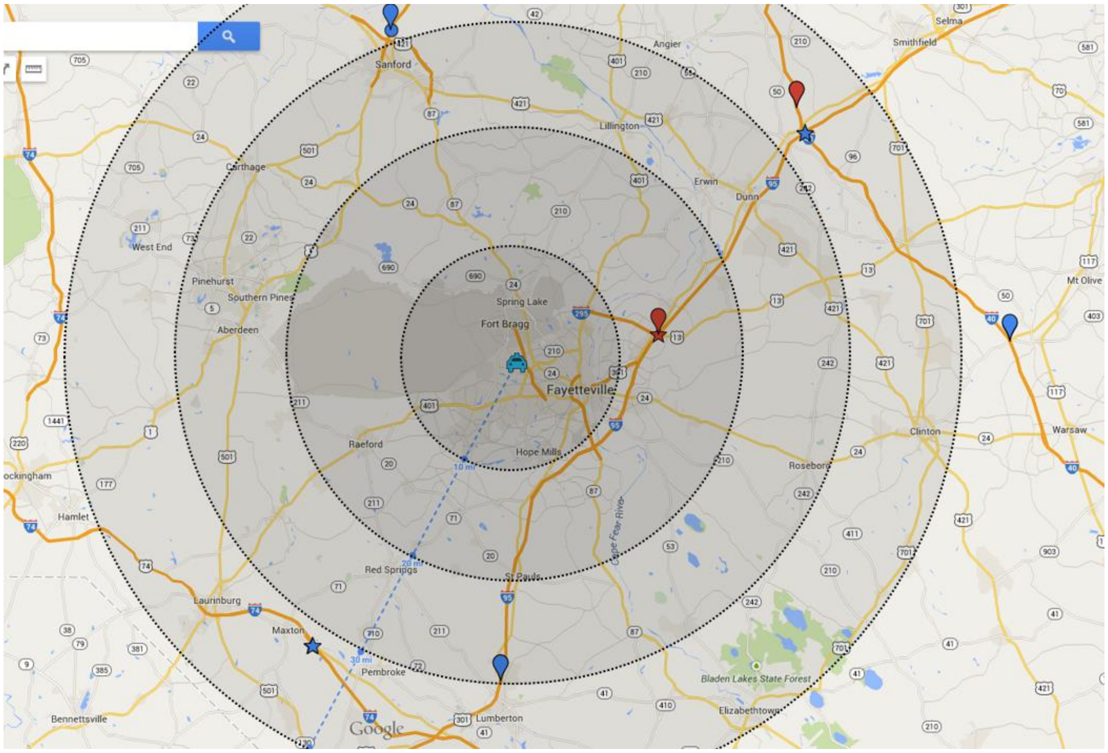
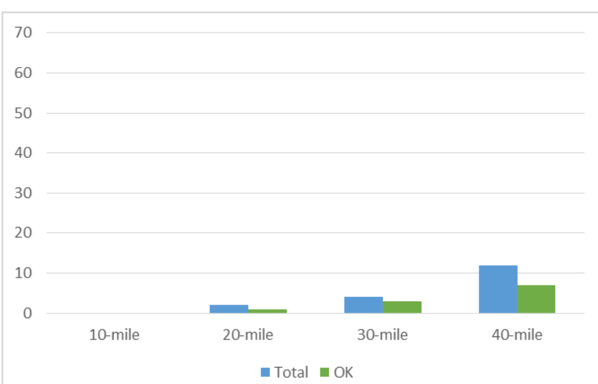


Exhibit 27: UCP Analysis Results of Winston-Salem



City	Population	Analysis		10-mile	20-mile	30-mile	40-mile
Fayetteville	204,408	1st Criterion	Total Station	0	2	4	12
			UCP Station	0	1	3	7
			UCP Percentage	0%	50%	75%	58%
		2nd Criterion	Total Station	0	2	4	12
			UCP Station	0	0	1	2
			UCP Percentage	0%	0%	25%	17%

The 1st UCP Rule (Boundary)



The 2nd UCP Rule (Direction)

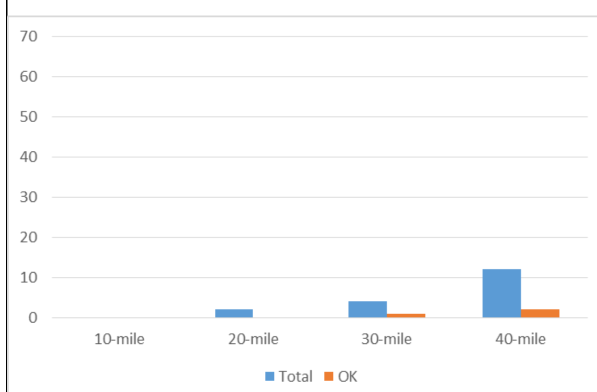
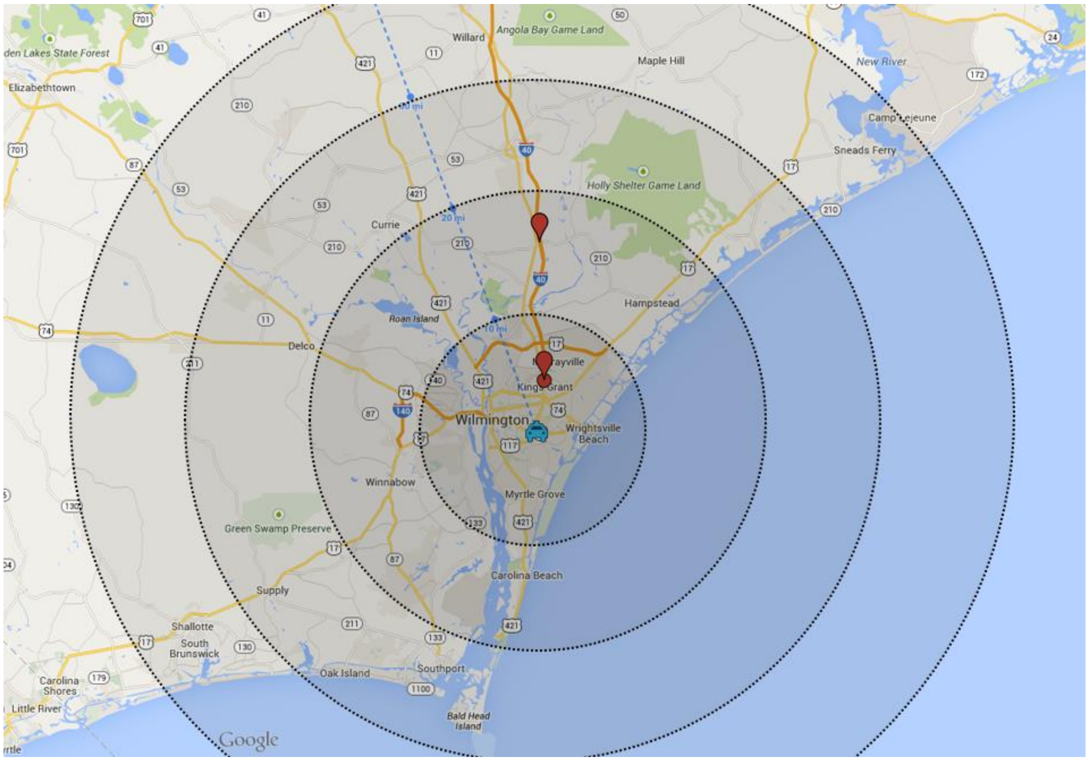
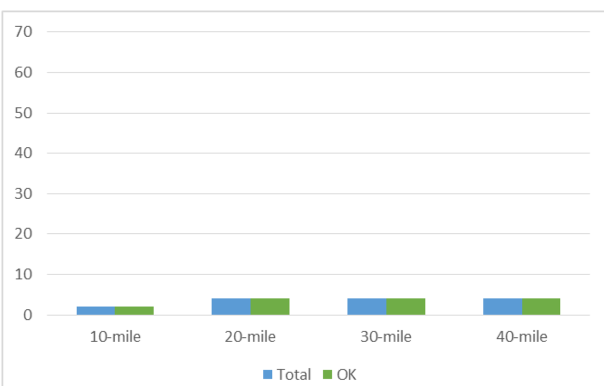


Exhibit 28: UCP Analysis Results of Fayetteville



City	Population	Analysis		10-mile	20-mile	30-mile	40-mile
Wilmington	112,067	1st Criterion	Total Station	2	4	4	4
			UCP Station	2	4	4	4
			UCP Percentage	100%	100%	100%	100%
		2nd Criterion	Total Station	2	4	4	4
			UCP Station	2	3	3	3
			UCP Percentage	100%	75%	75%	75%

The 1st UCP Rule (Boundary)



The 2nd UCP Rule (Direction)

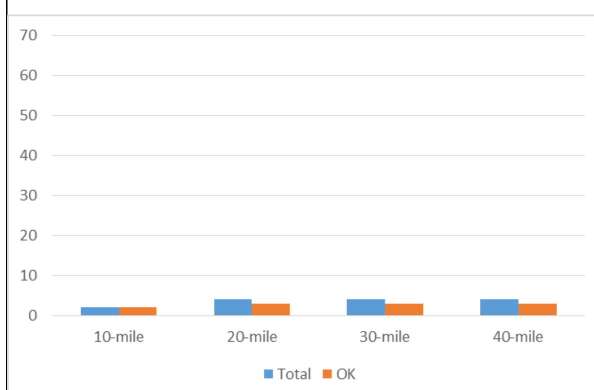
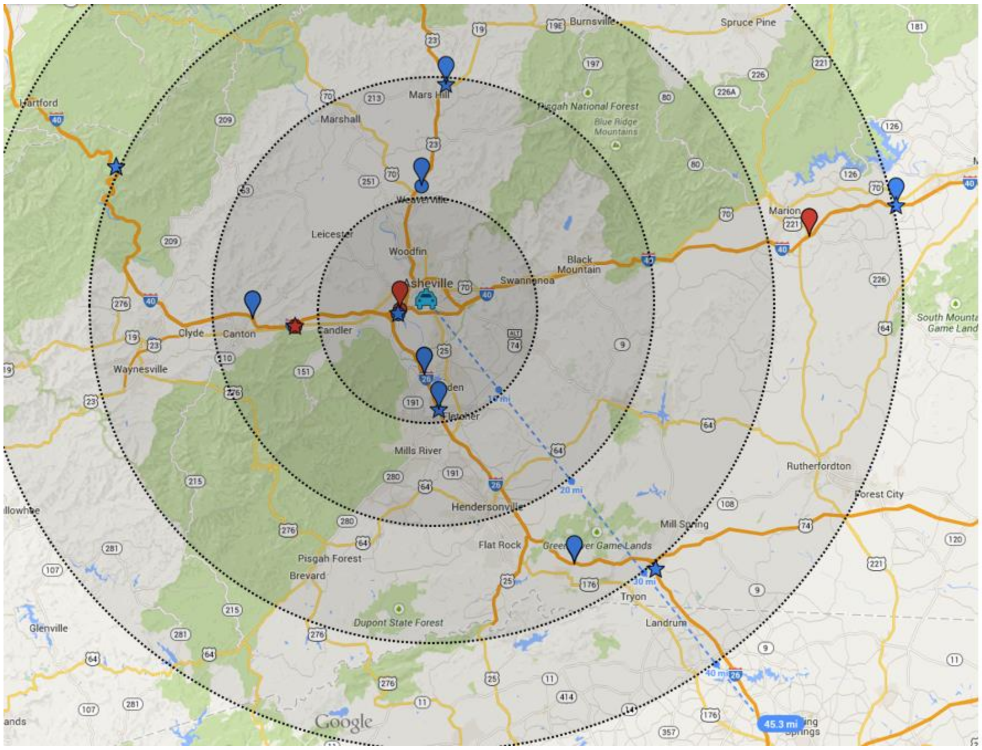
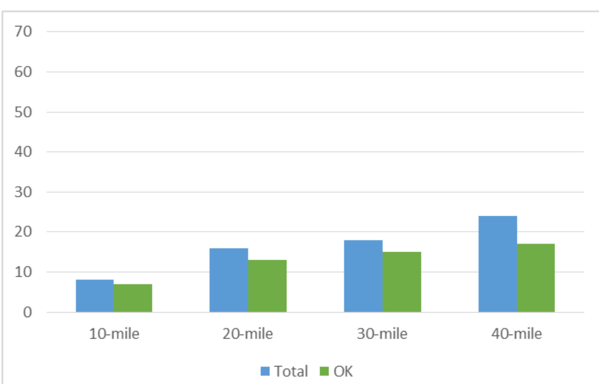


Exhibit 29: UCP Analysis Results of Wilmington



City	Population	Analysis		10-mile	20-mile	30-mile	40-mile
Asheville	87,236	1st Criterion	Total Station	8	16	18	24
			UCP Station	7	13	15	17
			UCP Percentage	88%	81%	83%	71%
		2nd Criterion	Total Station	8	16	18	24
			UCP Station	4	9	10	11
			UCP Percentage	50%	56%	56%	46%

The 1st UCP Rule (Boundary)



The 2nd UCP Rule (Direction)

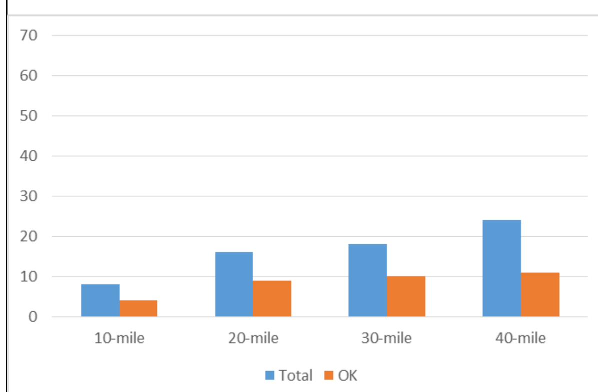


Exhibit 30: UCP Analysis Results of Asheville

In this analysis, the team examined both the 1st and 2nd UCP rules to see what percentage of stations followed each rule. A total of seven areas were examined having one UCP for each area. As a result of the analysis, the team can summarize the following key observations:

- *As the boundary of analysis increases, the percentage of sites following each rule decreases. This is intuitive, because this analysis was based on urban centroid concept, and the influence from the urban centroid is expected to decrease as one moves further away from the center.*
- *The size of city presented as a population showed considerable effect on the percentage of sites following the rules. This is also intuitive, because the larger cities are, the stronger tendency traffic has to behave according to the urban centroid concept. That means that it is more likely for urban vehicles to move to the center of a larger city in the AM peak and vice versa in the PM peak, than vehicles in smaller cities.*
- *The first rule usually had a higher percentage of sites that followed its premise, than did the second rule. This is presumably due to the fact that the second rule should follow not only volume characteristic (bimodal), but also directional characteristic (AM or PM peak).*

2.6 Volume Profile Application Guidance

In order to provide volume profiles in FREEVAL-WZ tool, the team collected and analyzed both permanent and temporary traffic volume data. As a result of the study, the team provides guidance for traffic volume profile usage separated by the source of volume data, direct station data, and UCP data.

2.6.1 Direct Station Data

FREEVAL-WZ users are given two options to apply volume profiles in the software. The first option is to directly use the traffic volume profile data obtained from a specific permanent count station. Whenever a work zone is expected near such traffic count station, each weekday volume profile provided in Appendix A is also available directly in the FREEVAL-WZ software. While using volume profiles from the permanent station is preferred, the other set of volume profiles obtained from temporary stations can also be examined as supplemental data. The temporary weekday volume data are provided in Appendix B. For weekend volume data, a unimodal volume profile presented in Exhibit 8 is recommended to be used in the program.

2.6.2 UCP Data

As a second option, users are also able to use typical weekday volume profiles provided by the UCP analysis results. Depending on the location of the UCP, users can select one of three volume profiles, unimodal, bimodal-AM, or bi-modal PM, (Exhibits 8 through 10) in the weekday condition that is expected to the best correspondence in the work zone. In the case of weekend condition, a unimodal volume profile is also recommended.

3 Work Zone Assessment Methodology

In this project, the proposed methodology to assess freeways operation is largely based on NCHRP 03-107 project for evaluating the work zones conditions *(12, 13)*. Majority of the material provided in this section is borrowed from 6th edition of Highway Capacity Manual (HCM). Research shows that the lane configuration, barrier type, area type, lateral distance of the work zone from travelled lanes, and lighting conditions (i.e., daytime or night) can affect the capacity of a work zone. This research also shows that non–work zone free-flow speed, work zone speed limit, lane configuration, barrier type, presence of ramps, and lighting conditions can affect the free-flow speed *(12, 13)*.

To determine the impacts of a work zone on basic freeway segment capacity, the analyst must first specify the lane closure type (e.g., shoulder closure, three-to-two lane closure), barrier type, area type, lateral distance, and whether daytime or nighttime operations are considered. To determine the work-zone impacts on free-flow speed, the analyst must specify the ratio of non-work-zone speed limit to work zone speed limit, the work zone regulatory speed limit, lane closure type, barrier type, day or night work, and the number of ramps within 3 mi of the center of the work zone.

The variables are defined as follows:

$LCSI$ = Lane closure severity index (described below);

f_{Br} = Indicator variable for barrier type:
= 0 for concrete and hard barrier separation, and
= 1 for cone, plastic drum, or other soft barrier separation;

f_{AT} = Indicator factor for area type:
= 0 for urban areas (i.e., typified by high development densities or concentrations of population), and
= 1 for rural areas (i.e., areas with widely scattered development and low housing and employment densities);

f_{LAT} = Lateral distance from the edge of travel lane adjacent to the work zone to the barrier, barricades, or cones (0–12 ft);

f_{DN} = Indicator variable for daylight or night:
= 0 for daylight, and
= 1 for night;

f_{Sr} = Speed ratio (decimal); the ratio of non–work zone speed limit (before the work zone was established) to work zone speed limit;

SL_{wz} = Work zone speed limit (mi/h); and

TRD = Total ramp density along the facility (ramps/mi); for isolated segment analyses, ramps should be counted 3 mi upstream and 3 mi downstream of the center of the work zone.

The barrier type indicator variable can largely be interpreted as being synonymous with the distinction of short-term versus long-term work zones, with longer-term work zones more likely to be configured using concrete barriers. In research, the barrier type was found to be more-clearly defined and more-readily applied than the distinction of short-term and long-term work zone effects. For long-term work zones, there may be a learning effect for drivers that increases capacities over time, but no conclusive evidence for this effect was found in the research.

The lane closure configuration in a work zone is expressed as *the ratio of the number of original lanes to the number of lanes present in the work zone*. For instance, a 3-to-1 lane closure configuration means that three lanes are normally available, but that two lanes were closed during construction and only one lane was open. Research shows that this ratio is effective in showing the influences of different lane configurations on speed or capacity.

It should be noted that this ratio cannot distinguish a 4-to-2 lane closure configuration from a 2-to-1 configuration, as both yield a ratio of 0.5. Field observations (*13*) and citations in the literature (*12*) both suggest that the per-lane capacity of a 2-to-1 lane closure is significantly less than that of a 4-to-2 closure, due to fewer open lanes being available. The Lane Closure Severity Index (LCSI) distinguishes such lane closure configurations. Equation 1 shows how the LCSI is calculated:

$$LCSI = \frac{1}{OR \times N_o} \tag{1}$$

where

$LCSI$ = Lane Closure Severity Index (decimal);

OR = Open Ratio, the ratio of the number of open lanes during road work to the total (or normal) number of lanes (decimal); and

N_o = Number of open lanes in the work zone (ln).

It is clear that the LCSI gives a unique value for different lane closure configurations, where higher values generally correspond to a more-severe lane closure scenario. This is illustrated in Exhibit 31.

Exhibit 31 – Lane Closure Severity Index as a Function of Open Lanes Ratio

Number of Total Lane(s)	Number of Open Lane(s)	Open Ratio	LCSI
3	3	1.00	0.33
2	2	1.00	0.50
4	3	0.75	0.44
3	2	0.67	0.75
4	2	0.50	1.00
2	1	0.50	2.00
3	1	0.33	3.00
4	1	0.25	4.00

In interpreting Exhibit 31, it is noted that not all work zones are associated with lane closure effects. For example, work zones may be limited to shoulder work only, or may feature a lane shift or crossover. This chapter's methodology also applies to work zones without lane closures. In the exhibit, a "2-to-2 work zone" can refer to shoulder closures or crossovers that do not impact the overall number of travel lanes.

Freeway work zone capacity corresponds to the maximum sustainable flow rate immediately preceding a breakdown. However, measuring the pre-breakdown value in work zones is often not feasible. On the other hand, queue discharge flow rates can be easily measured using video cameras or other data collection tools. Therefore, to arrive at an estimate of pre-breakdown work zone capacity, models to predict queue discharge rate as a function of work zone configurations and other prevailing conditions are presented. The queue discharge rate is then converted back to the corresponding pre-breakdown flow rate using a conversion ratio.

The average flow rate immediately downstream of an active bottleneck (following breakdown) measured over a 15-min sampling interval while there is active queuing upstream of the bottleneck is the queue discharge rate. Equation 2 gives a predictive model for freeway work-zone queue discharge rate as a function of the work-zone configuration and other prevailing conditions:

$$QDR_{wz} = 2{,}093 - 154 \times LCSI - 194 \times f_{Br} - 179 \times f_{AT} + 9 \times f_{LAT} - 59 \times f_{DN} \qquad (2)$$

Where QDR_{wz} is the average 15-min queue discharge rate (pc/h/ln) at the work zone bottleneck, and all other variables are as defined previously. As expected, the work zone queue discharge rate is lower at higher LCSI values, when soft barriers are present, in rural areas, with smaller lateral clearances, and at night. The pre-breakdown capacity for work zones can be estimated from the queue discharge flow rate, which is expected to be lower than the pre-breakdown flow rate. Equation 3 is used to determine the pre-breakdown capacity:

$$c_{WZ} = \frac{QDR_{wz}}{100 - \alpha_{wz}} \times 100 \qquad (3)$$

where c_{wz} is the work zone capacity (pre-breakdown flow rate) (pc/h/ln), α_{wz} is the percentage drop in pre-breakdown capacity at the work zone due to queuing conditions (%), and QDR_{wz} is as defined above.

Research shows an average queue discharge drop of 7% in non-work zone conditions, and an average value of 13.4% in freeway work zones (*12*). The underlying research measured pre-breakdown capacities, as well as queue discharge rates, to estimate the magnitude of α_{wz}. When there is little local information available on α_{wz}, these values can be used as defaults.

3.1 Work Zone Free-Flow Speed Model

A model for work zone free-flow speed has been developed through work zone observations during low-flow conditions (12, 13). The model should only be used if no local estimates of FFS are available. Equation 4 predicts FFS in freeway work zones based on work-zone configurations and other prevailing conditions:

$$FFS_{wz} = 9.95 + 33.49 \times f_{Sr} + 0.53 \times SL_{wz} - 5.60 \times LCSI - 3.84 \times f_{Br} - 1.71 \times f_{DN} - 8.7 \times TRD \quad (4)$$

Where FFS_{wz} is the work-zone free-flow speed (mi/h) and all other variables are as defined previously. The work zone FFS decreases as the LCSI increases, when soft barriers are used, at night, and as the ramp density increases. Higher work zone speed limits and higher speed ratios result in higher work zone FFS. The calculated work zone FFS should not be greater than the non–work zone FFS, and the result of Equation 4 should be capped as needed.

3.2 Work Zone Speed–Flow Model

Changes in work zone pre-breakdown capacity and work zone FFS impact the overall shape of the speed–flow model in the freeway segments impacted by the work zone. Work zone FFS is determined using Equation 4, while work zone capacity is determined using Equation 5 and Equation 6. Adjustment factors for capacity and FFS are used to reflect the effect of the work zone on speeds and flows. Equation 5 is used to determine the work-zone capacity adjustment factor.

$$CAF_{wz} = \frac{c_{wz}}{c} \quad (5)$$

where

CAF_{wz} = capacity adjustment factor for a work zone (decimal),

c = basic freeway segment capacity in non-work-zone conditions (pc/h/ln), and

c_{wz} = work zone capacity (pre-breakdown flow rate) (pc/h/ln).

Similarly, Equation 6 is used to determine the speed adjustment factor for work-zone conditions:

$$SAF_{wz} = \frac{FFS_{wz}}{FFS} \quad (6)$$

where

SAF_{wz} = free-flow-speed adjustment factor for work zone (decimal),

FFS = freeway free-flow speed in non-work-zone conditions (mi/h), and

FFS_{wz} = work zone free-flow speed (mi/h).

CAFs and SAFs for work zones should never be greater than 1.0, and the results of Equation 5 and 6 should be capped at 1.0 accordingly.

4 Computational Engine

The research team incorporated the methodological enhancements developed in this project into the FREEVAL-WZ computational engine as identified in the work plan, and after receiving input from NCDOT. In addition to incorporating these updates, the key objectives of the software update effort was improved reliability and user-friendliness of the tool, based on feedback received from NCDOT analysts. This involved moving all of the software outside of the existing Microsoft Excel/Visual Basic Environment, and into a Java-Based platform, to enhance computational speed. The final software tool, as well as a detailed user guide, are separate deliverables of this project.

The software development effort in this research is based on the computational engine for the Highway Capacity Manual’s freeway facility methodology, called FREEVAL. The method is ideally suited for evaluating work zone impacts on extended freeway facilities, as it already incorporates many of the building blocks needed to model work zone impacts on operations, including lane closures, capacity-adjustment factors, and reduced speed limits. The core tool was significantly enhanced in this research to add a planning-level user interface, and to incorporate NC specific work zone defaults based on this research. The modified tool is referred to as FREEVAL-WZ (work zone) in this document.

While all the above work zone impacts can be modeled in the original FREEVAL program, there was a need to facilitate data entry and customize the tool to the needs of the NCDOT. Specifically, the original FREEVAL requires 15-minute traffic demand flows to be entered for each segment and each time period. In addition to being coding intensive, the required demand data are usually not available in planning-level analyses that rely principally on estimates of average annual daily traffic (AADT). An important component of the new planning-level interface is the ability to use AADT volume inputs. Along with other enhancements, a comprehensive reporting component is added to the tool to generate summary reports in the PDF format. The customization of the report is defaulted based on NCDOT’s needs and requirements.

A comprehensive user’s guide is developed during the course of the project and is released to NCDOT as one of the projects deliverables.

5 Findings and Conclusions

This project enhanced the analysis methodology and associated software implementation for the evaluation of significant work zones on freeways and multi-lane highways in North Carolina. The FREEVAL-WZ tool allows the prediction of traffic operational impacts of work zones, including capacity reductions, lane closures, reduced speed limits and traffic diversions. The research is based on the 6th edition of Highway Capacity Manual Freeway Facilities methodology and its FREEVAL computational engine. Through this project, the tool was enhanced to allow for work-zone specific impact assessment, customized to the needs of the NCDOT Work Zone and Congestion Management Units. The tool includes a new planning-level feature that allows for a quick assessment of work zone impacts, while still allowing for a more detailed operational analysis. Work zone impacts are coded in the form of default values for North Carolina conditions, but can be adjusted by user input. Further, the methodology allows the analyst to calculate user cost impacts of the work zone.

One of the major contributions of this project is to develop default traffic volume distributions for different locations in North Carolina. As a result the analyst can manipulate analysis inputs simply by specifying the geometry and AADT on freeway mainline and ramps. All other inputs needed for the freeway facility analysis are obtained through automated functions and default values. This greatly enhances the user-friendliness of the tool, and reduced the analysis burden. Through the use of default values and streamlined data entry, the tool allows for the planning-level evaluation of a freeway work zone within a few minutes, as opposed to taking several hours in a traditional HCM analysis, or multiple days or weeks, as is the case for a simulation-based analysis of work zone impacts.

Another major improvement to the analysis is the integration of recently developed freeway work zone capacity, free-flow speed, and speed flow models for the Highway Capacity Manual under NCHRP project 03-107. All procedures from that research, including adjustments for work zone shoulder work, lane closures, and directional crossovers are directly integrated into the FREEVAL-WZ software.

Finally, the research team has created a customizable PDF report to provide a summary of the analysis that was performed in FREEVAL-WZ. A comprehensive user’s guide for FREEVAL-WZ is developed and delivered to NCDOT as a project deliverable.

This research addressed critical research needs for work zone analysis within NCDOT. The 24-hour analysis feature, the geographic expansion of volume distribution, and the development of “high-demand” k-factor profiles, are key research questions that go beyond the current state of knowledge within NCDOT, as well as in the Highway Capacity Manual. Full day analysis also will further position NCDOT to carry out reliability analyses in the future, which is a rapidly increasing focus of NCDOT, as well as the Federal Highway Administration. With NCDOT staff having had some hands-on practice with the tool over the past few years, there was a need and opportunity for improvements to the user guide and enhancing the usability of the tool itself to better match the needs of NCDOT. In summary, this project addressed critical research needs and offers specific customization and enhancements to the FREEVAL-WZ tool as a value added contribution to the research itself.

The main products of this research are new empirical results and methods to support 24-hour freeway analysis, to allow customized application for different geographic regions in North Carolina, and to provide additional demand distributions for general freeway and freeway work zone analysis. These empirically-based results will then be integrated in a significantly enhanced FREEVAL-WZ tool that enables the analyst to perform a planning-level assessment of freeway facilities and freeway work zones in a 24-hour context, with consideration of region-specific traffic demand patterns.

This research is important for day-to-day freeway work zone analyses performed by NCDOT through providing additional default values and customization of the FREEVAL-WZ tool and methodology. The project addresses critical needs and limitations of the tool and will lead to a more usable and reliable product to support NCDOT in-house analysis activities. A key objective of the project is a 24-hour analysis of freeway facilities, which will assist the department with work zone scheduling and evaluating contractor plans for construction.

6 Implementation and Technology Transfer Plan

The research team held several meetings at NCDOT and presented the work in progress to benefit from the feedback that StIC provides. As a result, the StIC closely monitored the progress of the project along with the software tool development. The research team also delivered a hands-on training session with StIC members and presented the software tool in a workshop. This gave the StIC the opportunity to actively use and test the tool. Along with this document, the research team is also providing a comprehensive users guide for future analysist assistance.

Beyond this research project, additional training and technology transfer activities are highly recommended to formally integrate the new procedure and software tool into day-to-day practices within the NCDOT work zone and congestion management units. There is a need for a general awareness campaign for NCDOT staff, along with hands-on training sessions that demonstrate the use of the tool. These training sessions should leverage the developed user guide, but would benefit from the incorporation of specific project examples and use cases for work zone analysis within North Carolina. Having these real-world examples, in addition to the ones provided in the accompanying user guide, will be critical to illustrate when and how to apply the tool.

After completing training workshops for NCDOT staff, it is further desirable to offer training to municipalities in North Carolina, as well as private contractor staff working for the NCDOT. The developed method provides great efficiencies in evaluating work zones, can thus result in significant cost-savings to the department if adopted by contractors over alternate methods. The NCDOT may consider the production of a one-page fact sheet to summarize the research and the software tool, which can be used to inform the various stakeholders in work zone analysis of the new capabilities developed in this project.

7 Recommendations

The product of this research is a systematic procedure for analyzing the impacts of significant work zones on traffic operations on freeways and multi-lane highways and a companion software tool implementing the methodology. The Java based FREEVAL-WZ is customized for the needs and requirements of the NCDOT. The product is adaptable for planning-level and operational analyses and can be calibrated to reflect present-day user cost and local estimates of work zone capacity in calculation algorithms consistent with HCM procedures.

With the completion of this research, FREEVAL-WZ is intended to be used by the Work Zone Traffic Control Section to evaluate traffic operational impacts of work zones on freeways and multi-lane highways in-house. The tool is shown to have greater accuracy than current state-of-the-practice tools and allows for more time-efficient analysis than is possible by contracting private entities for simulation analysis. The need for a more detailed simulation analysis remains for some more complex work zone scenarios, especially as the modeled geometry exceeds the limitations of the HCM analysis framework. Since it is based on the methods of the Highway Capacity Manual, the software further has application for other units within NCDOT, including Congestion Management.

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Appendix A – Volume Profiles for Permanent Traffic Count Stations

Figure A-1. Permanent Stations (a1~a13, b1~b7)

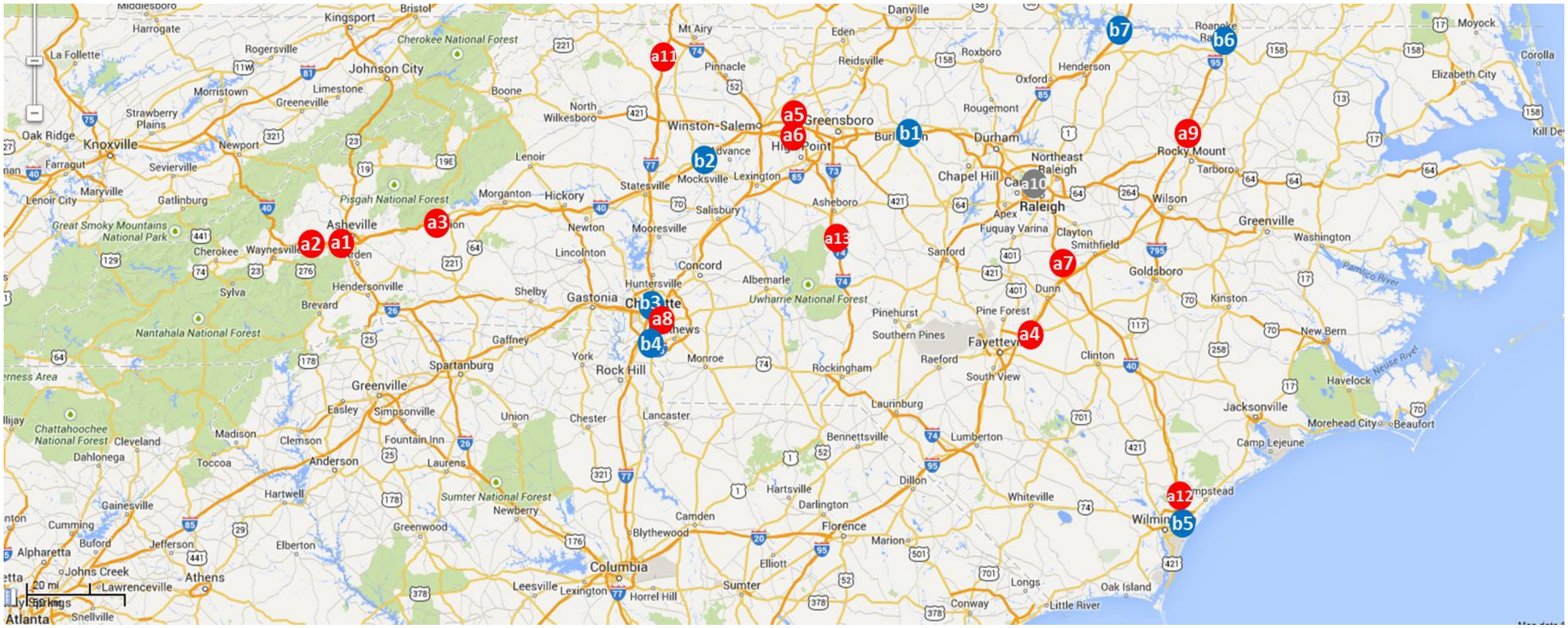

Figure A-2. Permanent Stations (s1~s7)

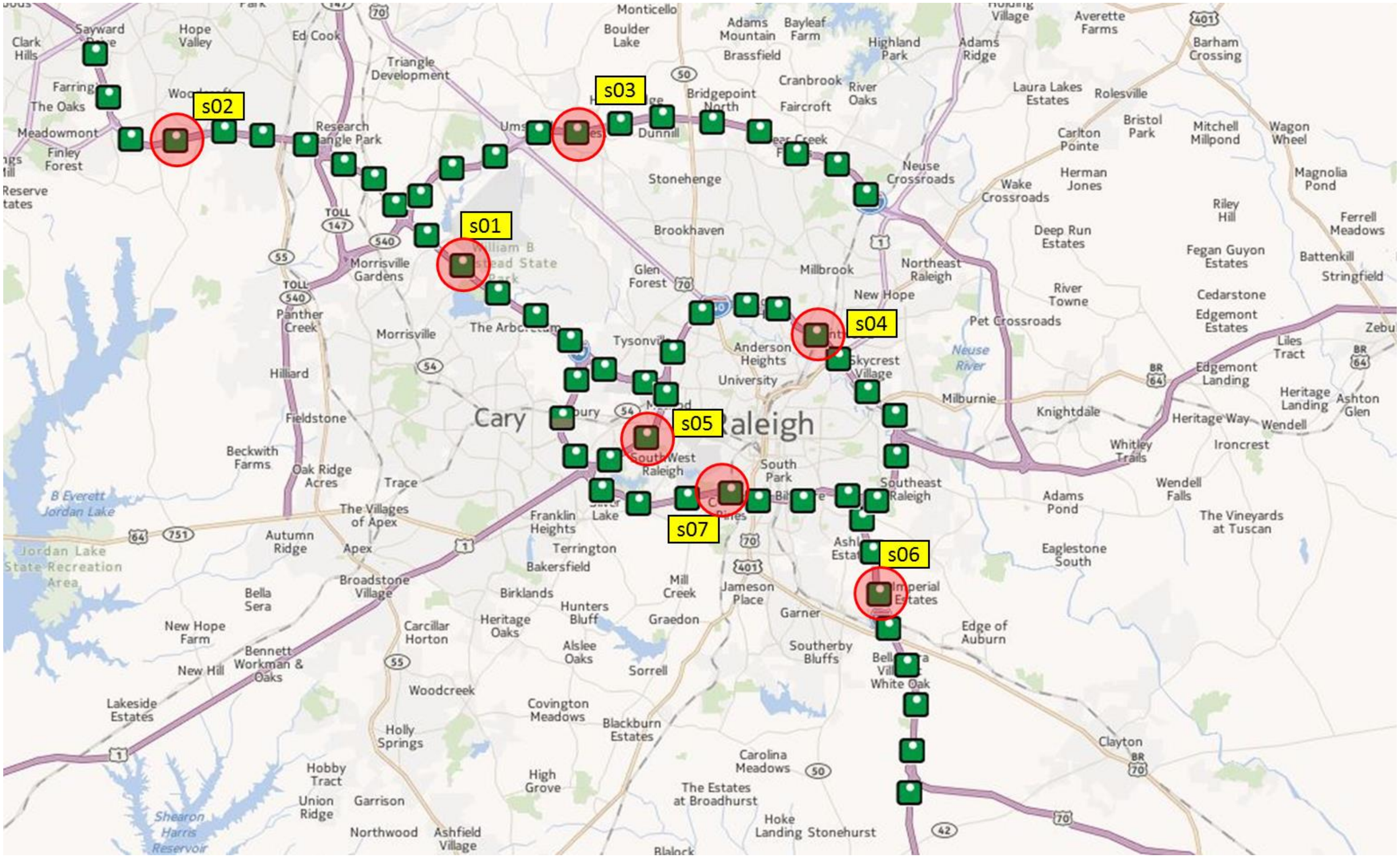

Table A-1. Permanent Station Weekday Volume Profile

(unit: %)

ID_bound \ Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
a1_EB	0.63	0.36	0.28	0.27	0.51	1.35	3.75	8.53	8.05	5.84	5.42	5.58	5.77	5.83	6.23	7.15	7.68	8.34	6.09	3.99	2.99	2.34	1.69	1.34
a1_WB	0.57	0.37	0.31	0.36	0.66	1.77	4.00	6.91	6.02	5.19	5.14	5.58	5.88	6.19	6.78	7.51	8.71	8.87	5.64	4.14	3.48	2.87	1.87	1.18
a2_EB	0.95	0.82	0.78	0.86	1.22	2.20	4.45	7.11	6.18	5.72	6.08	6.31	6.37	6.25	6.45	6.59	6.81	6.98	5.47	3.84	2.93	2.36	1.89	1.37
a2_WB	1.02	0.72	0.60	0.55	0.70	1.07	2.13	4.14	4.79	4.97	5.52	5.82	6.13	6.58	7.19	7.95	8.54	8.96	6.39	4.92	4.01	3.28	2.35	1.69
a3_EB	0.67	0.49	0.47	0.56	1.02	2.66	4.84	6.14	5.31	5.25	5.63	5.84	6.13	6.48	7.27	7.82	7.98	7.92	5.53	3.78	2.84	2.23	1.80	1.36
a3_WB	0.72	0.56	0.46	0.48	0.75	1.83	4.07	6.81	5.69	5.37	5.61	5.89	5.94	6.17	7.03	8.12	7.92	7.69	5.41	4.17	3.37	2.57	1.96	1.40
a4_NB	1.15	0.94	0.86	0.93	1.29	2.08	3.36	4.31	5.00	5.25	5.66	6.04	6.25	6.59	6.84	7.42	7.81	7.75	5.90	4.42	3.47	2.86	2.18	1.62
a4_SB	1.31	1.04	0.88	0.95	1.22	2.01	3.88	5.81	5.62	5.93	6.20	6.30	6.12	6.34	6.62	6.66	6.69	6.39	5.37	4.24	3.33	2.77	2.38	1.93
a5_EB	0.70	0.51	0.45	0.57	1.11	2.75	6.31	10.16	7.46	5.06	4.72	4.87	5.23	5.35	5.71	6.37	7.03	7.86	5.55	3.71	2.92	2.43	1.85	1.35
a5_WB	0.86	0.53	0.47	0.45	0.66	1.55	3.94	7.23	6.36	5.02	4.79	5.20	5.35	5.56	6.16	7.43	8.67	10.31	6.05	4.02	3.11	2.60	2.00	1.68
a6_EB	0.74	0.53	0.51	0.64	1.16	2.67	6.19	10.19	8.42	5.56	5.04	5.08	5.18	5.38	5.78	6.18	6.44	7.26	5.28	3.68	2.80	2.29	1.76	1.24
a6_WB	0.91	0.59	0.53	0.55	0.71	1.37	3.12	5.75	5.82	4.82	4.87	5.18	5.43	5.74	6.46	7.77	8.96	10.83	6.44	4.26	3.28	2.76	2.11	1.75
a7_EB	0.81	0.51	0.39	0.47	0.80	1.84	3.88	5.64	5.63	5.66	5.82	5.73	5.76	6.16	6.60	7.24	8.08	7.69	6.60	4.93	3.55	2.75	2.05	1.42
a7_WB	0.63	0.44	0.42	0.53	1.04	2.82	6.23	5.67	5.67	5.57	5.40	5.59	5.77	6.08	6.56	7.07	7.47	7.73	6.11	4.35	3.30	2.54	1.87	1.16
a8_NB	0.83	0.52	0.48	0.48	0.81	2.10	5.11	6.86	5.95	5.10	4.93	5.21	5.53	6.02	6.53	7.17	7.47	6.82	5.60	4.95	4.02	3.32	2.43	1.76
a8_SB	1.00	0.68	0.58	0.50	0.73	1.94	5.22	7.74	7.54	5.91	5.10	5.00	5.21	5.48	5.75	6.10	6.72	6.89	6.16	4.54	3.65	3.10	2.62	1.85
a9_NB	1.34	1.09	0.98	1.00	1.25	1.70	2.73	4.29	4.97	5.69	6.29	6.50	6.53	6.75	6.96	7.05	6.94	6.65	5.70	4.61	3.69	3.05	2.40	1.83
a9_SB	1.54	1.24	1.11	1.12	1.35	1.83	2.85	4.04	4.87	5.51	6.00	6.25	6.40	6.79	7.08	7.04	6.88	6.50	5.28	4.23	3.62	3.21	2.87	2.37
a11_NB	1.37	1.12	0.99	1.07	1.22	1.66	2.67	4.27	5.07	5.52	6.67	7.02	6.65	6.63	6.76	6.96	6.75	6.44	5.32	4.57	3.89	3.01	2.42	1.96

ID_bound \ Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
a11_SB	1.73	1.35	1.22	1.23	1.48	2.04	2.91	3.64	4.32	4.78	5.45	5.87	6.14	6.61	7.06	7.15	7.10	6.67	5.77	4.69	3.95	3.47	2.99	2.40
a12_EB	0.67	0.49	0.37	0.42	0.76	2.21	4.96	5.79	5.32	5.52	5.88	6.05	6.07	6.38	7.11	7.65	7.95	7.34	5.45	4.39	3.48	2.65	1.89	1.21
a12_WB	0.39	0.31	0.39	0.57	1.27	2.69	5.25	6.60	6.29	6.05	5.98	6.03	6.46	6.98	7.54	7.93	8.14	7.19	4.52	3.19	2.48	1.87	1.18	0.70
a13_NB	0.57	0.41	0.39	0.49	1.03	3.25	6.66	7.82	5.41	5.23	5.51	5.89	6.14	6.65	6.99	7.02	7.20	6.81	5.32	3.63	2.65	2.15	1.69	1.09
a13_SB	0.69	0.46	0.48	0.59	1.02	1.89	3.69	5.29	5.34	5.67	6.18	6.21	6.15	6.24	6.56	7.81	7.92	8.13	5.95	4.51	3.39	2.58	1.79	1.46
b1_EB	1.26	0.96	0.87	0.90	1.29	2.23	4.76	6.32	5.74	5.35	5.30	5.44	5.61	5.84	6.39	6.87	6.68	6.85	5.55	4.43	3.84	3.22	2.42	1.89
b1_WB	1.37	0.87	0.72	0.68	0.85	1.44	3.42	5.59	4.93	5.24	5.54	5.74	5.81	6.10	6.77	7.85	7.85	7.60	6.08	4.62	3.52	2.88	2.52	2.01
b2_EB	0.84	0.61	0.58	0.62	0.89	1.91	4.46	6.91	6.22	5.69	5.76	5.84	5.95	6.27	6.59	6.92	7.13	7.36	5.92	4.26	3.31	2.63	1.99	1.34
b2_WB	0.80	0.53	0.44	0.47	0.75	1.62	3.05	5.22	5.23	5.35	5.62	6.05	6.18	6.52	7.09	7.76	8.37	8.64	6.23	4.49	3.50	2.82	1.91	1.33
b3_NB	1.19	0.84	0.78	0.73	0.91	1.77	4.20	6.32	5.88	5.10	5.14	5.52	5.62	5.83	6.40	7.49	7.43	6.63	5.85	4.60	3.74	3.28	2.68	2.06
b3_SB	1.04	0.71	0.62	0.67	0.98	2.47	7.12	9.21	7.10	5.13	4.85	5.03	5.28	5.57	5.83	6.30	6.49	6.50	5.15	3.94	3.26	2.84	2.23	1.71
b4_EB	0.93	0.55	0.47	0.36	0.48	1.12	3.73	6.65	6.53	5.32	5.12	5.91	6.26	6.16	6.47	7.31	7.27	6.08	6.06	5.51	4.05	3.39	2.51	1.78
b4_WB	0.64	0.35	0.31	0.34	0.69	2.00	6.37	8.85	8.15	5.96	5.06	5.09	5.56	5.97	5.95	6.19	6.34	6.86	5.52	4.17	3.37	2.98	2.05	1.25
b5_EB	0.76	0.54	0.34	0.33	0.42	1.28	5.68	10.00	7.14	5.51	5.33	5.47	5.42	5.31	5.55	6.71	7.29	7.67	6.11	4.21	3.22	2.57	1.84	1.31
b5_WB	0.54	0.34	0.30	0.31	0.57	1.43	3.91	5.98	5.03	4.72	4.87	5.06	5.54	6.10	6.92	8.00	9.19	10.61	6.74	4.52	3.50	2.83	1.86	1.13
b6_NB	1.64	1.37	1.24	1.27	1.76	2.55	2.83	3.64	4.38	5.15	5.95	6.29	6.26	6.47	6.84	6.86	6.82	6.30	5.34	4.69	4.00	3.37	2.80	2.18
b6_SB	1.72	1.40	1.33	1.32	1.47	1.99	2.62	3.76	4.60	5.35	5.92	6.15	6.50	6.79	6.94	6.96	6.84	6.11	5.08	4.18	3.80	3.51	3.09	2.57
b7_NB	1.83	1.59	1.48	1.46	1.78	2.27	3.03	3.82	4.44	5.14	5.93	6.23	6.21	6.35	6.39	6.49	6.64	6.35	5.48	4.71	3.97	3.39	2.75	2.29
b7_SB	1.79	1.52	1.44	1.55	1.70	2.04	2.72	3.55	4.00	4.60	5.34	5.68	6.07	6.60	6.98	6.97	6.80	6.36	5.17	4.61	4.22	3.96	3.58	2.74
s1_EB	0.82	0.45	0.35	0.36	0.50	1.21	3.67	6.95	7.61	5.66	4.68	5.03	5.30	5.37	5.81	7.15	8.91	8.61	7.06	4.64	3.40	2.85	2.14	1.45
s1_WB	1.00	0.63	0.56	0.66	1.07	2.56	5.22	7.29	7.26	6.33	5.34	5.36	5.50	5.51	5.41	5.60	6.24	7.00	5.67	4.24	3.56	3.34	2.76	1.89
s2_EB	0.84	0.49	0.39	0.43	0.72	1.54	3.71	7.22	8.04	6.06	5.11	5.31	5.52	5.61	5.91	6.71	7.66	7.75	6.18	4.56	3.60	2.98	2.15	1.49
s2_WB	0.81	0.44	0.33	0.34	0.56	1.33	3.74	6.99	7.48	6.05	5.23	5.28	5.54	5.70	5.97	6.47	7.81	8.50	6.85	4.47	3.40	2.91	2.30	1.50

ID_bound \ Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
s3_EB	0.89	0.40	0.27	0.23	0.32	0.72	2.17	4.45	5.19	4.05	3.77	4.23	4.81	5.09	5.93	7.91	11.72	11.94	9.20	5.54	4.02	3.28	2.31	1.57
s3_WB	0.36	0.22	0.21	0.45	0.88	2.46	6.93	12.70	12.27	7.53	5.02	4.82	4.74	4.69	4.60	4.91	5.47	6.56	5.21	3.24	2.45	2.00	1.40	0.87
s4_EB	0.81	0.44	0.34	0.31	0.38	0.97	3.18	5.69	5.65	4.70	4.53	4.94	5.51	5.75	6.40	7.69	9.45	9.93	7.01	4.85	3.92	3.46	2.48	1.63
s4_WB	0.58	0.35	0.32	0.40	0.67	1.96	6.10	9.92	9.12	6.67	5.42	5.34	5.51	5.57	5.70	6.06	6.48	6.64	5.41	3.78	2.83	2.34	1.71	1.14
s5_EB	0.51	0.28	0.18	0.21	0.31	1.14	4.35	9.08	9.21	6.83	5.46	5.50	5.72	5.73	5.75	6.10	6.89	7.72	6.38	4.17	3.10	2.55	1.71	1.10
s5_WB	0.64	0.34	0.28	0.23	0.30	0.84	2.81	6.16	6.55	4.97	4.55	5.23	5.79	6.01	6.52	7.71	8.96	9.23	6.96	4.81	3.93	3.48	2.33	1.38
s6_EB	0.92	0.54	0.44	0.46	0.66	1.49	3.30	5.10	4.82	4.52	4.63	4.90	5.25	5.60	6.34	8.15	9.79	9.74	7.41	5.02	3.78	3.16	2.36	1.64
s6_WB	0.59	0.38	0.37	0.56	1.05	3.18	9.08	10.83	8.71	6.31	5.22	4.98	5.02	5.08	5.17	5.36	5.72	6.27	5.18	3.51	2.62	2.11	1.64	1.05
s7_EB	0.95	0.56	0.40	0.41	0.63	1.45	3.87	6.88	6.52	5.26	4.74	4.87	5.17	5.41	5.95	7.34	8.59	8.77	6.97	4.78	3.57	3.03	2.27	1.62
s7_WB	0.62	0.40	0.37	0.53	0.89	2.43	7.00	9.70	7.95	5.93	4.93	4.96	5.11	5.25	5.61	6.12	7.21	7.69	5.42	3.64	2.79	2.35	1.86	1.24

Appendix B – Volume Profiles for Temporary Traffic Count Stations

Figure B-1. Temporary Stations (413~485) [https://mapsengine.google.com/map/u/0/edit?mid=z3FCbJOIh7NM.kv-kY8A67CmQ]

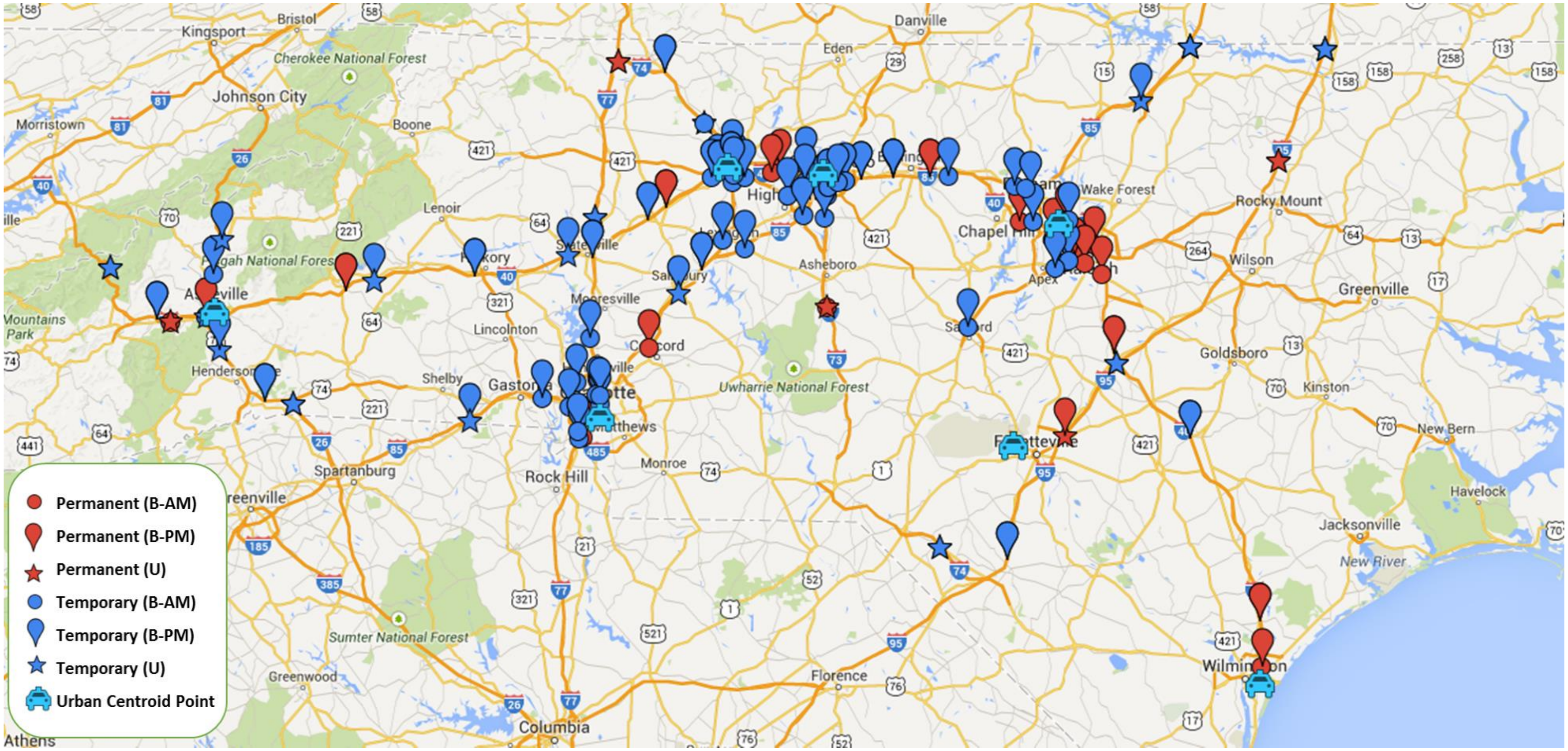

Table B-1. Temporary Station Weekday Volume Profile

(unit: %)

Header ID_bound \ Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
413_EB	0.91	0.68	0.71	0.71	1.04	2.47	4.93	8.19	7.42	6.48	5.05	5.25	4.60	5.68	6.22	6.68	7.24	8.24	5.58	3.76	2.90	2.37	1.62	1.29
413_WB	1.09	0.60	0.52	0.40	0.58	1.19	2.91	6.50	7.08	5.76	5.45	5.45	5.75	5.89	6.47	7.27	7.85	8.62	6.32	4.35	3.39	2.82	2.10	1.66
414_EB	1.15	1.02	1.10	0.97	1.37	2.17	4.12	6.34	6.24	6.25	6.56	6.20	6.14	5.79	6.41	6.24	6.70	6.86	5.42	4.16	2.83	2.35	1.99	1.63
414_WB	1.19	0.87	0.73	0.66	0.85	1.20	2.31	4.56	5.57	5.93	6.22	5.83	5.98	6.78	6.91	7.32	7.76	8.21	6.20	4.33	3.65	3.09	2.26	1.59
415_EB	1.24	0.96	0.97	0.89	1.15	1.77	3.14	4.78	5.31	5.85	6.50	6.59	6.07	6.49	6.86	7.26	7.62	6.98	5.78	4.01	3.55	2.52	2.03	1.68
415_WB	1.04	0.73	0.64	0.61	0.94	1.59	3.51	6.25	6.38	6.28	6.48	6.74	6.56	6.70	6.97	7.10	6.51	6.20	5.64	3.75	3.21	2.61	2.08	1.46
416_NB	0.64	0.32	0.19	0.29	0.53	1.44	4.90	9.89	8.74	6.75	5.28	5.60	5.57	4.76	5.05	5.97	6.89	8.88	6.76	4.11	2.94	2.10	1.39	1.00
416_SB	0.72	0.35	0.25	0.24	0.34	1.11	3.63	6.82	7.35	5.35	4.48	4.78	5.10	5.03	5.71	7.43	8.66	10.08	7.46	4.88	3.76	3.11	2.07	1.30
417_NB	0.80	0.40	0.23	0.38	0.59	1.00	2.32	7.17	7.85	4.43	3.96	4.38	4.38	4.72	5.08	6.60	8.30	13.16	8.75	5.03	3.89	3.28	2.11	1.17
417_SB	0.63	0.26	0.20	0.20	0.44	1.52	4.30	12.03	11.20	4.97	4.42	4.30	4.41	5.29	4.75	5.36	6.51	9.62	6.46	3.72	3.34	2.99	1.93	1.18
418_NB	0.97	0.79	0.67	0.69	1.09	2.19	5.72	9.98	10.02	6.36	5.22	5.10	5.19	5.09	5.52	5.52	6.06	6.27	5.24	3.60	2.89	2.47	2.00	1.36
418_SB	0.99	0.63	0.51	0.56	0.69	1.26	2.57	4.22	4.76	4.45	4.58	4.98	5.43	5.59	6.25	7.48	10.17	11.74	7.42	4.61	3.79	3.15	2.50	1.69
419_NB	1.39	1.13	1.00	1.00	1.18	1.78	3.06	4.58	5.14	5.54	6.16	6.25	6.53	6.62	6.86	7.04	6.91	6.92	5.83	4.54	3.17	3.14	2.47	1.77
419_SB	1.43	1.11	1.04	1.05	1.26	2.01	3.50	4.25	4.91	5.26	5.89	6.11	6.34	6.62	6.81	7.05	7.01	6.95	5.45	4.25	3.52	3.33	2.72	2.13
420_EB	0.75	0.50	0.38	0.38	0.69	1.41	3.61	7.28	8.41	5.98	4.94	5.05	5.33	5.82	5.82	6.75	7.61	7.57	6.33	4.56	3.71	3.31	2.34	1.48
420_WB	0.95	0.45	0.31	0.30	0.44	1.13	3.49	6.45	7.14	6.55	5.45	5.66	5.93	5.69	5.58	6.11	7.69	8.59	7.30	4.62	3.51	2.95	2.18	1.54

Header ID_bound \ Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
421_EB	0.96	0.54	0.37	0.38	0.55	1.25	3.61	6.57	6.59	5.15	4.48	4.84	5.10	5.31	5.79	7.31	8.89	8.93	7.51	4.97	3.78	3.23	2.32	1.55
421_WB	0.66	0.41	0.31	0.46	0.80	2.25	6.61	9.52	8.68	6.33	5.05	4.98	5.28	5.25	5.43	5.91	7.01	7.34	5.58	3.66	2.79	2.47	1.94	1.26
422_NB	0.93	0.69	0.54	0.56	0.78	1.50	3.34	5.42	5.40	4.74	4.53	5.04	5.31	5.79	6.26	7.01	8.69	9.60	6.95	4.99	4.23	3.51	2.50	1.70
422_SB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
423_NB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
423_SB	1.03	0.65	0.59	0.61	0.87	1.58	4.65	7.81	7.67	5.80	5.31	5.31	5.51	5.46	5.83	6.31	7.07	7.24	5.80	4.30	3.63	2.83	2.34	1.78
424_EB	1.17	0.85	0.78	0.73	0.93	1.80	3.82	6.00	6.69	5.86	5.34	5.46	5.55	5.62	6.04	6.73	7.42	8.33	6.30	4.36	3.59	2.76	2.20	1.69
424_WB	1.40	0.94	0.78	0.82	1.10	2.61	2.79	4.34	6.12	5.41	5.47	5.45	5.75	6.12	6.23	6.77	7.31	7.50	6.87	5.05	3.85	3.04	2.43	1.88
425_NB	0.97	0.76	0.68	0.73	1.07	2.27	5.75	8.73	7.29	5.63	5.17	5.06	5.30	5.45	5.86	6.15	6.50	6.90	5.62	4.08	3.58	2.79	2.08	1.57
425_SB	1.37	0.75	0.53	0.54	0.73	1.33	2.92	5.21	5.34	5.09	5.09	5.43	5.56	5.65	5.83	7.38	8.98	9.91	7.11	4.69	3.64	2.82	2.33	1.75
426_NB	1.38	1.07	0.97	0.99	1.35	2.86	4.63	7.08	6.21	5.67	5.61	5.48	5.40	5.69	6.05	6.47	6.22	6.47	5.13	4.55	3.51	2.37	2.90	1.94
426_SB	1.29	0.96	0.78	0.78	0.92	1.56	3.13	4.79	5.09	4.92	5.22	5.51	5.68	6.00	6.94	7.43	8.06	8.07	6.75	5.26	3.80	3.00	2.27	1.81
427_NB	1.04	0.73	0.65	0.70	0.98	1.84	3.74	6.13	5.85	5.10	4.89	5.02	5.13	5.24	5.77	6.77	8.32	10.38	6.60	4.57	3.75	2.89	2.16	1.72
427_SB	0.88	0.65	0.51	0.51	0.81	1.96	4.58	9.26	7.93	5.39	5.01	5.05	4.94	5.28	5.81	6.12	7.33	7.71	6.76	4.71	3.16	2.44	1.87	1.31
428_NB	0.56	0.31	0.27	0.32	0.55	1.67	5.24	12.94	11.41	6.80	5.25	5.12	4.94	4.93	5.25	5.48	5.79	6.71	5.88	4.00	2.46	1.75	1.36	1.05
428_SB	0.74	0.39	0.34	0.37	0.46	0.75	2.15	3.97	4.53	3.93	4.19	4.81	4.92	5.73	6.56	7.59	9.28	13.07	7.76	5.52	4.85	3.74	2.38	1.98
429_NB	0.55	0.36	0.37	0.40	0.83	2.86	7.26	8.52	6.16	4.95	5.01	5.31	5.58	6.03	6.49	6.95	7.08	8.11	5.75	3.64	2.77	2.13	1.67	1.22
429_SB	0.71	0.39	0.38	0.37	0.58	1.43	3.35	7.04	6.88	5.34	5.46	5.44	5.52	5.58	6.21	7.77	8.38	9.05	6.48	4.56	3.28	2.40	2.05	1.37
430_NB	1.32	0.65	0.49	0.52	1.02	2.90	6.93	9.40	7.02	5.50	5.15	5.14	5.06	5.28	5.47	5.95	6.83	7.34	5.13	3.60	2.94	2.57	2.00	1.80
430_SB	0.83	0.56	0.55	0.60	0.94	2.57	4.57	6.43	6.33	5.27	5.04	4.93	5.19	5.18	5.79	7.47	8.71	9.84	6.59	3.95	2.94	2.33	1.80	1.61
431_NB	0.56	0.41	0.33	0.52	1.00	2.49	5.89	11.79	9.73	5.52	4.59	4.59	4.66	4.82	5.38	5.68	6.60	8.54	5.90	3.70	2.65	2.08	1.57	1.00
431_SB	0.79	0.55	0.49	0.49	0.74	1.55	3.34	6.81	6.69	4.96	4.58	4.59	4.58	4.89	5.51	7.36	9.35	12.49	6.93	4.25	3.28	2.60	1.70	1.48
432_NB	1.24	0.65	0.48	0.54	0.63	0.94	1.98	4.32	4.44	4.51	4.98	5.23	5.79	5.85	6.29	8.12	10.17	10.94	7.39	4.74	3.93	2.94	2.13	1.75

Header ID_bound \ Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
432_SB	0.81	0.57	0.64	0.76	1.30	3.71	8.49	10.94	7.38	5.32	4.94	4.92	5.14	5.28	5.76	5.47	5.61	6.01	5.03	3.56	2.76	2.18	1.90	1.49
433_EB	0.81	0.53	0.45	0.48	0.80	1.92	4.44	6.47	5.76	4.23	4.43	4.89	5.16	5.33	6.13	7.75	8.94	9.70	6.67	4.71	3.72	2.95	2.26	1.49
433_WB	0.71	0.49	0.45	0.52	0.65	1.62	4.63	8.98	8.75	6.25	5.56	5.21	5.31	5.31	5.88	6.70	7.06	7.34	5.87	3.88	3.04	2.36	1.83	1.59
434_NB	0.88	0.48	0.43	0.51	0.89	2.76	6.99	12.85	9.43	5.63	5.04	4.81	4.86	4.80	4.95	6.12	6.14	6.72	4.83	3.20	2.34	2.09	1.80	1.47
434_SB	0.84	0.45	0.49	0.47	0.73	1.67	4.23	5.21	5.12	4.21	4.22	4.46	4.90	5.25	6.31	7.83	9.69	11.82	6.95	4.69	3.73	3.00	2.15	1.58
435_NB	0.94	0.61	0.49	0.56	0.68	1.56	3.85	7.25	6.30	4.78	4.78	5.24	5.49	5.41	6.01	7.84	8.29	8.71	6.12	4.49	3.62	2.81	2.20	1.94
435_SB	0.95	0.59	0.62	0.58	0.89	2.46	5.68	8.95	7.57	5.05	4.74	4.82	5.34	5.36	5.73	6.67	7.50	7.63	5.48	3.91	3.22	2.64	2.06	1.57
436_EB	0.42	0.28	0.23	0.21	0.46	1.79	5.12	10.79	10.96	6.83	5.23	5.29	5.93	5.90	5.77	6.17	6.41	6.52	5.58	3.58	2.72	1.79	1.24	0.78
436_WB	0.61	0.36	0.25	0.27	0.33	0.82	2.21	4.50	5.45	4.39	4.67	5.54	6.14	5.82	6.30	7.93	9.84	12.21	7.93	5.43	3.70	2.79	1.55	0.98
437_EB	0.40	0.42	0.30	0.31	0.63	1.84	5.50	11.63	9.54	6.80	5.53	5.32	5.31	5.44	5.89	5.94	6.24	6.79	5.39	3.83	2.70	2.01	1.23	0.99
437_WB	0.65	0.41	0.34	0.39	0.65	1.51	2.70	4.72	5.43	4.67	4.77	5.09	5.38	5.49	6.17	7.50	9.58	12.22	7.66	5.31	3.75	2.74	1.83	1.04
438_EB	0.69	0.41	0.37	0.37	0.65	1.82	4.61	8.10	7.12	5.05	4.72	4.92	5.19	5.58	5.99	6.81	7.70	9.75	6.15	4.43	3.71	2.81	1.76	1.30
438_WB	0.72	0.43	0.37	0.41	0.62	1.56	3.89	7.49	8.20	5.52	5.13	5.26	5.38	5.38	5.89	7.10	7.88	9.62	6.68	4.13	3.16	2.41	1.64	1.14
439_EB	0.83	0.58	0.53	0.60	1.00	2.43	5.79	8.90	8.08	5.28	5.02	5.14	5.19	5.44	5.89	6.39	6.64	8.54	5.32	3.82	3.06	2.39	1.84	1.29
439_WB	0.96	0.58	0.56	0.57	0.77	1.50	2.99	5.86	6.69	4.90	4.87	5.32	5.41	5.84	6.35	7.51	8.27	10.90	6.66	4.19	3.28	2.56	1.93	1.53
440_EB	1.39	1.10	0.96	1.47	1.76	2.69	4.63	6.70	6.59	5.93	5.22	5.24	5.00	4.83	5.15	5.98	6.42	7.17	5.92	4.47	3.81	3.36	2.41	1.79
440_WB	1.08	0.74	0.64	0.64	0.94	1.85	4.22	7.89	6.95	5.55	5.29	5.21	5.18	5.63	6.04	6.58	7.41	8.09	6.01	4.47	3.17	2.81	2.09	1.52
441_EB	0.65	0.43	0.33	0.40	0.64	1.59	4.01	7.90	6.92	5.07	4.85	5.16	5.35	5.78	6.18	6.88	7.78	9.65	6.27	4.62	3.76	2.87	1.75	1.16
441_WB	0.66	0.37	0.33	0.36	0.54	1.44	3.69	7.31	8.43	5.80	5.18	5.32	5.49	5.53	6.00	7.11	7.86	9.64	6.55	4.16	3.28	2.33	1.54	1.09
442_NB	0.63	0.29	0.36	0.46	0.93	2.53	6.84	12.42	8.77	5.65	5.12	5.25	5.18	5.14	5.48	5.97	6.41	7.36	5.35	3.46	2.34	1.76	1.32	0.99
442_SB	0.74	0.45	0.39	0.42	0.67	1.13	2.73	5.41	5.74	4.96	5.08	5.06	5.19	5.48	6.15	7.34	8.58	11.77	7.48	4.90	3.98	2.96	2.06	1.36
443_NB	1.26	0.98	0.94	0.99	1.44	2.56	4.88	6.57	6.11	6.18	5.85	5.51	5.23	5.49	6.13	6.32	6.92	7.07	5.30	4.40	3.27	2.76	2.19	1.65
443_SB	1.25	0.94	0.87	0.86	1.30	2.24	4.31	5.60	5.68	5.45	5.53	5.73	5.82	5.96	6.35	7.04	7.51	7.57	6.11	4.36	3.20	2.51	2.04	1.75

Header ID_bound \ Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
444_EB	0.71	0.40	0.35	0.30	0.43	1.24	3.63	7.37	6.85	4.86	4.65	4.95	5.91	6.26	6.70	7.44	8.30	8.22	6.21	4.83	3.69	2.90	2.23	1.57
444_WB	0.62	0.44	0.32	0.29	0.45	1.46	3.94	7.70	7.68	5.56	5.16	5.66	5.95	5.69	6.41	7.39	7.90	7.92	6.54	4.31	3.17	2.43	1.76	1.27
445_EB	0.70	0.42	0.33	0.33	0.70	1.98	4.53	9.07	7.88	4.51	4.39	4.82	4.82	5.26	5.78	6.73	7.35	9.55	6.51	4.71	3.44	2.81	2.00	1.41
445_WB	0.67	0.43	0.40	0.42	0.70	2.14	4.68	9.63	8.14	5.02	4.87	4.85	5.03	5.18	5.37	5.93	7.12	9.57	6.32	4.12	3.39	2.70	1.92	1.40
446_NB	1.04	0.68	0.65	0.77	1.08	1.94	5.02	9.16	7.74	5.14	4.89	4.93	5.49	5.40	5.97	6.47	6.62	6.93	5.45	4.31	3.41	2.70	2.40	1.81
446_SB	1.17	0.77	0.66	0.84	0.91	1.74	3.43	6.42	6.19	4.89	4.77	4.99	5.35	5.46	6.11	6.98	7.93	9.58	6.34	4.55	3.58	2.92	2.34	2.08
447_NB	1.04	0.68	0.65	0.77	1.08	1.94	5.02	9.16	7.74	5.14	4.89	4.93	5.49	5.40	5.97	6.47	6.62	6.93	5.45	4.31	3.41	2.70	2.40	1.81
447_SB	1.17	0.77	0.66	0.84	0.91	1.74	3.43	6.42	6.19	4.89	4.77	4.99	5.35	5.46	6.11	6.98	7.93	9.58	6.34	4.55	3.58	2.92	2.34	2.08
448_EB	1.06	0.77	0.72	0.84	1.17	1.89	3.96	5.42	5.35	4.78	4.80	5.06	5.62	5.88	6.67	7.47	7.56	8.72	6.48	4.54	3.89	3.25	2.44	1.65
448_WB	1.22	0.74	0.58	0.60	0.89	1.66	4.09	7.54	7.16	5.30	5.31	5.43	5.59	5.80	6.22	6.78	7.03	7.33	5.87	4.70	3.32	2.65	2.28	1.90
449_NB	1.19	0.91	0.88	0.99	1.24	2.11	4.33	5.98	5.61	5.62	5.60	5.80	5.66	5.90	6.31	6.76	7.02	7.06	5.79	4.81	3.67	2.76	2.23	1.76
449_SB	1.17	0.88	0.76	0.74	1.17	2.10	3.94	5.13	4.83	5.09	5.50	5.77	5.98	6.34	6.77	7.20	7.63	7.44	6.29	4.87	3.69	2.78	2.11	1.81
450_EB	0.55	0.40	0.35	0.36	0.67	1.25	3.85	8.15	8.49	6.62	6.74	6.62	6.31	6.65	6.74	6.69	6.72	6.75	5.41	3.54	2.64	1.97	1.55	0.99
450_WB	0.64	0.43	0.42	0.37	0.51	0.90	2.01	4.35	5.07	4.96	5.44	5.87	6.04	6.52	7.19	8.52	9.60	10.29	6.88	4.82	3.47	2.76	1.77	1.17
451_EB	0.39	0.28	0.27	0.29	0.64	2.19	5.00	10.64	7.62	6.32	6.00	6.05	6.21	6.01	6.04	7.31	6.61	6.74	5.73	3.57	2.34	1.76	1.14	0.86
451_WB	0.78	0.48	0.39	0.33	0.39	0.74	1.70	5.54	4.09	4.41	4.48	4.85	5.46	5.70	6.86	7.97	8.94	10.43	8.36	6.19	4.76	3.44	2.20	1.52
452_EB	0.66	0.50	0.48	0.55	0.93	2.43	4.81	6.65	6.43	5.26	5.57	6.03	6.01	6.16	6.65	7.52	7.51	7.87	5.97	4.09	2.87	2.31	1.64	1.13
452_WB	0.77	0.64	0.50	0.51	0.57	1.51	3.24	5.33	4.94	5.00	5.36	6.05	5.98	6.46	7.01	7.96	8.26	8.80	6.34	4.78	3.76	2.85	2.02	1.35
453_EB	0.94	0.68	0.55	0.58	0.82	1.38	2.99	5.15	5.54	5.21	5.93	6.22	6.09	6.47	7.09	7.43	7.76	8.20	6.22	4.56	3.63	2.92	2.04	1.58
453_WB	0.76	0.55	0.41	0.50	0.85	1.84	3.58	6.54	6.57	5.84	6.14	6.59	6.65	6.50	6.93	6.91	6.86	7.41	5.52	4.15	2.96	2.18	2.30	1.46
454_EB	0.79	0.57	0.54	0.59	0.95	2.07	4.28	6.77	6.46	5.52	5.31	5.88	6.14	6.23	7.07	7.32	7.54	7.72	5.97	4.19	2.96	2.32	1.69	1.12
454_WB	0.86	0.64	0.56	0.55	0.76	1.59	3.29	5.04	5.08	5.22	5.75	6.06	6.29	6.64	7.03	7.68	7.89	8.60	6.42	4.57	3.60	2.65	1.83	1.38
455_EB	0.80	0.49	0.41	0.46	0.70	1.82	4.97	9.23	8.26	5.20	4.33	4.32	4.41	4.55	5.04	6.19	8.28	10.88	7.67	4.11	2.65	2.16	1.75	1.31

Header ID_bound \ Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
455_WB	0.72	0.53	0.44	0.47	0.76	1.76	5.54	9.37	7.21	4.91	4.35	4.21	4.63	4.95	5.70	6.87	8.45	9.29	6.46	4.01	3.33	2.85	1.91	1.29
456_NB	1.30	0.67	0.58	0.56	0.73	1.55	3.68	5.85	5.80	4.40	4.26	4.50	4.93	5.24	5.93	7.06	8.52	10.70	7.21	4.85	3.98	3.32	2.51	1.89
456_SB	0.67	0.40	0.41	0.53	0.88	2.27	5.52	10.88	8.41	5.45	4.78	4.65	4.96	5.26	5.78	6.51	6.67	7.28	5.85	4.00	2.94	2.43	1.98	1.50
457_EB	1.63	1.28	1.20	1.17	1.52	2.52	3.78	4.64	4.71	5.29	5.22	5.28	5.79	6.18	6.92	7.25	7.34	6.86	5.64	4.29	3.51	3.27	2.68	2.03
457_WB	1.65	1.22	1.18	1.27	1.32	2.14	3.41	4.66	4.77	5.63	6.04	6.37	6.44	6.14	6.65	6.75	7.17	6.55	5.79	4.40	3.35	2.79	2.46	1.88
458_NB	0.79	0.54	0.49	0.53	0.87	2.17	5.41	9.23	8.22	5.60	4.91	5.00	5.15	5.39	5.90	6.96	6.97	7.77	5.80	3.69	2.78	2.26	1.93	1.64
458_SB	0.91	0.58	0.44	0.49	0.72	1.79	4.11	6.11	5.86	4.67	4.64	5.11	5.27	5.33	6.33	7.56	8.85	10.41	6.25	4.33	3.39	2.96	2.29	1.60
459_NB	0.88	0.52	0.46	0.45	0.63	1.22	3.61	7.54	7.49	5.70	5.54	5.59	5.65	5.88	6.50	6.95	7.49	7.48	6.19	4.37	3.51	2.80	2.11	1.44
459_SB	0.72	0.51	0.46	0.46	0.89	2.38	6.60	5.47	5.46	5.64	5.71	5.94	6.19	6.17	6.34	7.02	7.10	7.72	6.34	4.21	3.19	2.51	1.75	1.24
460_EB	0.93	0.66	0.58	0.66	0.93	2.06	3.93	6.14	5.78	5.65	5.53	5.80	6.04	6.07	6.85	7.06	7.90	8.28	6.28	4.14	3.08	2.48	1.87	1.30
460_WB	0.74	0.55	0.50	0.56	1.00	2.33	3.87	5.60	5.71	5.55	5.73	5.99	6.13	6.38	7.10	7.48	7.78	7.83	6.02	4.28	3.19	2.58	1.83	1.26
461_NB	0.99	0.50	0.50	0.51	0.69	1.20	2.33	6.78	6.25	5.49	5.53	5.72	6.02	5.95	6.34	7.78	8.81	8.91	6.74	4.06	3.16	2.47	1.86	1.43
461_SB	0.88	0.58	0.69	0.71	1.12	2.90	5.89	7.77	5.83	5.02	4.94	5.32	5.65	6.00	6.60	6.79	6.83	8.28	5.66	3.81	3.01	2.49	1.89	1.32
462_EB	0.75	0.63	0.55	0.59	0.81	2.09	4.03	5.67	5.22	5.48	5.77	6.26	6.55	6.70	7.31	7.69	7.76	7.50	5.91	3.81	3.06	2.33	2.09	1.42
462_WB	0.71	0.60	0.49	0.49	0.73	1.40	2.99	4.41	4.89	5.11	5.83	6.57	6.61	6.71	7.41	8.31	8.19	7.87	6.18	4.49	3.61	2.80	2.00	1.61
463_NB	1.08	0.67	0.52	0.61	0.70	1.55	3.85	7.98	7.81	5.47	4.94	4.77	4.94	5.31	6.24	6.95	7.00	7.72	6.37	4.41	3.54	3.07	2.42	2.08
463_SB	1.01	0.53	0.56	0.59	0.94	2.17	4.67	7.75	6.47	4.99	4.81	5.02	5.34	5.50	6.20	6.88	7.63	8.02	6.21	4.32	3.55	2.88	2.31	1.65
464_NB	0.72	0.38	0.44	0.45	0.80	1.87	4.46	7.49	7.02	4.75	4.19	4.11	4.37	4.57	5.36	7.09	10.46	12.26	7.44	3.80	2.74	2.27	1.62	1.35
464_SB	0.66	0.45	0.40	0.53	0.89	2.57	7.21	12.54	9.87	5.55	4.26	4.04	4.13	4.49	5.04	5.75	6.90	7.80	5.48	3.49	2.51	2.26	1.89	1.27
465_NB	0.71	0.44	0.45	0.52	0.99	2.74	7.36	11.48	8.55	5.78	5.08	5.12	5.24	5.32	5.46	5.68	5.94	6.25	5.20	3.54	2.64	2.21	1.88	1.43
465_SB	0.91	0.59	0.55	0.60	0.78	1.59	3.80	5.68	5.14	4.50	4.41	4.83	5.07	5.26	6.22	7.25	9.72	10.80	7.74	4.50	3.29	2.82	2.36	1.60
466_NB	0.63	0.40	0.40	0.48	0.83	2.17	5.56	8.79	7.77	5.18	4.32	4.64	5.00	5.00	5.53	6.33	8.28	9.56	6.31	3.82	3.11	2.66	1.95	1.27
466_SB	0.75	0.42	0.41	0.45	0.76	1.92	5.34	9.21	7.92	5.71	4.85	5.02	5.17	5.39	5.71	6.62	7.73	7.53	5.95	4.13	3.00	2.50	2.03	1.48

Header ID_bound \ Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
467_NB	1.05	0.67	0.60	0.53	0.68	1.56	3.87	5.44	5.08	4.82	4.73	5.08	5.29	5.53	6.15	7.12	8.64	9.23	7.11	5.13	3.93	3.29	2.55	1.93
467_SB	0.75	0.54	0.49	0.54	0.89	2.16	6.37	9.49	8.96	6.62	5.58	5.33	5.27	5.46	5.60	5.66	5.78	6.19	5.62	3.97	2.85	2.54	2.05	1.30
468_NB	1.28	1.03	1.01	1.13	1.51	2.55	5.29	9.38	8.18	6.35	5.65	5.32	4.81	4.92	5.17	5.75	6.05	6.61	4.81	4.04	3.00	2.40	2.09	1.67
468_SB	1.30	1.00	0.79	0.93	1.11	1.82	3.09	4.78	4.87	4.70	4.98	5.33	5.28	5.61	6.31	7.22	8.36	10.54	6.79	4.42	3.80	2.90	2.28	1.77
469_NB	1.42	1.32	1.23	1.18	1.76	2.77	3.24	3.98	4.68	5.32	5.93	5.71	6.72	6.63	7.00	6.74	6.87	6.42	5.35	4.47	3.86	2.90	2.58	1.92
469_SB	1.60	1.42	1.10	1.16	1.34	1.91	2.73	4.02	4.74	5.36	5.95	6.08	6.43	6.94	7.22	7.16	7.30	6.41	5.08	3.73	3.80	3.21	2.86	2.45
470_EB	0.80	0.71	0.85	0.84	1.21	2.00	3.26	5.20	5.20	5.24	6.00	6.35	6.56	6.72	6.84	7.67	7.79	7.44	5.89	4.29	3.41	2.31	1.69	1.73
470_WB	0.60	0.56	0.59	0.70	1.22	2.06	4.08	5.33	5.39	6.07	6.48	7.00	6.71	7.06	7.86	7.63	7.05	7.02	5.04	3.46	2.51	2.36	2.08	1.14
471_NB	1.20	0.88	0.81	0.92	1.26	2.15	3.37	5.51	5.44	5.11	5.76	5.91	6.18	6.28	6.49	7.22	7.40	7.80	5.85	4.43	3.59	2.81	2.00	1.61
471_SB	1.18	0.93	0.88	0.93	1.16	1.58	2.99	5.22	5.80	5.72	5.91	6.17	6.39	6.62	7.10	7.27	7.32	7.09	5.53	4.21	3.44	2.68	2.06	1.82
472_EB	1.05	0.95	0.48	0.42	0.77	1.52	3.17	5.02	5.78	5.63	6.02	5.76	5.61	6.13	7.05	7.63	8.08	7.75	5.65	5.48	3.89	2.72	1.94	1.49
472_WB	0.50	0.52	0.41	0.60	0.85	1.86	3.11	4.59	5.39	6.32	6.10	6.51	6.48	6.50	7.74	8.10	8.23	7.97	6.39	4.36	3.02	1.97	1.33	1.16
473_NB	1.61	1.06	0.92	0.96	1.12	1.50	2.41	4.58	4.29	4.58	5.06	5.61	6.08	6.44	6.77	8.11	8.26	8.34	6.22	4.80	3.74	3.17	2.33	2.04
473_SB	1.12	0.95	0.88	0.99	1.36	2.70	4.45	6.75	6.56	5.57	5.35	5.58	5.74	6.01	6.78	7.09	6.79	6.49	5.13	3.58	3.07	2.62	2.45	2.00
474_NB	1.65	1.42	1.31	1.39	1.78	2.23	3.27	4.06	4.68	5.05	5.75	6.07	6.15	6.55	6.48	6.90	7.24	6.47	5.75	4.61	3.38	3.06	2.56	2.20
474_SB	1.78	1.53	1.36	1.52	1.68	2.13	3.01	3.81	4.10	4.72	5.14	5.44	5.74	6.33	6.87	7.49	7.46	6.68	5.31	4.39	3.98	3.56	3.36	2.62
475_NB	1.17	0.91	0.84	0.87	1.11	1.80	2.77	4.46	4.52	5.76	6.85	6.90	6.52	6.62	6.76	6.94	6.76	7.66	5.79	4.70	3.75	2.85	2.12	1.58
475_SB	1.36	1.08	0.95	1.05	1.37	2.58	3.67	4.72	4.50	5.02	5.73	6.05	6.27	6.47	7.27	7.03	6.82	7.04	5.80	4.45	3.58	2.95	2.37	1.87
476_NB	0.99	0.66	0.64	0.65	0.91	1.71	3.67	6.96	6.21	6.11	5.88	6.00	5.72	6.10	6.18	6.73	7.00	7.48	5.87	4.60	3.56	2.72	2.24	1.41
476_SB	0.95	0.73	0.67	0.63	1.00	2.22	5.02	5.73	5.48	5.20	5.39	5.59	6.13	6.29	6.68	6.70	7.13	7.84	6.16	4.60	3.54	2.76	2.03	1.52
477_EB	0.78	0.50	0.52	0.63	0.92	1.78	3.34	5.20	5.19	6.16	6.96	7.32	7.11	6.95	7.35	7.42	7.25	7.27	5.57	3.96	2.74	2.22	1.68	1.16
477_WB	0.88	0.71	0.58	0.54	0.70	1.23	2.43	4.25	5.01	6.08	6.42	6.03	5.89	6.12	6.37	7.33	7.91	8.09	6.86	5.50	4.32	2.98	2.00	1.77
478_EB	0.87	0.73	0.66	0.63	0.92	1.56	3.02	4.40	4.92	5.91	6.99	7.64	7.28	7.19	7.22	7.43	7.38	7.24	5.66	4.07	3.04	2.30	1.64	1.30

Header ID_bound \ Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
478_WB	0.88	0.56	0.48	0.51	0.78	1.13	2.39	4.37	4.88	5.07	6.22	7.09	7.39	7.49	7.92	8.02	7.88	7.30	5.76	3.93	2.94	2.85	2.84	1.29
479_NB	0.45	0.29	0.17	0.31	0.56	1.53	4.99	9.90	8.71	6.52	5.12	5.27	5.42	5.05	5.25	6.15	7.40	8.76	7.36	3.81	2.67	1.94	1.36	1.02
479_SB	0.59	0.31	0.24	0.25	0.52	1.44	3.86	7.27	7.25	5.19	4.25	4.42	5.14	5.47	5.99	7.30	8.79	9.55	7.10	4.46	3.61	3.28	2.48	1.23
480_NB	0.99	0.75	0.69	0.80	1.29	3.10	6.77	8.24	6.64	5.24	4.97	4.89	5.17	5.44	5.99	6.44	6.58	6.75	5.43	4.03	3.18	2.73	2.32	1.58
480_SB	1.23	0.84	0.85	0.78	0.97	1.76	3.59	5.81	5.70	5.29	5.19	5.40	5.52	5.52	6.19	7.28	8.37	7.91	6.82	4.35	3.35	2.83	2.39	2.07
481_NB	1.28	0.84	0.83	0.73	0.85	1.62	3.81	6.70	6.39	5.23	4.89	4.93	5.12	5.39	5.95	6.61	7.50	7.82	6.64	4.76	3.71	3.37	2.88	2.14
481_SB	0.98	0.68	0.60	0.70	1.15	2.46	6.11	8.58	7.24	5.61	4.82	4.93	5.09	5.14	5.65	6.04	6.90	7.43	5.83	4.06	3.26	2.82	2.31	1.62
482_EB	1.64	1.27	1.27	1.46	1.70	2.02	2.11	2.86	3.86	5.56	6.81	7.43	7.13	6.87	6.69	6.69	6.78	6.59	5.60	4.62	3.66	2.83	2.50	2.05
482_WB	1.51	1.08	1.06	0.96	1.01	1.20	1.67	2.46	3.43	4.76	6.13	6.80	7.01	6.84	7.38	7.56	7.41	6.96	6.33	5.60	4.41	3.63	2.42	2.38
483_NB	0.36	0.30	0.24	0.46	1.34	3.60	7.94	10.03	7.58	5.57	5.07	4.85	5.23	5.28	5.61	6.10	7.18	8.66	5.55	2.89	2.10	1.81	1.32	0.93
483_SB	0.86	0.45	0.30	0.31	0.44	1.47	3.73	7.98	6.36	4.93	4.73	4.76	4.70	4.99	5.72	6.70	9.12	10.02	8.07	4.70	3.18	2.77	2.32	1.38
484_EB	1.10	0.82	0.76	0.86	1.03	1.84	3.96	6.39	6.54	5.53	5.28	5.33	5.49	5.50	6.01	6.89	7.23	8.40	6.31	4.53	3.58	2.87	2.20	1.55
484_WB	1.32	0.99	0.83	0.86	1.23	2.05	3.96	5.86	5.83	5.20	5.32	5.55	5.74	6.01	6.22	6.33	7.03	7.31	6.03	4.68	3.81	3.13	2.62	2.09
485_EB	0.82	0.37	0.22	0.21	0.28	0.65	2.30	4.76	5.33	4.10	3.50	3.85	4.39	4.68	5.18	7.27	11.73	13.12	10.07	6.04	3.95	3.39	2.38	1.38
485_WB	0.32	0.18	0.18	0.38	0.75	2.36	6.84	13.63	14.21	7.94	4.86	4.60	4.46	4.32	4.30	4.45	5.37	6.69	4.83	2.83	2.32	2.11	1.24	0.83