Analysis, Modeling, and Simulation (AMS) Testbed Development and Evaluation to Support Dynamic Mobility Applications (DMA) and Active Transportation and Demand Management (ATDM) Programs

Calibration Report for Dallas Testbed

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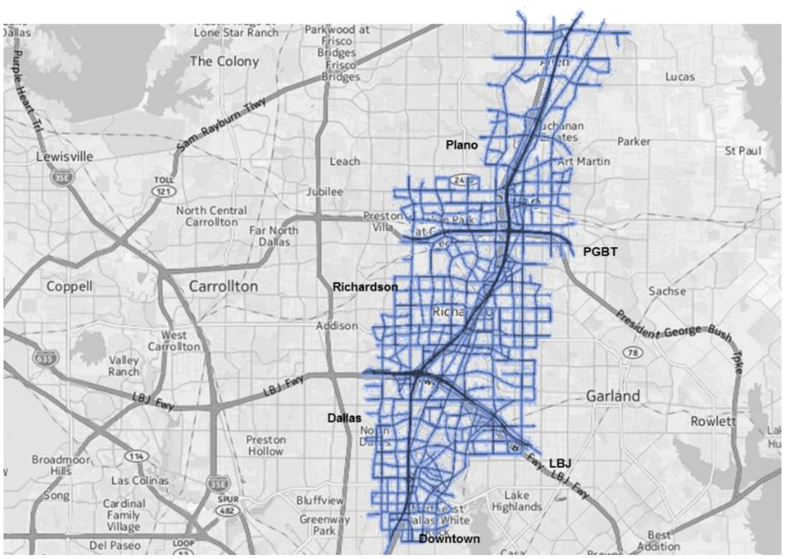

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16. Abstract

The primary objective of this project is to develop multiple simulation testbeds/transportation models to evaluate the impacts of DMA connected vehicle applications and the active and dynamic transportation management (ATDM) strategies. The outputs (modeling results) from this project will help USDOT prioritize their investment decisions for DMA and ATDM programs.

The primary purpose of this report is to document the calibration process for AMS ICM Dallas Testbed. The report discusses the field observed data used to calibrate the simulation models, calibration methodology, calibrated data and also the margins of error for the efforts for each baseline operational condition.

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Name	Organization
Alex Skabardonis	Kittelson & Associates
Brandon Nevers	Kittelson & Associates
Chung Tran	Federal Highway Administration (FHWA)
David Roden	AECOM
James Colyar	Federal Highway Administration (FHWA)
Jim Sturrock	Federal Highway Administration (FHWA)
John Halkias	Federal Highway Administration (FHWA)
Karl Wunderlich	Noblis
Matthew Juckes	Transport Simulation Systems (TSS)
Meenakshy Vasudevan	Noblis
Peiwei Wang	Noblis
Pitu Mirchandani	Arizona State University (ASU)
Ram Pendyala	Arizona State University (ASU)
Richard Dowling	Kittelson & Associates
Roemer Alfelor	Federal Highway Administration (FHWA)
Sampson Asare	Noblis
Thomas Bauer	Traffic Technology Solutions (TTS)
Xuesong Zhou	Arizona State University (ASU)

Table of Contents

List of Tables

List of Figures

Chapter 1. Introduction

The United States Department of Transportation (USDOT) initiated the Active Transportation and Demand Management (ATDM) and the Dynamic Mobility Applications (DMA) programs to achieve transformative mobility, safety, and environmental benefits through enhanced, performance-driven operational practices in surface transportation systems management. In order to explore a potential transformation in the transportation system's performance, both programs require an Analysis, Modeling, and Simulation (AMS) capability. Capable, reliable AMS Testbeds provide valuable mechanisms to address this shared need by providing a laboratory to refine and integrate research concepts in virtual computer-based simulation environments prior to field deployments.

The foundational work conducted for the DMA and ATDM programs revealed a number of technical risks associated with developing an AMS Testbed which can facilitate detailed evaluation of the DMA and ATDM concepts. Therefore, instead of selecting a single Testbed, it is desirable to identify a portfolio of AMS Testbeds and mitigate the risks posed by a single Testbed approach by conducting the analysis using more than an "optimal" number of Testbeds. At the conclusion of the AMS Testbed selection process, five (5) AMS Testbeds were selected to form a diversified portfolio to achieve rigorous DMA bundle and ATDM strategy evaluation: San Mateo (US 101), Pasadena, ICM Dallas, Phoenix, and Chicago Testbeds.

In a preceding set of deliverables, the analysis plans developed for the selected AMS Testbeds are presented. These analysis plans describe the baseline operation scenarios to be considered for each Testbed. These baseline scenarios were obtained based on a cluster analysis that is conducted to determine common operational conditions for each Testbed. A primary task of this research project is to calibrate the traffic network simulation models that are used to simulate the traffic conditions of these Testbeds to ensure that the models are capable of replicating the observed traffic patterns in the network.

The primary purpose of this report is to document the model calibration effort for the **ICM Dallas** Testbed to represent the different baseline scenarios. The ICM Dallas Testbed is developed for the US 75 Corridor in Dallas, Texas. The corridor is a major north-south radial corridor connecting downtown Dallas with many of the suburbs and cities north of Dallas. The corridor is a 20.1 mile long stretch of the US 75 freeway with continuous frontage roads and several parallel and crossing major regional arterial streets. The corridor includes a light-rail line (DART Red Line) and 10 park-and-ride lots.

This Testbed will be used to test several ATDM strategies considering a proactive network management approach that adopts simulation-based prediction capabilities. These strategies include Dynamic Shoulder Lane, Dynamic Signal Control, Dynamic Routing, Ramp Metering and Dynamic Priced Parking. The Testbed is developed using the DIRECT software (Dynamic Intermodal Routing Environment for Control and Telematics), which was developed by researchers at Southern Methodist University (SMU).

This report is organized into four chapters as follows:

- Chapter 1 – Introduction: This chapter presents the report overview and objective

- Chapter 2 – Testbed Description: This chapter presents the regional characteristics of the Testbed, the proposed operational conditions, the results of the cluster analysis and the selection of the baseline scenarios.
- Chapter 3 – Model Calibration Methodology: This chapter presents the methodology used to calibrate the DIRECT model against the operational conditions of the baseline scenarios selected for the Testbed. The methodology describes the process used to adjust the different model parameters.
- Chapter 4 – Calibration Results: This chapter summarizes the model calibration results. It provides a comparison between the operational conditions observed for each scenario and the corresponding model results.

Chapter 2. Testbed Description

2.1 Testbed Overview

The US 75 Corridor in Dallas, Texas is used as one of the AMS Testbeds. As illustrated in Figure 2-1, the US 75 Corridor is a major north-south radial corridor connecting downtown Dallas with many of the suburbs and cities north of Dallas. It contains a primary freeway, an HOV facility in the northern section, continuous frontage roads, a light-rail line, park-and-ride lots, major regional arterial streets, and significant intelligent transportation system (ITS) infrastructure. The length of the corridor is about 21 miles and its width is in the range of 4 miles. The corridor is equipped with 13 Dynamic Message Signs (DMSs) and numerous cameras that cover all critical sections of the US 75 freeway.

The US 75 corridor is a multimodal corridor where travelers can use the following mode options: a) private car; b) transit; c) park-and-ride; and d) carpooling. Pure transit and park-and-ride travelers are estimated to represent less than 2% of the traveler population. The freeway consists of four lanes per direction for most of its sections with the exception of the section at the High-Five interchange which consists of three lanes only. This lane reduction creates a major bottleneck during the morning and afternoon peak periods. Traffic incidents are also frequently observed nearby this bottleneck.

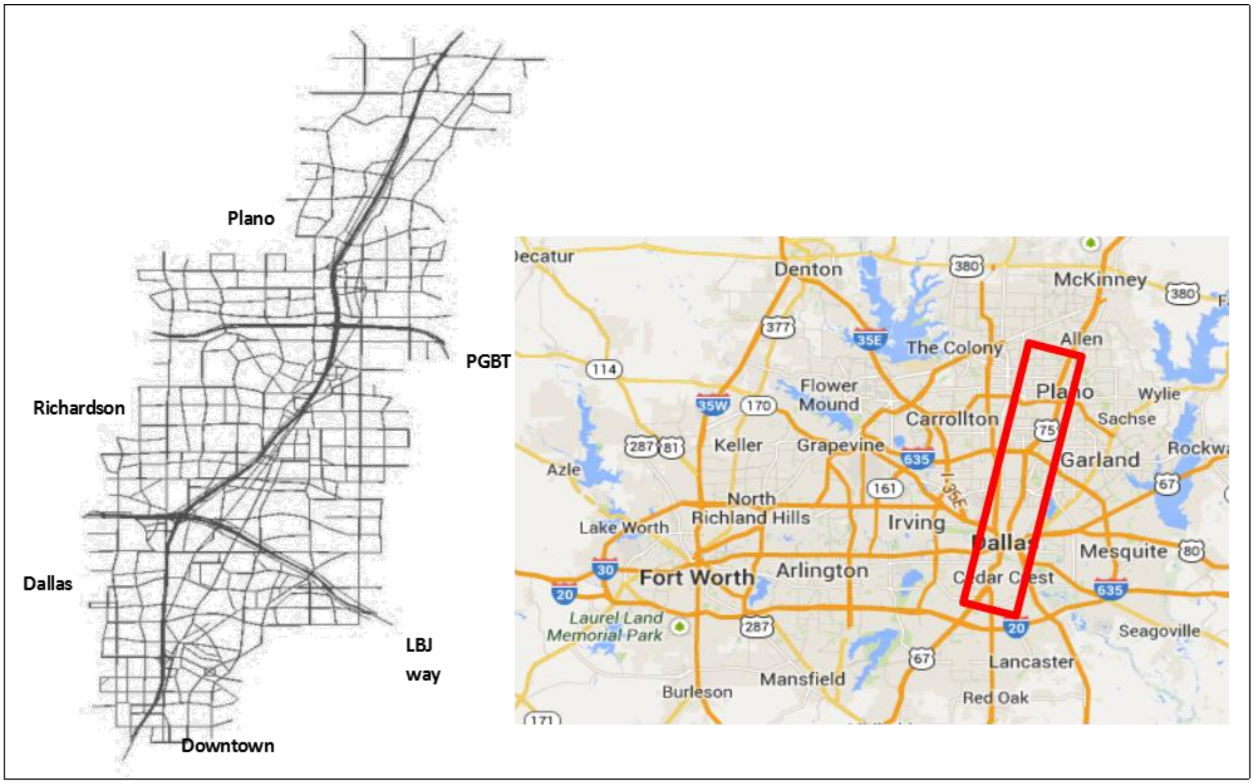


Figure 2-1: The US 75 Corridor in Dallas, Texas [Source: SMU and Google Maps]

For the US 75, the freeway incidents occur at an average frequency of about two incidents per day; resulting in severe congestion especially during the peak periods. In general, the travel time for about 50% of the peak periods is greater than the average travel time recorded during the peak period for the US 75 freeway. This pattern is observed for the northbound and southbound directions. Congestion related to adverse weather conditions has also been observed along the corridor. While such conditions are not frequently encountered, their impact on the overall operational performance of the corridor is significant as drivers are generally not used to driving in such conditions. Based on data collected in 2013, the highest level of congestion is observed along the NB direction in the afternoon peak period with an average speed of about 25 miles per hour. In the morning peak period, congestion is typically observed along the SB direction with an average speed of about 32 miles per hour. The measured daily VMT varies by no more than ±10% from the average value of all days observed. Another important observation is that the morning peak period is generally subjected to more variability in the demand level than the afternoon peak period. The VMT ratio - which is defined as the ration between the VMT recorded for a peak period and the average VMT for all peak periods in the analysis horizon - ranges from 0.2 to 1.4 in the morning peak period, and it ranges from 0.3 to 1.2 in the afternoon peak periods.

Several operation management strategies have been developed for the US 75 corridor as part of the ongoing ICM project. These strategies focus primarily on a) providing real-time multimodal traveler information that allows travelers to better plan their trips using a newly-developed regional 511 system; and b) implementing efficient traffic management schemes (response plans) to mitigate non-recurrent congestion. The real-time simulation-based prediction subsystem, DIRECT, is used to quantify the potential benefits associated with deploying a response plan as recommended by the decision support system.

2.2 Cluster Analysis Results

A cluster analysis was performed to determine the main operational conditions of the ICM Dallas Testbed. The detailed approach and results of the cluster analysis are presented in “The ICM Dallas Testbed Analysis Plan (Task 5)” document. Based on the cluster analysis conducted for the ICM Dallas Testbed, four main clusters are determined. Each cluster includes a set of peak periods with minimum variation in terms of the attributes that describes operational conditions of these days.

Table 2-1 provides a description of the main four clusters obtained based on this analysis. The Table gives the number of peak periods and the average value for each variable used in the analysis. Comparing the values of these variables against the average values for all data records, we can generally obtain some meaningful description of these four clusters. For example, comparing the VMT level of these five clusters with the average VMT value, it can be suggested that Clusters I and IV represent the medium-high demand level. Clusters II and III represent the high demand level. For the incident severity level, one can describe Cluster IV as the major incident cluster. In this cluster, the total lane closure is recorded at about 140 minutes. Clusters I and II are characterized by lower incident severity. Cluster III could be characterized as medium severity incident. No precipitation is recorded for these clusters (except one cluster with average precipitation of 1.0 mm) suggesting that they represent dry operational conditions.

Table 2-1: The Time-Varying Travel Time for the Main Four Clusters Obtained for the PM Peak Period

Variables	All	Cluster I	Cluster II	Cluster III	Cluster IV
No. Records	124	25	42	32	10
Records (%)	100%	20%	34%	26%	8%
Cluster Description		Medium to High Demand + Minor Incident + Dry	High Demand + Minor Incident + Dry	High Demand + Medium Severity Incident + Dry	Medium to High Demand + High Severity Incident + Dry
VMT (vehicle-miles)	334,175	324,504	362,694	349,158	332,891
Incident severity (minute-lanes closure)	27.0	12.6	10.2	32.2	141.6
Level of precipitation (mm)	0	0	1	0	0
Travel Time (min)	32	23	32	40	45

Based on this analysis, the following four operational scenarios are proposed to represent the main operational conditions in the evening peak period.

Baseline Scenario I: Medium-High Demand + Minor Severity Incident + Dry Conditions

Baseline Scenario II: High Demand + Minor Incident + Dry Conditions

Baseline Scenario III: High Demand + Medium Severity Incident + Dry Conditions

Baseline Scenario IV: Medium-High Demand + High Severity Incident + Dry Conditions

2.3 Identification of Baseline Scenarios

Given the results of the cluster analysis, the next step is to pick a peak period from each cluster as a representative for that cluster. The model is then calibrated to replicate the operational conditions for each of these days representing the baseline scenarios.

A good representative peak period for a cluster is recommended to be as close as possible to the center of this cluster. For each cluster, a proximity measure is calculated for each peak period in this cluster. This proximity measure is computed as the Euclidian distance between the peak period and the center of the cluster, as illustrated in Equation 1. As mentioned earlier, four main variables are used to describe the operational conditions for each peak period. These variables include the total vehicle miles traveled during the peak period, the incident severity, the travel time along the freeway and the level of precipitations.

$$D_i = \sqrt{(VMT_i - \overline{VMT})^2 + (IS_i - \overline{IS})^2 + (P_i - \overline{P})^2 + (TT_i - \overline{TT})^2} \quad (1)$$

Where,

i: Index of peak period in the cluster

D_i: The Euclidian distance between peak period i and the center of the cluster

VMT_i : The normalized vehicle miles traveled during peak period i

$\overline{VMT}$: The normalized average vehicle miles traveled for all peak periods in the cluster

IS_i : The normalized incident severity for peak period i

$\overline{IS}$: The normalized average incident severity for all peak periods in the cluster

P_i : The normalized level of precipitations measured for peak period i

$\overline{P}$: The normalized average level of precipitations for all peak periods in the cluster

TT_i : The normalized travel time measured during peak period i

$\overline{TT}$: The average travel time for all peak periods in the cluster

Figure 2-2 to Figure 2-5 provide a summary of the computed Euclidian distances (proximity to the center) for the peak periods in the four clusters. As shown in the figures, the Euclidian distances for the different peak periods in each cluster are sorted from the smallest (left) to the largest (right). Peak periods in each cluster are examined. A peak period is selected to represent a cluster if it satisfies the following two conditions: a) the peak period is close to the center of the cluster (i.e., small Euclidian distance), and b) the congestion pattern observed for this peak period is consistent with the average value observed in the cluster and the incident information available for this peak period. As shown in the figures, the day selected for each cluster is marked using a different color.

Table 2-2 provides a summary of the values of the attributes that are used to conduct the cluster analysis. The values are given for the center of each cluster (the average of all peak periods in the cluster), and the peak period that is selected to represent this cluster. As shown in the table, the values of the attributes of the representative peak period are close to their corresponding values of the center of the cluster.

Finally, Figure 2-6 provides a summary of the incidents reported for each selected representative peak period. The figure illustrates the location of each incident along the US 75 freeway. In addition, the start time, duration and number of closed lanes of each incident are provided.

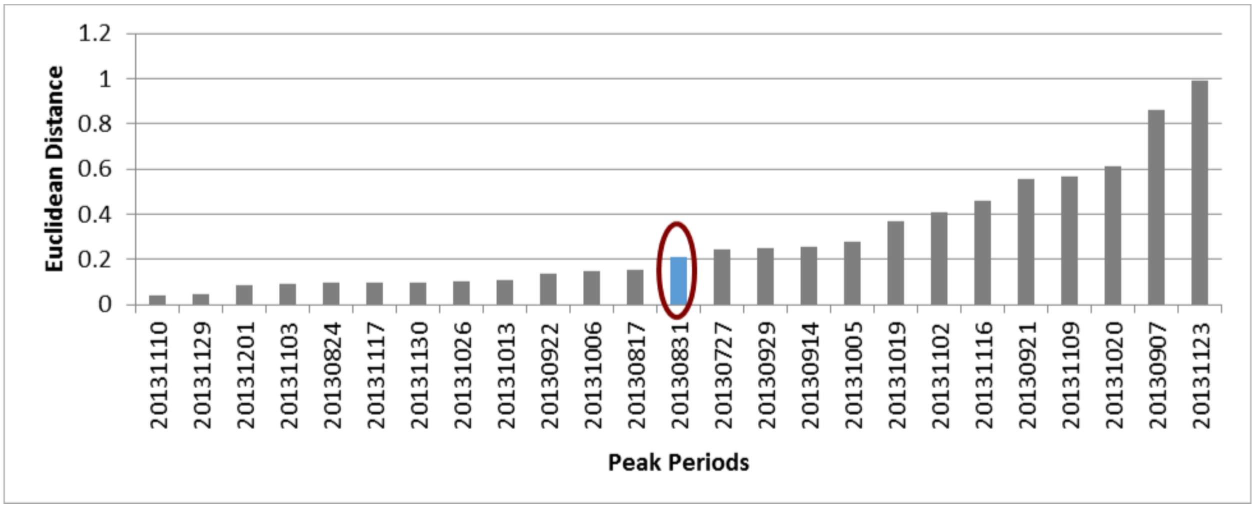


Figure 2-2: The Proximity of the Peak Periods in Cluster I to its Center [Source: SMU]

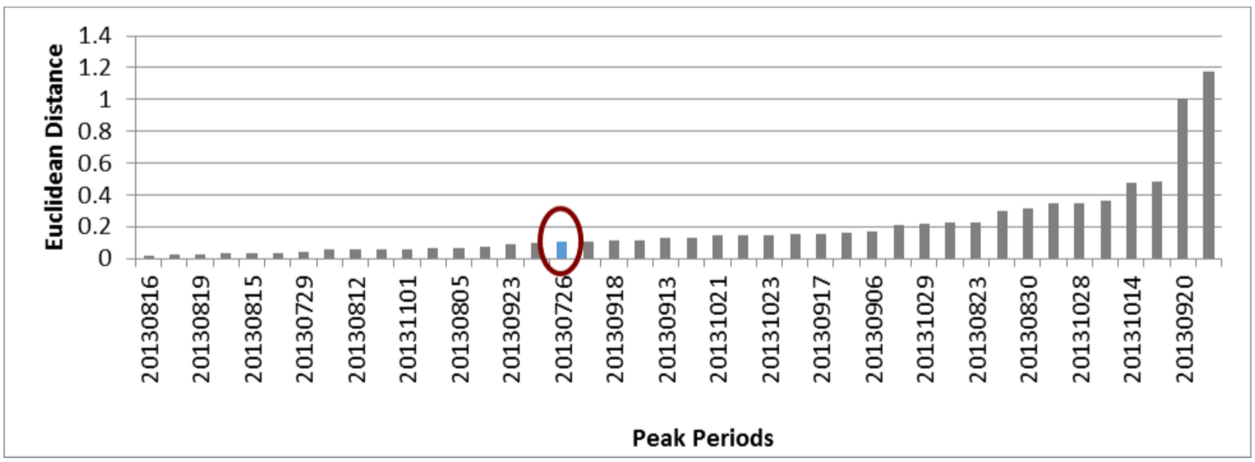


Figure 2-3: The Proximity of the Peak Periods in Cluster II to its Center [Source: SMU]

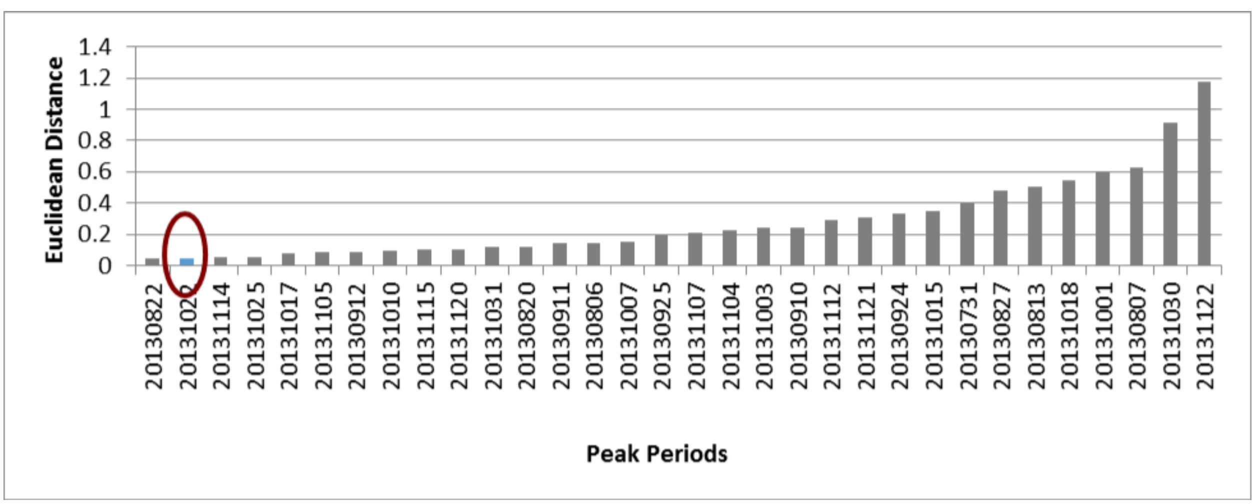


Figure 2-4: The Proximity of the Peak Periods in Cluster III to its Center [Source: SMU]

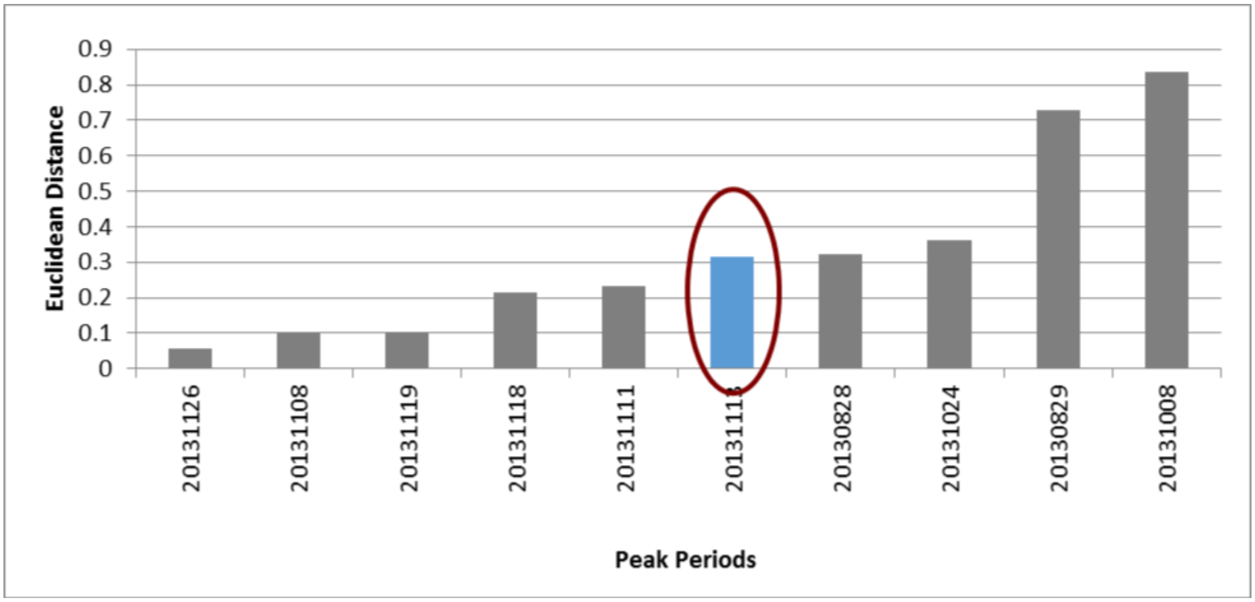


Figure 2-5: The Proximity of the Peak Periods in Cluster IV to its Center [Source: SMU]

Table 2-2: A Summary of the Operational Conditions for the Representative Peak Periods Selected for the Baseline Scenarios

Cluster	Date	Attributes	Cluster Average	Selected Day
Cluster I	08-31-2013	VMT (vehicle miles)	324,504	300,420
		Incident Severity (closed lanes minutes)	12	26
		Precipitation (mm)	0.07	0
		Avg. Travel Time (minutes)	23	22
Cluster II	07-26-2013	VMT (vehicle miles)	362,694	341,048
		Incident Severity (closed lanes minutes)	10	12
		Precipitation (mm)	0.88	0.50
		Avg. Travel Time (minutes)	32	31
Cluster III	10-22-2013	VMT (vehicle miles)	349,158	359,817
		Incident Severity (closed lanes minutes)	32	31
		Precipitation (mm)	0.11	0
		Avg. Travel Time (minutes)	40	38
Cluster IV	11-13-2013	VMT (vehicle miles)	332,891	332,645
		Incident Severity (closed lanes minutes)	142	136
		Precipitation (mm)	0	0
		Avg. Travel Time (minutes)	45	43

a) The incidents reported for Baseline I
Day: 08-31-2013

b) The incidents reported for Baseline II
Day: 07-26-2013

c) The incidents reported for Baseline III
Day: 10-22-2013

d) The incidents reported for Baseline IV
Day: 11-13-2013

Figure 2-6: Incidents Reported for Each Representative Peak Period [Source: SMU]

Chapter 3. Model Calibration Methodology

This chapter describes the methodology used to calibrate the model against the selected baseline scenarios identified through the cluster analysis.

This chapter describes the calibration methodology and illustrates how the different model parameters are adjusted such that the observed traffic pattern and associated congestion phenomena are replicated.

3.1 An Overview of the Calibration Methodology

This section provides an overview of the model calibration methodology which can be summarized using the following main steps:

1) Identify a representative peak period for each cluster of operational conditions. A good representative peak period should be as close as possible to the core of the cluster (i.e., minimum deviation from the center of the cluster).
2) Obtain the real-world observations for each representative peak period. These real-world observations include:
    a. The hourly volumes for all US 75 freeway detectors
    b. The speed profile for all US 75 freeway detectors
    c. The time-varying travel time for both directions of the US 75 freeway
    d. d) Available vehicle counts along arterial links. It is worth mentioning that this arterial data is based on one day sample that is collected as part of the ICM system evaluation task. In other words, they do not represent the traffic pattern for the different baseline scenarios considered in this study. For instance, if a baseline scenario includes an incident, the traffic is expected to divert to some of these arterials. As such, these counts would no longer represent the pattern that the model should replicate. However, based on our previous model calibration effort for during the Dallas ICM effort, the model shown to reasonably replicate the vehicle counts observed along the arterials during an average day of non-recurrent congestion.
    e. The location, number of closed lanes and duration of each incident reported on that day within the study area
3) An iterative procedure is used to calibrate the model against each baseline day. Following this procedure, the model parameters are iteratively adjusted till model is able to replicate the observed traffic pattern at a satisfactory level.
4) For the purpose of this study, two model parameter sets are simultaneously adjusted. These parameters include the time-dependent OD demand table and the parameters of the flow propagation models for the different highway links. The objective of adjusting the OD demand table is to ensure that the model reasonably replicates the observed vehicle counts at the different locations and the associated congestion pattern. The parameters of the flow propagation models (i.e., parameters of the Greenshield's model that is used model the vehicle movements on the links) are adjusted such that the model captures the flow and speed patterns along the different highway facilities.

5) Based on the obtained demand table, travelers are loaded into the network to obtain a traveler-path file that represents the travelers' historical route choice behavior. In this simulation run, the traffic is moved using the calibrated propagation models for the different links. The travel-path file lists all travelers in terms of their trip start time, origin, destination and route.
6) For baseline days with incidents, an incident input file is created to replicate the incidents reported on those baseline days. The incident file describes the different incidents to be simulated within the simulation horizon including the link on which the incident occurred, number of closed lanes, start time and end time.
7) Given the traveler-path and the incident input files, another simulation run is performed to emulate the travelers' response (e.g., route diversion) to the non-recurrent congestion resulting from the incident.
8) Based on this simulation run, the estimated vehicle counts, speed profiles and travel times are extracted from the model and compared to their corresponding observed ones.
9) If the calibration results are satisfying, the procedure is stopped. Otherwise, steps (4) to (8) are repeated with further parameter adjustments based on the results obtained in the current iterations.

3.2 Time Dependent Origin-Destination Demand Adjustment

The time-dependent OD demand adjustment process for the different baseline scenarios involves the use of a combination of a) an optimization-based demand estimation methodology and b) manual adjustment to the demand. The objective is to obtain a time-dependent OD demand pattern that replicates the observed congestion pattern in the network. The optimization-based methodology is used to prepare a base demand pattern that represents the so-called average day of operations along the corridor network. The manual adjustment process is used to tweak this base demand to replicate the demand pattern that corresponds to the observed congestion pattern along the different baseline peak periods.

The optimization-based methodology is applied as part of the ICM project. The input to this methodology is the average traffic volume on the different links in the network considering a long horizon (multiple months). The output is a time-dependent demand matrix that could be a starting point for further adjustments to represent the operations conditions of the different baseline scenarios. In this study, the corridor network is divided into 100 demand zones with a departure time interval equal to one hour. Considering a peak period from 4:00 pm to 7:00 pm, a simulation horizon of six hours is considered. The horizon includes shoulder intervals of two hours before the peak period and one hour after the peak period. Thus the simulation horizon extends from 2:00 pm to 8:00 pm.

The optimization-based demand estimation methodology used to prepare the base demand pattern is developed by researchers at Southern Methodist University. It determines the time-dependent OD demand pattern that minimizes the difference between the estimated and observed link flows. As such, the methodology tends to provide good demand estimation results only when the network is not congested. As the network got congested, flow breakdowns is expected to occur which affects the algorithm's ability to estimate the correct demand pattern. Thus, for the purpose of this study, the optimization-based methodology is used to obtain the overall demand pattern in the network and the manual adjustment procedure is considered to improve the results of the optimization-based methodology. It is worth mentioning that the process involves several demand iterations that involves the demand estimation and the assignment until an acceptable pattern that replicates the observed traffic flows is obtained.

The demand estimation methodology used in this study takes advantage of the structure of the conventional least-square error minimization formulation of the OD demand estimation problem. It adopts a separable programming approach to derive an approximate linear formulation of the problem, which can be efficiently solved.

Assume the network is divided into a set of zones Z. Also, the estimation horizon R is divided into $\mathrm{R^d}$ departure intervals and $\mathrm{R^s}$ observation intervals. Traffic originates from origins $\mathrm{I} \in \mathrm{Z}$ to destinations $\mathrm{J} \in \mathrm{Z}$ during the different departure time intervals $\tau \in \mathrm{R^d}$. Define P as the demand assignment matrix such that an element $p_{ij\tau}^{at}$ in this matrix represents the portion of vehicles observed on link $a \in A$ in interval $t \in \mathrm{R^s}$ that belongs to the OD pair ij and departure interval $\tau \in \mathrm{R^d}$.

This link-flow proportion matrix is generated using the network state estimation module. The simulation-based DTA model, DIRECT, assigns the vehicle trips to routes and tracks their movements along the links of these routes till these reach their final destination. Thus, the link proportion values $p_{ij\tau}^{at} \in \mathrm{P}$ are estimated for the demand estimation horizon. The conventional formulation of the OD demand estimation problem in the form of a least-square error minimization as follows.

Minimize $$\sum_{a \in A} \sum_{t \in R^S} \left(y_{at} - \sum_{i} \sum_{j} \sum_{\tau} p_{ij\tau}^{at} . \hat{d}_{ij\tau}\right)^2 \qquad (2a)$$

Subject to: $$\hat{d}_{ij\tau} \geq 0 \qquad \forall\ i,\ j \text{ and } \tau \qquad (2b)$$

Where, y_{at} is the observed vehicle count on link a in observation interval t, and $\hat{d}_{ij\tau}$ is the estimated demand between OD pair ij in departure interval τ.

The program above consists of a quadratic objective function with linear constraints, which can be decomposed into terms such that each term includes only one variable that is represented by a convex function. Such structure of the problem allows the use of the separable programming approach to efficiently solve the problem. The idea of separable programming is to solve an approximation of the problem through providing a piecewise-linear approximation of the non-linear terms. Efficient algorithms are developed to convert the mathematical program in (1) into its equivalent linear formulation, and to retrieve the solution from this linear formulation to a time-dependent OD demand table.

Given the time-dependent OD matrix that represents the average operation conditions along the corridor. A manual adjustment is applied to replicate the congestion pattern for the different baseline scenarios. The manual demand adjustment procedure consists of several steps. These steps can be summarized as follows:

1) Perform a simulation run using the base demand pattern and record the time-varying estimated vehicle counts on all links that are equipped with detectors. The simulation run is marked as the first iteration in the process.
2) Identify *n* highway links in the network with the highest difference between the estimated and observed link flows.
3) Based on the route assignment results obtained from the preceding iteration, identify OD pairs with the highest contribution (e.g., top 10 OD pairs) to the traffic flow on each of the links identified in (2). An OD pair is contributing to the estimated flow on a link, if the vehicles traveling between this OD pair is using a path that includes this link. OD pairs could be then ordered in terms of their number of generated vehicles that use a link. This information is readily available by the model.
4) Adjust the demand of these OD pairs based on the difference between estimated and observed link flows. For instance, if the estimated vehicle count on a link is underestimated, the demand

value of OD pairs and departure time intervals that contribute to the flow on this link are increased. In this step, we try to avoid modifying OD pairs that their demand might impact the vehicle counts on other links that do not need correction. In other words, if changing the demand of an OD pair is expected to impact the estimated vehicle count for a link which perfectly matches the observed count, this OD pair is not modified to maintain this match between the estimated and observed counts.

5) As all links with estimation error are scanned, the new adjusted demand matrix is simulated and a new estimated link flows are obtained for all links.
6) Compare the estimated and observed link flows.
7) Repeat steps (2) to (6) until the difference between the estimated and observed links flows is acceptable by the analyst.

3.3 Demand Adjustment: Comparison among the Different Baselines

This section provides an example to illustrate how the demand adjustment is used to replicate the observed traffic pattern for the different baselines. As explained above, the time-dependent OD table is adjusted such that when this demand is assigned into the network, the difference between the estimated and observed hourly traffic volumes for all detectors is minimized.

In this example, an illustration on how the demand is adjusted across the different baseline scenarios to reduce the difference between the estimated and observed traffic hourly volumes for two freeway links along the NB direction of US 75 is presented in Figure 3-1. The first link is in the northern section of the corridor (north of President George Bush Turnpike (PGBT)) and the other link is located in the middle section (north of LBJ freeway and south of PGBT).

Figure 3-1: Location of Highway Links Used to Illustrate Demand Adjustment for the Different Baseline Scenarios [Source: SMU]

Table 3-1 to Table 3-4 provide a summary of how the demand adjustments impacted these two links in the different baseline scenarios. In each table, the top ten OD pairs with the highest contributions to the estimated flows on these two links during the PM peak are identified. As mentioned above, based on the path assignment results, the model records the path of each vehicle. Thus, if a vehicle belonging to an OD pair is recorded on a link that is part of the vehicle's path, the OD pair is marked as an OD pair that contributes to the flow on that link. OD pairs that contribute to the flow on a link could be ordered in terms of the value of their contribution (i.e., number of vehicles).

The tables give the IDs of these OD pairs (from-to) along with their number of generated vehicles. The table shows the top 10 OD pairs with contribution in the entire simulation horizon (six hours). In other words, there are many other OD pairs that contribute to the flow on these links but with smaller number of vehicles. For completeness, the tables also give a comparison between the estimated and observed link flows for the different hours in the PM peak period (4:00 pm to 7:00 pm). Please note that the sum of the OD contributions is not equal to the observed counts as not all OD pairs that contribute to the link flow are included in the table. Also, the count contribution from the different OD pairs is recorded for the entire simulation horizon and not for the peak period hours.

For example, Table 3-1 provides the data for these two links in the first baseline scenario (Cluster I). As shown in the table, the model estimates 953 vehicles from OD pair z219-z236 that use Link 1 as part of their trips. The second largest number of vehicles (847 vehicles) that use Link 1 as part of their paths are traveling between OD pair z161-z236. Similarly, for Link 2, 1233 vehicles that use this link are traveling between OD pair z1005-z34, and 939 vehicles use the link as part of the routes between OD pair z144-z219. Adjusting the demand for these OD pairs in the successive iterations is done such that the difference between the estimated and observed hourly volumes is minimized. The table gives the estimated and observed hourly volumes for both links as the termination of the demand adjustment process.

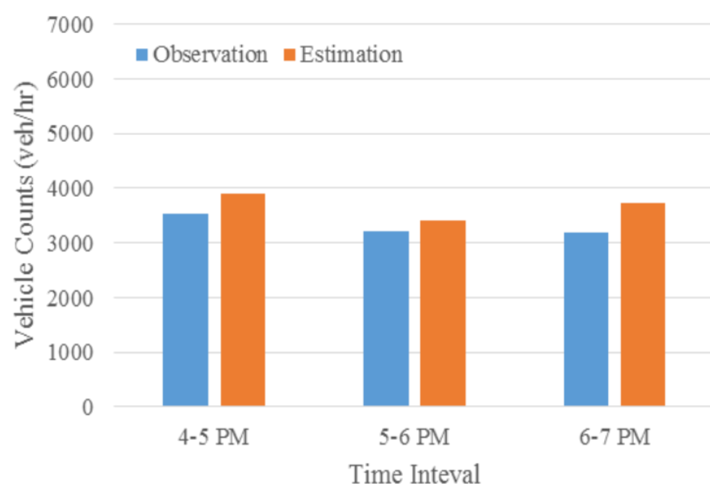
To match the hourly volumes in the different baseline scenarios, the demand for the different OD pairs that contribute to the flow on the different links is adjusted. The data in the tables below could be used to provide an illustration of how the demand is adjusted to match the vehicle counts for these two links. For instance, for Link 2, the list of top ten OD pairs is unchanged across the different baselines. However, the demand between these OD pairs is adjusted to capture the different congestion levels observed for these scenarios. For Link 1, the list of top ten OD pairs that contribute to the estimated vehicle count on that link has been changed across the different baseline scenarios with few entries/exits. Also, the demand values for OD pairs that are common among the different baselines have been modified.

Table 3-1: Demand Adjustment to Match the Observed Link Flows for Two Links in Cluster I

Cluster ID	OD Pairs with the Highest Contribution to the Estimated Link Flows during PM Peak Period	Hourly Traffic Counts Comparison
Link 1 Cluster I	See Link 1 table below	See Link 1 chart below
Link 2 Cluster I	See Link 2 table below	See Link 2 chart below

Link 1 Cluster I

Link 1	
OD Pair	No. of vehicles
z219-z236	953
z161-z236	847
z32-z236	544
z250-z236	521
z227-z166	504
z36-z236	485
z57-z236	352
z34-z236	347
z80-z169	300
z219-z162	286
SUM	**4385**



Link 2 Cluster I

Link 2	
OD Pair	No. of vehicles
z1005-z34	1233
z144-z219	939
z140-z255	743
z80-z34	511
z42-z34	506
z144-z34	476
z84-z227	382
z140-z32	377
z82-z227	350
z140-z227	341
SUM	**5858**

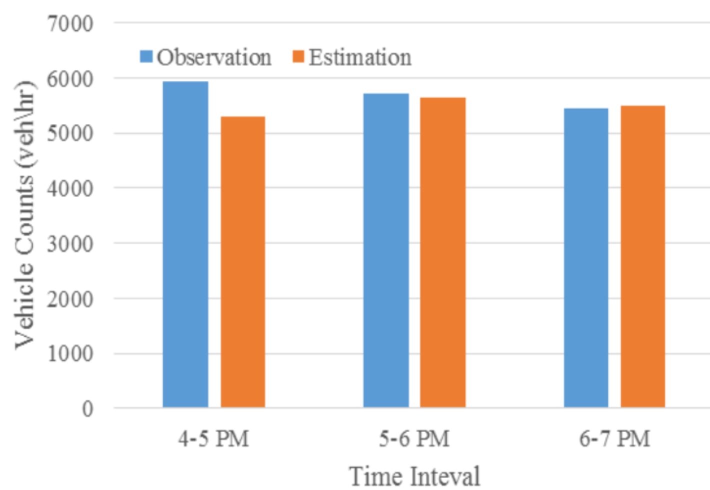
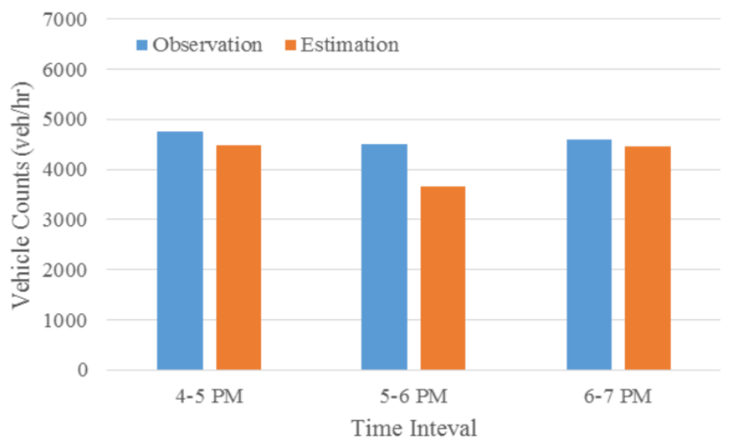


Table 3-2: Demand Adjustment to Match the Observed Link Flows for Two Links in Cluster II

Cluster ID	OD Pairs with the Highest Contribution to the Estimated Link Flows during PM Peak Period	Hourly Traffic Counts Comparison
Link 1 Cluster II	see Link 1 table below	see Link 1 chart below
Link 2 Cluster II	see Link 2 table below	see Link 2 chart below

Link 1 Cluster II

Link 1	
OD Pair	No. of vehicles
z53-z236	2336
z1003-z236	1630
z219-z236	875
z32-z236	605
z250-z236	543
z161-z236	533
z36-z236	494
z35-z168	382
z57-z236	366
z227-z166	316
SUM	**8080**



Link 2 Cluster II

Link 2	
OD Pair	No. of vehicles
z53z236	2336
z1003z236	1630
z1005z34	900
z144z219	581
z140z255	527
z140z32	457
z80z34	456
z144z255	443
z140z227	364
z84z227	357
SUM	**8051**

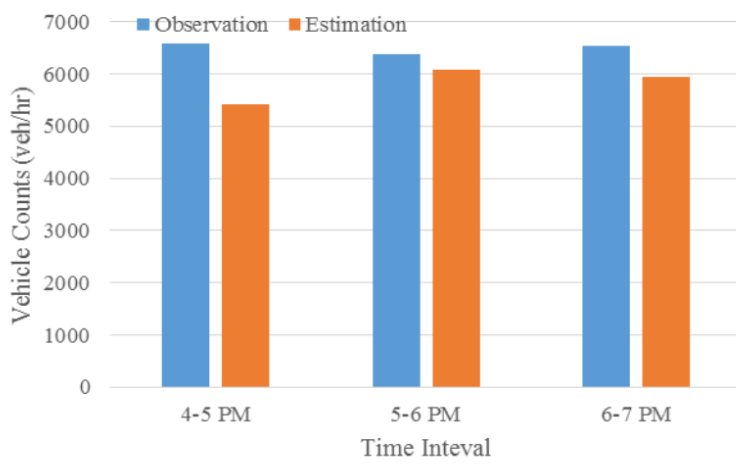
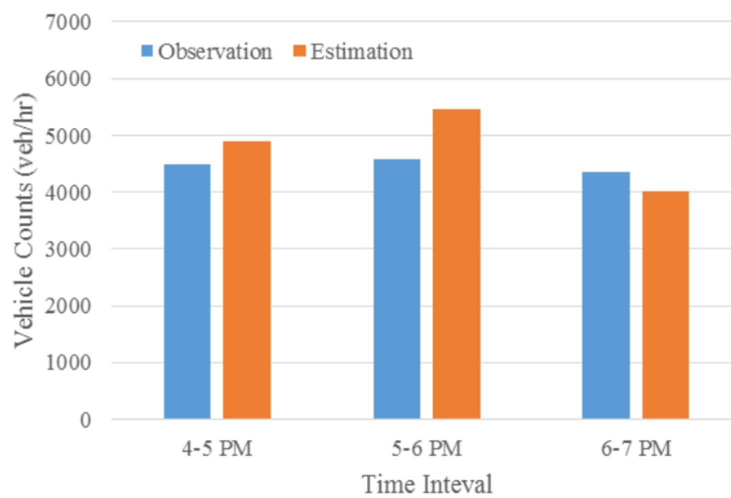
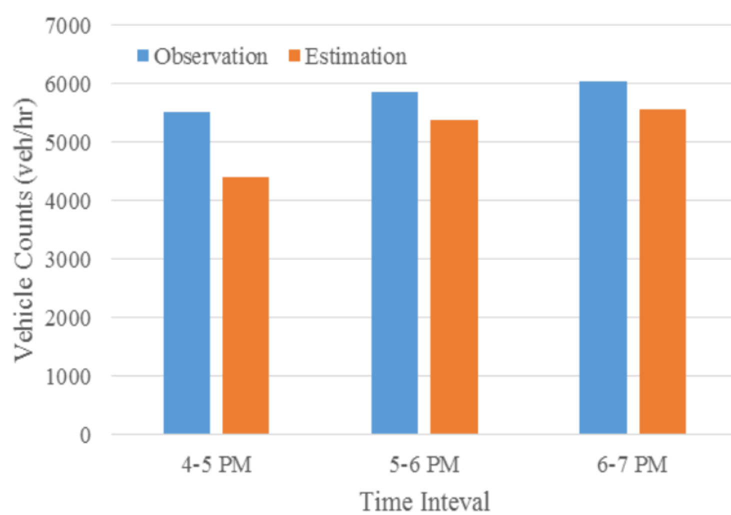


Table 3-3: Demand Adjustment to Match the Observed Link Flows for Two Links in Cluster III

<table>
<tr><th>Cluster ID</th><th>OD Pairs with the Highest Contribution to the Estimated Link Flows during PM Peak Period</th><th>Hourly Traffic Counts Comparison</th></tr>
<tr><td>Link 1
Cluster III</td><td>
<table>
<tr><th colspan="2">Link 1</th></tr>
<tr><th>OD Pair</th><th>No. of vehicles</th></tr>
<tr><td>z53-z236</td><td>1345</td></tr>
<tr><td>z35-z166</td><td>1256</td></tr>
<tr><td>z1003-z236</td><td>866</td></tr>
<tr><td>z219-z236</td><td>775</td></tr>
<tr><td>z1005-z166</td><td>630</td></tr>
<tr><td>z32-z159</td><td>605</td></tr>
<tr><td>z32-z166</td><td>603</td></tr>
<tr><td>z59-z159</td><td>544</td></tr>
<tr><td>z227-z166</td><td>535</td></tr>
<tr><td>z42-z166</td><td>531</td></tr>
<tr><td>SUM</td><td>7690</td></tr>
</table>
</td><td>


</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>Link 2
Cluster III</td><td>
<table>
<tr><th colspan="2">Link 2</th></tr>
<tr><th>OD Pair</th><th>No. of vehicles</th></tr>
<tr><td>z53z236</td><td>1345</td></tr>
<tr><td>z144z34</td><td>1231</td></tr>
<tr><td>z1003z236</td><td>866</td></tr>
<tr><td>z140z255</td><td>734</td></tr>
<tr><td>z1005z166</td><td>630</td></tr>
<tr><td>z42z166</td><td>519</td></tr>
<tr><td>z35z166</td><td>480</td></tr>
<tr><td>z84z34</td><td>449</td></tr>
<tr><td>z80z34</td><td>422</td></tr>
<tr><td>z140z32</td><td>416</td></tr>
<tr><td>SUM</td><td>7092</td></tr>
</table>
</td><td>


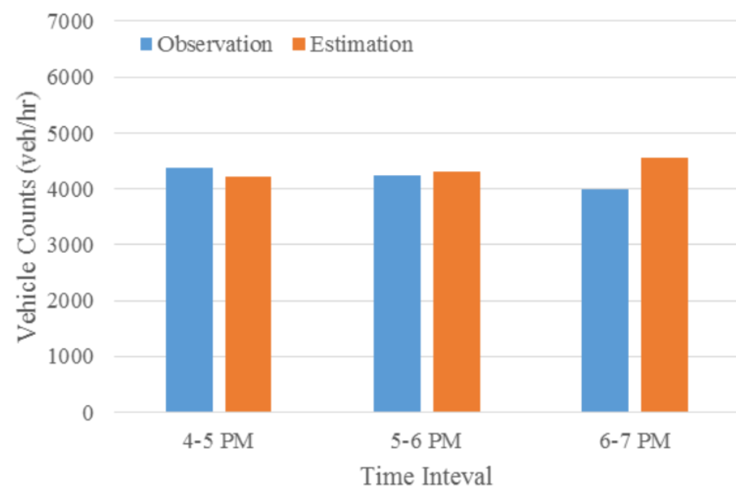
</td></tr>
</table>

Table 3-4: Demand Adjustment to Match the Observed Link Flows for Two Links in Cluster IV

Cluster ID	OD Pairs with the Highest Contribution to the Estimated Link Flows during PM Peak Period	Hourly Traffic Counts Comparison

Link 1 Cluster IV

Link 1	
OD Pair	No. of vehicles
z53z236	1558
z1003z236	1115
z219z236	911
z161z236	869
z32z236	591
z250z236	579
z227z166	503
z36z236	493
z35z236	426
z57z236	392
SUM	**7437**



Link 2 Cluster IV

Link 2	
OD Pair	No. of vehicles
z53z236	1508
z1003z236	1101
z129z34	1029
z144z219	572
z140z255	459
z144z34	450
z140z34	405
z140z32	377
z80z34	367
z140z250	308
SUM	**6576**

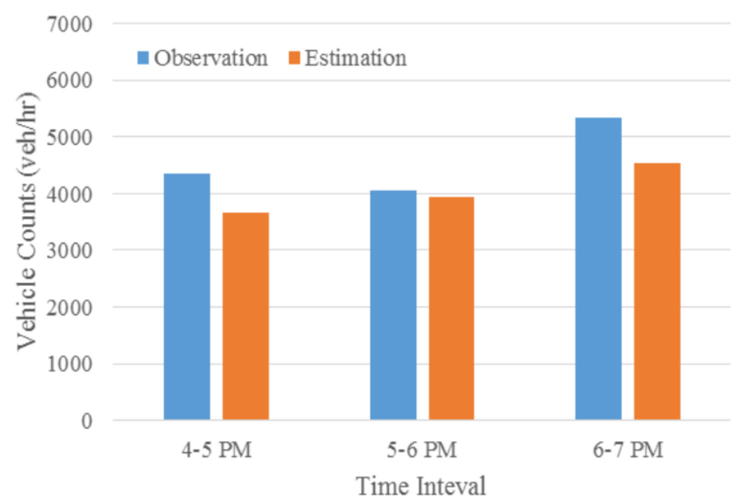


Figure 3-2 provides a summary of the demand distribution for the PM peak period for the four baselines. The demand pattern is presented in the form of an OD demand matrix between six super-zones as presented in the figure. Each super-zone includes a subset of the demand zones considered in the model. As shown in the figure, each blue dot represents the centroid of one of the original demand zones. Based on the location of the centroid, we assigned the zone to a super-zone as illustrated in the figure. The aggregated demand matrices provide an overview of how the demand pattern is modified for the different baselines to replicate their vehicle counts. They are also used to ensure that the manual demand adjustment process of the individual OD pairs does not cause a significant deformation of the overall demand pattern in the network.

Baseline Scenario I

	1	2	3	4	5	6
1	39361	22957	11236	6891	4103	2274
2	25329	31343	34859	4266	3677	2436
3	18796	34754	37447	19922	4914	4192
4	10052	4982	26773	40727	14738	7740
5	7415	4428	4379	26063	64722	9256
6	3067	2846	1886	5619	13090	15520

Baseline Scenario II

	1	2	3	4	5	6
1	41821	26195	9131	6960	4054	2314
2	23720	33302	36966	4634	4171	2690
3	16546	36926	40174	22952	5221	4454
4	11107	5293	27137	43272	15659	10120
5	7878	4705	4958	27692	68768	9834
6	3259	3024	6933	5970	13908	16490

Baseline Scenario III

	1	2	3	4	5	6
1	44065	25125	9521	11586	4359	2416
2	26990	33302	37038	5575	3907	2588
3	21671	36926	39788	21167	5221	4454
4	13110	7440	23380	43272	15552	9505
5	7878	4705	4958	27398	68211	9834
6	3620	3024	6466	8979	21387	19571

Baseline Scenario IV

	1	2	3	4	5	6
1	41821	22830	10721	15717	4359	2416
2	27726	32895	37038	4532	3907	2588
3	17166	39368	39788	21932	7242	4454
4	17005	7042	22615	43782	15659	10120
5	7878	4705	4958	27692	68768	9834
6	3259	3024	5234	5970	13908	16490

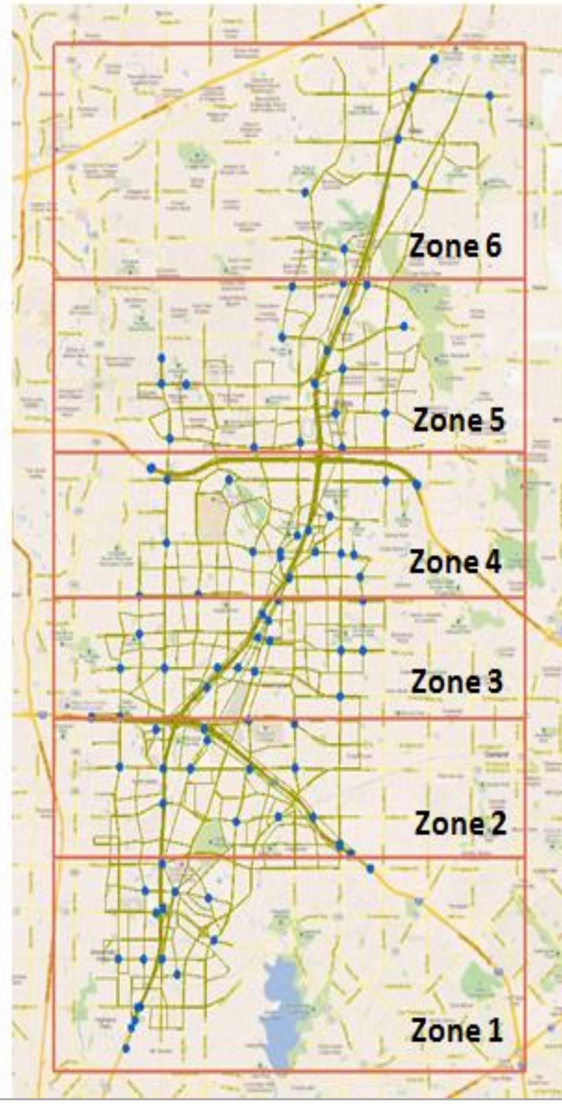


Figure 3-2: Demand Distribution in the Corridor Network for the Different Baseline Scenarios [Source: SMU]

3.4 Flow Propagation Model Adjustment

As described earlier, the DIRECT model adopts mesoscopic simulation logic to replicate the vehicle movements along the different highway links. The logic adopts the modified Greenshield's model which is implemented at the lane level. For each simulation interval, the average speed for all vehicles traveling on the lane is determined as a function of the average density of that lane. Equation (3) describes how the Greenshield's model is adopted in the DIRECT model to determine the average speed for each lane in each simulation interval.

$$v_t^{ai} = v_{max}^{a}\left[1-\left(\frac{k_t^{ai}}{k_{max}^{a}}\right)^{\propto^{a}(\tau)}\right] \qquad (3)$$

Where,

a: Index of all links

i: Index for the lanes of link l

t: Simulation interval (six seconds)

τ: Model adjustment (calibration) interval

v^{a}_{max}: The free flow speed of link a (~ speed limit)

k^{a}_{max}: The jam density of link a (200 pcu/mile/lane)

v^{ai}_{t}: The average speed of lane i on link a in simulation interval t

k^{ai}_{t}: The traffic density of lane i on link a in simulation interval t

$\propto^{a}(\tau)$: A model parameter to be estimated for each link a in each interval τ

Based on the available time-varying speed observations for the different highways links, the model allows adjusting the parameter $\propto^{a}(\tau)$ for each of these links such that the model replicates the observed time-varying speed pattern. One can think of the parameter $\propto^{a}(\tau)$ as variable that is used to represent all missing information on the link that are not represented using a mesoscopic simulation logic (e.g., geometrics (grades and curvature), intensive weaving maneuvers). To obtain the value of $\propto^{a}(\tau)$ for each link in each calibration interval, a routine is developed as part of the DIRECT model. As presented in (4), given the average observed speed during calibration interval τ, the routine computes the value of $\propto^{a}(\tau)$ such that the model produces an average speed value for the link during this interval τ that is equal to the observed value. The obtained $\propto^{a}$ is used for all lanes that are part of link a.

$$\propto^{a}(\tau) = \frac{ln\left[1 - \frac{v_{\tau}^{a\,(observed)}}{v_{max}^{a}}\right]}{ln\frac{k_{\tau}^{a}}{k_{max}^{a}}} \qquad (4)$$

Where,

$v_{t}^{a\,(observed)}$: The observed speed of link a in calibration interval τ (for all lanes)

k_{t}^{a}: The average density of link a in calibration interval τ (for all lanes)

In this calibration exercise, the link speed observations are available at five minutes resolution. Thus, we allowed the model to estimate a new value for the parameter $\propto^{a}$ every five minutes. Within each calibration interval, the value of the density k_{t}^{ai} for each lane is updated every six seconds (i.e., the length of the simulation interval) and the corresponding average speed for that lane during this six seconds interval is obtained as illustrated in Equation (3).

To provide a closer look the flow propagation model calibration across the different baseline scenarios, we present the calibration results for a link along the NB direction of US 75. As presented in Figure 3-3 to Figure 3-6, the estimated and observed time-varying speed profiles are given along with the corresponding value of the parameter ∝ for that link for all baseline scenarios. The results are presented for the entire simulation horizon (2:00 pm to 8:00 pm). As shown in these figures, the adjustment process of the flow propagation model allows achieving close match with the observed time-varying speed profile. As mentioned earlier, the flow propagation adjustment is conducted simultaneously with the demand adjustment such that the model replicates both the speed profile as well as the flow pattern for the different links. A detailed representation of the calibration results based on this methodology is presented in the next section.

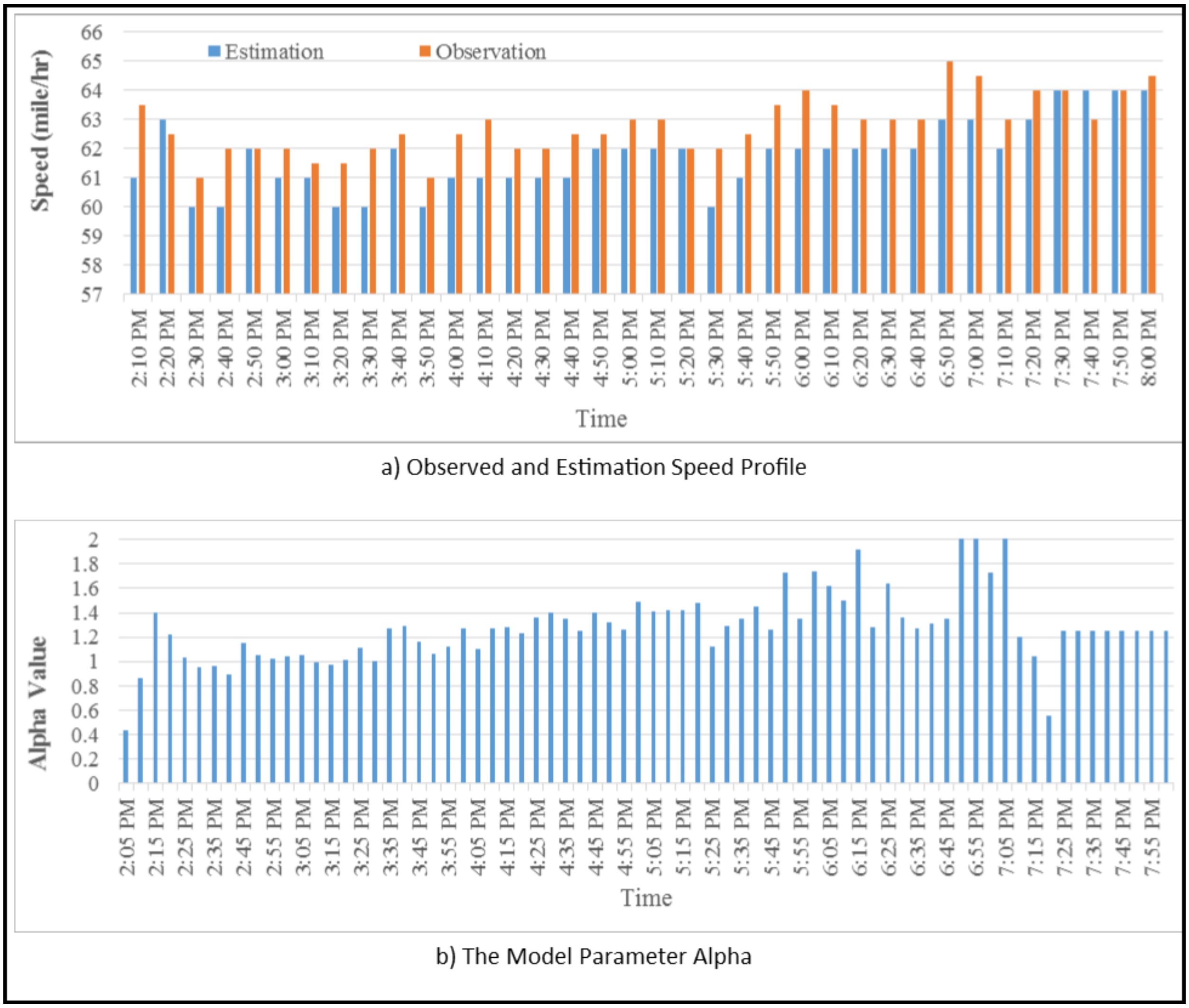
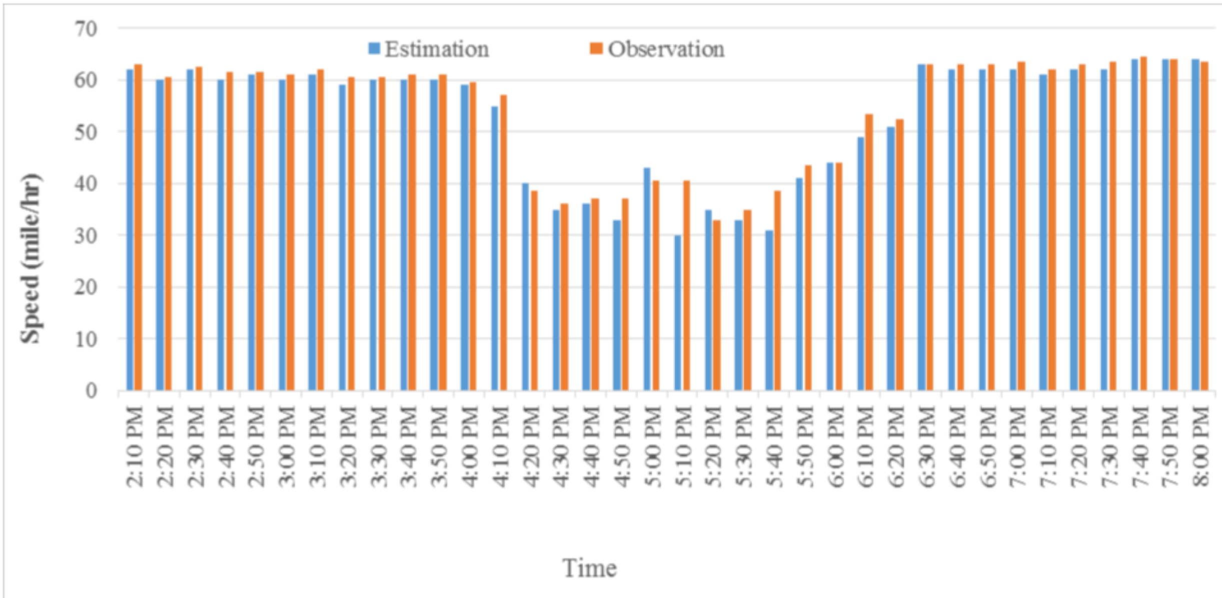
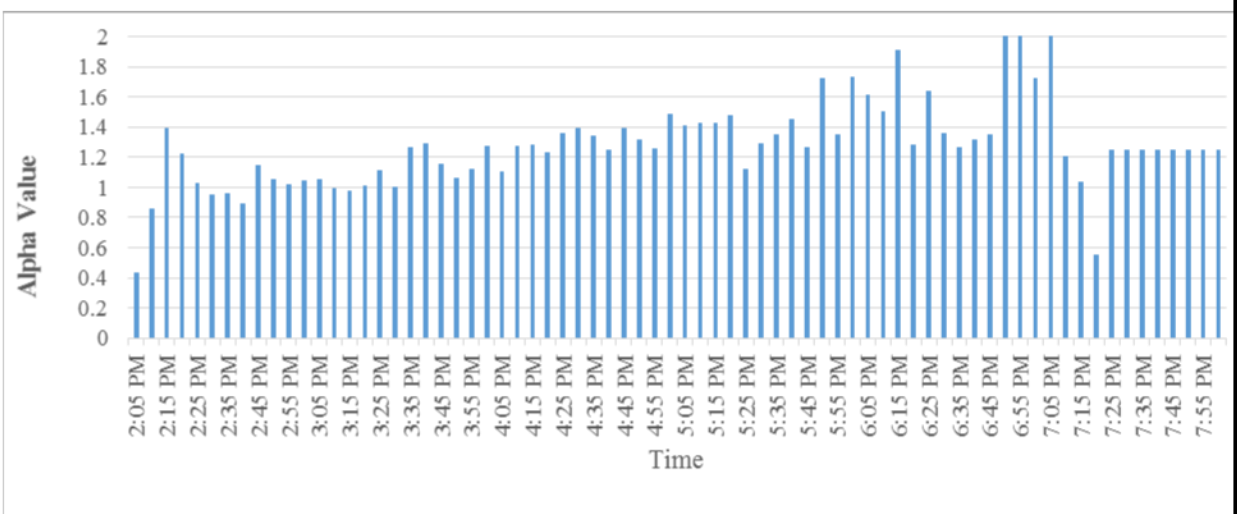


Figure 3-3: Time-Varying Speed Profile and Associated Alpha for a Freeway Link in Baseline I [Source: SMU]

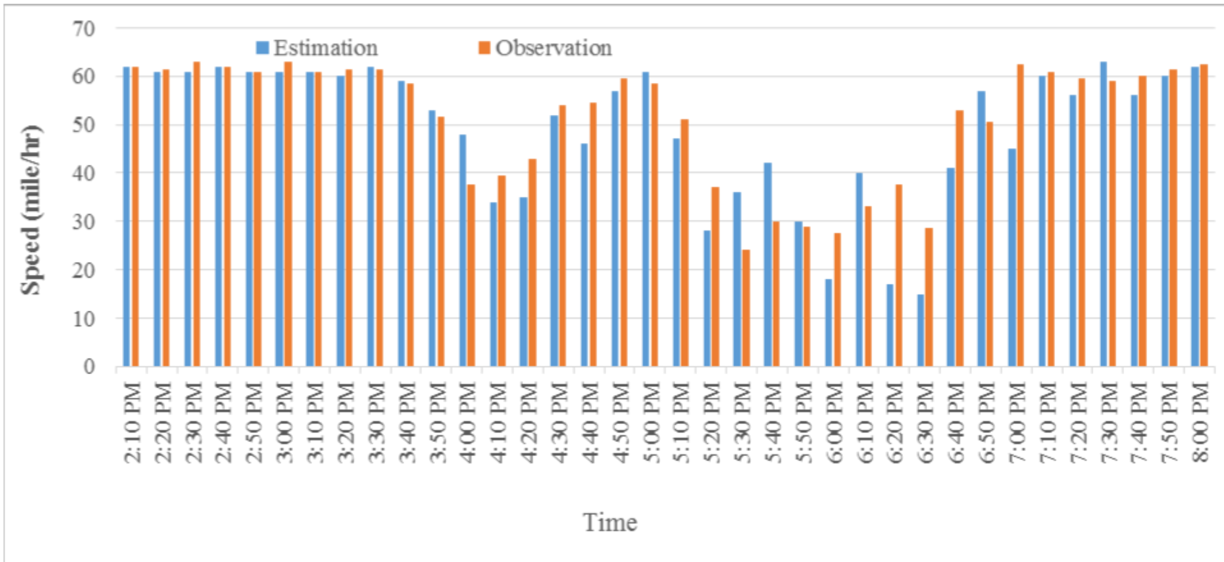


a) Observed and Estimation Speed Profile

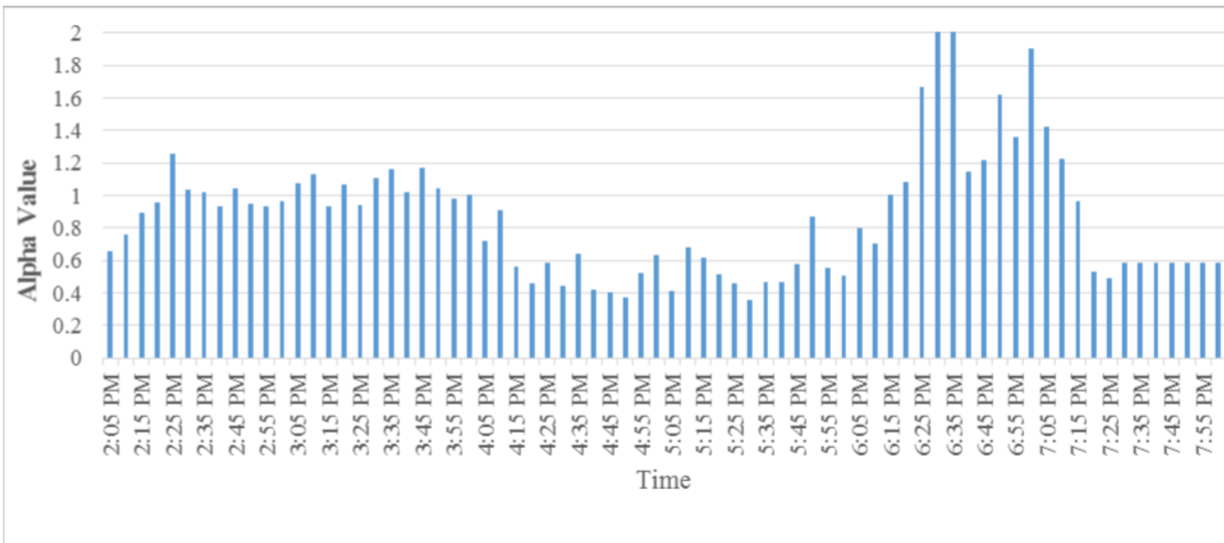


b) The Model Parameter Alpha

Figure 3-4: Time-Varying Speed Profile and Associated Alpha for a Freeway Link in Baseline II [Source: SMU]



a) Observed and Estimation Speed Profile



b) The Model Parameter Alpha

Figure 3-5: Time-Varying Speed Profile and Associated Alpha for a Freeway Link in Baseline III [Source: SMU]

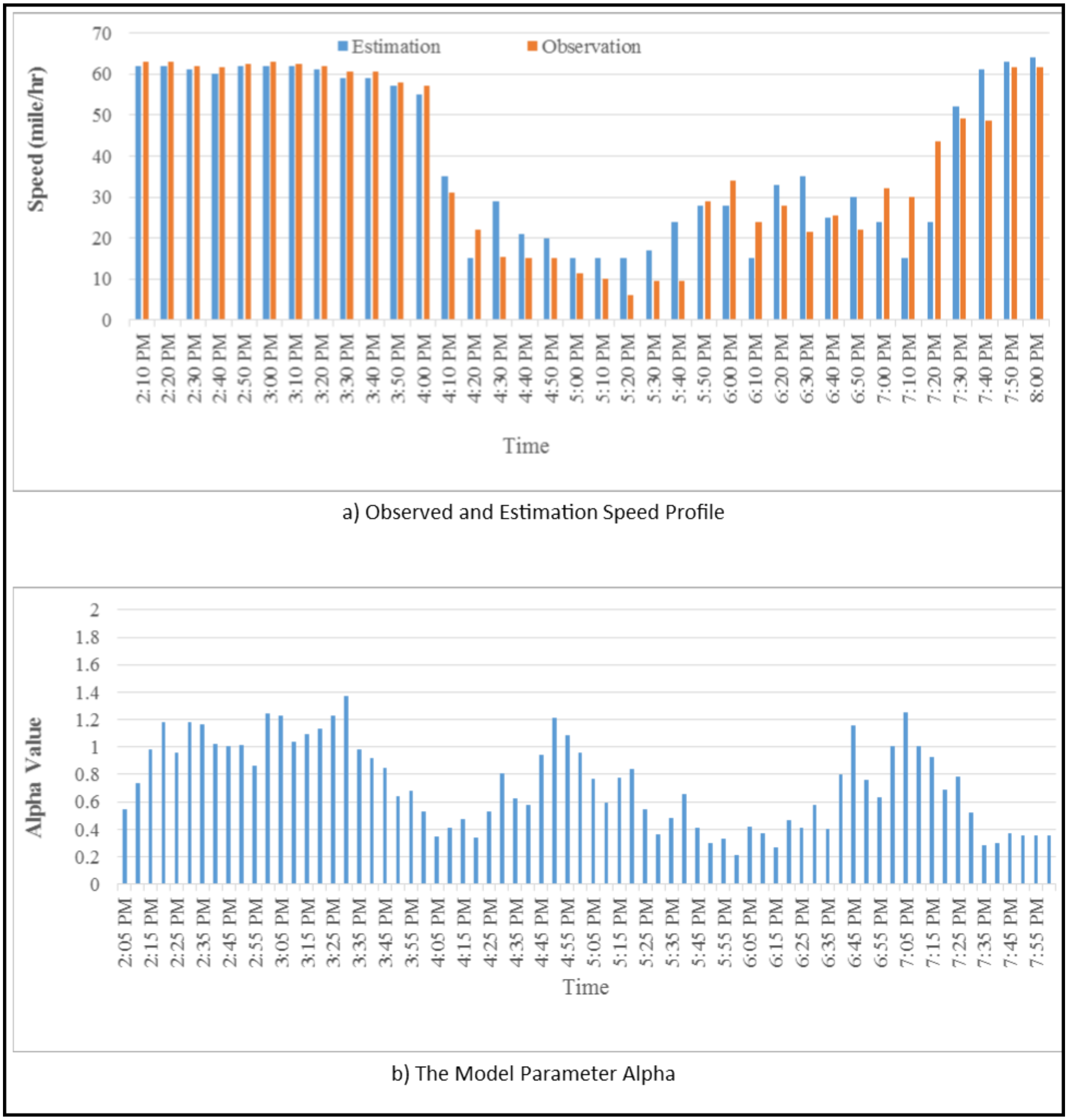


Figure 3-6: Time-Varying Speed Profile and Associated Alpha for a Freeway Link in Baseline IV [Source: SMU]

Chapter 4. Calibration Results

As described above, analyzing the operational conditions along the US 75 Corridor has resulted in identifying four main clusters that define the dominant operational condition for the corridor. A representative peak period is identified for each of these clusters as explained in Chapter 2. An intensive calibration effort is then performed to ensure that the model is realistically able to replicate the traffic pattern for each representative peak period. Thus, the model is calibrated to represent four different baseline scenarios.

This chapter summarizes the results of the model calibration effort. It provides a comparison between the model estimation results and the corresponding real-world observations. The results are presented for each representative peak period.

4.1 Calibration Metrics

A set of comparison metrics are generated for each calibrated baseline conditions. The metrics include:

1. The percentage error between the observed and estimated hourly traffic volumes for all freeway detectors for both directions.

This error is computed as the absolute difference between the observed hourly volume and the estimated hourly volume as a percentage of the observed volume. The percentage error is calculated for each hour in the evening peak period (4:00 pm to 7:00 pm) and for each available detector. In addition, the percentage error is recorded for the entire peak period for each detector. The error considering all detectors is also recorded for each hour in the peak period. A color code is used for all figures that show this comparison to indicate the magnitude of error. A green color indicates less percentage error (< 15%) while a red color indicates a high percentage error (> 40%).

2. Correlation between the observed and estimated hourly traffic volumes for all freeway detectors for both directions

A correlation chart is generated to illustrate the overall correlation between the observed and estimated hourly traffic volume. One chart is produced for the detectors in each freeway direction. The slope of the best-fitting line provides an insight on how the estimated vehicle counts matches the observed ones. In general, low (< 1) or high (> 1) slope values indicate the model underestimates or overestimates the traffic demand in the network. As the slope of the best-fitting line is close to one, the model generally captures the correct demand level in the network.

3. Visual comparison between the observed and estimated speed profile for both freeway directions

The estimated time-varying speed profile for each detector is compared against its observed one. The detectors are ordered based on their sequence along the freeway and the speed is recorded for each observation interval (10 minutes). A color code is used to indicate the level of congestion with the green representing high speed, yellow and orange representing moderate speed and red representing slow traffic. A visual inspection is used to conduct this comparison. The objective is to ensure that the model is generally able to capture the bottleneck patterns and speed reduction associated with non-recurrent congestion, if any.

4. Time-varying travel time comparison for both freeway directions

The estimated and observed total travel time for both freeway directions are recorded at five-minute intervals. A graph that depicts the estimated and observed time-varying travel time is generated for both freeway directions. Those graphs are visually inspected to ensure that the model is able to replicate the time-varying travel time along the US 75 freeway including delays associated with non-recurrent congestion situations.

4.2 Calibration Results for Baseline Scenario I

As described earlier, based on the conducted cluster analysis, the operation conditions of Cluster I represent a baseline scenario in which medium demand, with minor incident, and dry conditions are considered. A representative peak period that represents this cluster is selected. Figure 4-1 through Figure 4-4 illustrate the model calibration results against the observed traffic pattern for this representative peak period.

Figure 4-1 and **Figure** 4**-**2 give the percentage error in the hourly traffic volumes for the US 75 freeway for the NB and SB directions, respectively. As shown in Figure 4-1 a, which provides the percentage error for the NB direction, 65% of the hourly observations have percentage error less than 15%, and 79% of the observations have percentage error that is less than 25%. No hourly observations with error that is greater than 40% have been recorded. Considering the entire peak period, out of the 30 detectors available on the freeway in the NB direction, a percentage error of less than 15% is recorded for 21 detectors, an error that is greater than 15% and less than 25% is recorded for three detectors, and six detectors are recorded with error that is greater than 25% and less than 40%.

Considering all detectors along the NB directions (the last row), the percentage error in the first hour of the peak period (4:00 to 5:00) is recorded at 15.04%. This error is recorded at 13.64% and 14.08% for the second and third hours of the peak period, respectively.

As shown in Figure 4-1 b, the slope of the best-fitting line between the observed and estimated hourly volumes is recorded at 1.003, which indicates that the model is generally capturing the overall demand level along the NB travel direction.

For the SB direction, as illustrated in **Figure** 4**-**2 a, 50% of the hourly observations have percentage error that is less than 15%, and 81% of the observations have percentage error that is less than 25%. No observations with error that is greater than 40% have been recorded. Considering the entire peak period for the SB direction, out of the 38 detectors available along that direction, a percentage error of less than 15% is recorded for 22 detectors, 14 detectors have error that is greater than 15% and less than 25%, and two detectors have an error that is greater than 25% and less than 40%. Considering all detectors along the SB directions, the percentage error is recorded at 13.55% for the first hour, 14.66% for the second hour, and 16.57% for the third hour. As shown in **Figure** 4**-**2 b, the slope of the best-fitting line between observed and estimated hourly volumes is recorded at 0.9184, which indicates that the model is generally capturing the overall demand level along the SB travel direction.

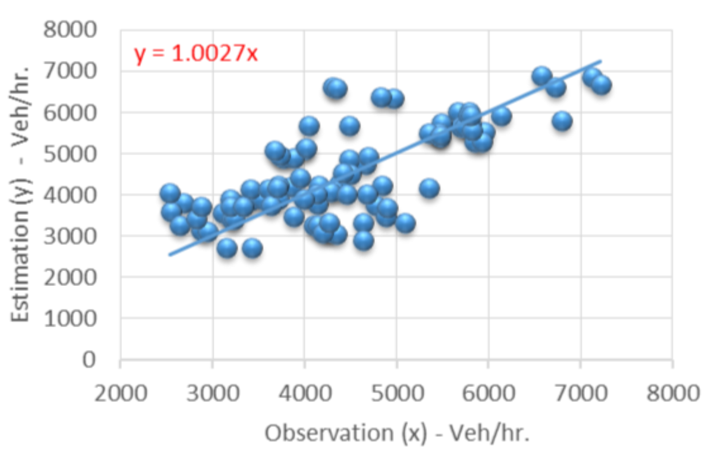
The estimated and observed US 75 speed profiles are given in Figure 4-3 for both NB and SB directions. As mentioned above, the estimated and observed speed is recorded for each detector at 10 minute intervals. The top of the figure gives the speed for the north section of the freeway (City of Plano), while the bottom of the figure gives the speed for the south section (north of downtown Dallas).

As illustrated in these figures, the model is generally replicating the observed speed profile in both directions. For instance, in the NB direction, the model replicates the slight reduction in the speed in the south and north sections of the freeway. The model also the reduction in speed observed along the SB direction during the period of 5:00 pm to 6:00 pm. Finally, the comparison between for estimated and observed time-varying travel time for both directions is given in Figure 4-4. The figure shows that model generally replicates the travel time along the freeway for both directions. For both directions, the RMSE between the observed and estimated travel time is less than 0.5 minute.

Detector Location	Percentage Errors %				Observed Values			
	4-5 PM	5-6 PM	6-7 PM	All PM	4-5 PM	5-6 PM	6-7 PM	All PM
5888-21228$US 75 N Exchange Pkwy TO Stacy Rd$US75$NB	13.72	21.11	13.10	7.79	3412	3410	3145	9967
5887-5888$US 75 N Allen Dr TO Exchange Pkwy$US75$NB	4.63	14.76	20.28	0.08	3717	3597	3422	10736
5927-5887$US 75 N McDermott Dr TO Allen Dr$US75$NB	2.63	8.51	4.58	0.53	4379	4478	4281	13138
5588-5589$US 75 N Bethany Dr TO McDermott Dr$US75$NB	4.77	0.27	2.35	2.25	4316	4498	4128	12942
21219-5588$US 75 N Bethany Dr TO McDermott Dr$US75$NB	21.68	12.51	9.70	14.73	4770	4845	4452	14067
5792-5781$US 75 N Enterprise Blvd TO Bethany Dr$US75$NB	8.78	1.59	2.75	3.32	4145	4148	3994	12287
5815-5792$US 75 N Chase Oaks Blvd TO Ridgemont Dr$US75$NB	9.04	11.88	12.94	11.27	3851	3947	3701	11499
5823-5815$US 75 N Legacy Dr TO Chase Oaks Blvd$US75$NB	9.15	6.01	23.47	12.52	2875	2945	2637	8457
5664-5823$US 75 N Spring Creek Pkwy TO Legacy Dr$US75$NB	25.87	27.09	21.25	24.77	4236	4271	4146	12653
5692-5664$US 75 N Spring Creek Pkwy TO Legacy Dr$US75$NB	17.96	14.99	21.54	18.05	3230	3109	2814	9153
5691-5692$US 75 N Parker Rd TO Spring Creek Pkwy$US75$NB	28.10	29.89	26.43	28.16	4633	4352	4189	13174
21214-5691$US 75 N Parker Rd TO Spring Creek Pkwy$US75$NB	10.27	6.04	16.69	10.96	3536	3211	3194	9941
5732-21214$US 75 N Parker Rd TO Spring Creek Pkwy$US75$NB	21.92	5.58	29.63	18.63	3194	3226	2875	9295
83-53$US 75 N Park Blvd TO Parker Rd$US75$NB	28.70	37.63	21.97	29.62	4882	4640	4269	13791
82-300004$US 75 N 15th St TO Park Blvd$US75$NB	14.31	3.31	11.57	9.71	3710	3625	3329	10664
4414-4478$US 75 N Plano Pkwy TO 15th St$US75$NB	22.25	34.42	24.79	27.10	5345	5087	4890	15322
4314-4457$US 75 N SH 190/President George Bush TPKE TO Plano Pkwy$US7!	1.59	14.03	2.90	3.30	4657	4675	4416	13748
4081-4359$US 75 N Campbell Rd TO Galatyn Pkwy$US75$NB	7.07	1.86	4.81	1.54	5952	5805	5488	17245
4079-4081$US 75 N Collins Blvd TO Campbell Rd$US75$NB	9.75	0.72	0.44	3.45	5848	5691	5468	17007
4078-4079$US 75 N Arapaho Rd TO Collins Blvd$US75$NB	10.73	1.54	0.79	3.98	5930	5729	5454	17113
188-189$US 75 N Belt Line Rd TO Arapaho Rd$US75$NB	27.18	27.91	38.15	30.88	4006	4009	3670	11685
3289-3290$US 75 N Spring Valley Rd TO Belt Line Rd$US75$NB	0.36	4.40	2.96	0.45	5788	5813	5345	16946
3306-3307$US 75 N Midpark Rd TO Spring Valley Rd$US75$NB	28.13	32.30	26.91	29.15	4960	4824	4478	14262
3087-3094$US 75 N Cottonwood Creek TO Midpark Rd$US75$NB	4.78	1.52	3.20	0.08	6566	6725	6127	19418
2144-579$US 75 N Meadow Rd TO Royal Ln$US75$NB	3.74	7.25	14.37	8.36	7116	7212	6790	21118
2169-2145$US 75 N Walnut Hill Ln TO Meadow Rd$US75$NB	5.82	2.28	0.88	2.45	5671	5777	5466	16914
2152-2169$US 75 N Park Ln TO Walnut Hill Ln$US75$NB	4.01	2.29	0.69	1.92	5785	5802	5478	17065
2084-2056$US 75 N University Blvd TO Lovers Ln$US75$NB	29.55	5.25	10.18	14.11	3773	4688	4243	12704
2083-2084$US 75 N SMU Blvd TO University Blvd$US75$NB	26.06	32.52	28.46	28.97	3884	3727	3630	11241
735-737$US 75 N Mockingbird Ln TO SMU Blvd$US75$NB	20.11	9.92	12.80	14.43	4102	3872	3554	11528
All Detectors	15.04	13.64	14.08	13.04	138269	137738	129073	405080

Error Legend	
<=15%	
15-25%	
25-40%	
>=40%	

a) Hourly Traffic Volume Comparison for US 75 Freeway - NB



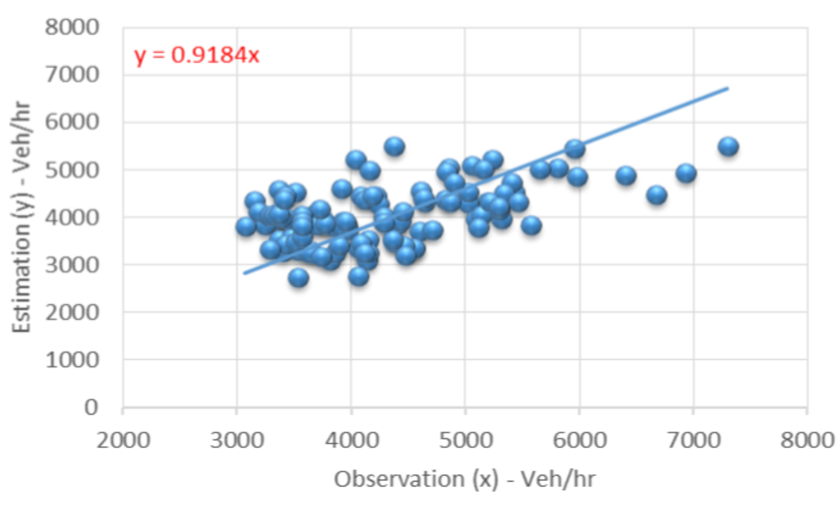
b) Correlation between Observed and Estimated Traffic Volumes for the US 75 Freeway – NB

Figure 4-1: Hourly Traffic Volume Comparison for US 75 Freeway NB - Cluster I [Source: SMU]

Detector Location	Percentage Errors %				Observed Values			
	4-5 PM	5-6 PM	6-7 PM	All PM	4-5 PM	5-6 PM	6-7 PM	All PM
21227-5876$US 75 S Exchange Pkwy TO Allen Dr$US75$SB	6.40	17.62	12.43	12.19	3971	4064	3887	11922
5876-5877$US 75 S Allen Dr TO McDermott Dr$US75$SB	19.30	26.55	23.79	23.20	4602	4557	4464	13623
5877-5917$US 75 S Allen Dr TO McDermott Dr$US75$SB	5.29	0.45	6.33	4.01	4216	4241	4188	12645
5590-5591$US 75 S McDermott Dr TO Bethany Dr$US75$SB	9.02	6.22	17.30	10.75	4080	4113	3918	12111
5591-21217$US 75 S McDermott Dr TO Bethany Dr$US75$SB	9.53	6.70	1.34	5.92	4825	4639	4613	14077
5772-5809$US 75 S Ridgemont Dr TO Chase Oaks Blvd$US75$SB	26.56	20.72	19.21	22.23	4556	4377	4367	13300
5809-5810$US 75 S Ridgemont Dr TO Chase Oaks Blvd$US75$SB	3.24	2.66	1.09	0.61	3955	3765	3945	11665
5810-5811$US 75 S Ridgemont Dr TO Chase Oaks Blvd$US75$SB	12.04	12.36	12.00	12.13	4344	4410	4434	13188
5811-5662$US 75 S Legacy Dr TO Spring Creek Pkwy$US75$SB	18.65	16.08	10.99	15.31	3813	3855	3632	11300
5662-5663$US 75 S Legacy Dr TO Spring Creek Pkwy$US75$SB	25.50	21.82	21.50	22.94	4133	4148	4117	12398
5688-5689$US 75 S Spring Creek Pkwy TO Parker Rd$US75$SB	6.61	14.95	22.88	14.58	3583	3444	3287	10314
5689-5690$US 75 S Spring Creek Pkwy TO Parker Rd$US75$SB	31.46	22.30	21.42	25.25	5578	5090	5140	15808
5690-21213$US 75 S Parker Rd TO Park Blvd$US75$SB	1.15	18.92	13.14	9.83	3841	3335	3570	10746
21213-5731$US 75 S Parker Rd TO Park Blvd$US75$SB	6.89	15.14	22.07	14.54	3542	3448	3316	10306
20-4482$US 75 S Park Blvd TO 15th St$US75$SB	9.91	3.94	0.74	4.94	3644	3400	3505	10549
4409-4410$US 75 S 15th St TO Plano Pkwy$US75$SB	4.70	18.15	23.79	15.27	3361	3245	3069	9675
4456-4310$US 75 S SH 190/President George Bush TPKE TO Renner Rd$US	14.84	11.74	9.29	4.75	4150	3722	4285	12157
4310-4311$US 75 S Renner Rd TO Dallas Collin County Line$US75$SB	2.56	37.65	9.42	15.80	3477	3150	3568	10195
4363-4364$US 75 S Galatyn Pkwy TO Campbell Rd$US75$SB	7.07	22.07	0.08	4.59	3538	3276	3564	10378
4358-4082$US 75 S Campbell Rd TO Collins Blvd$US75$SB	16.82	0.65	15.76	10.79	5190	5053	5337	15580
4082-21180$US 75 S Collins Blvd TO Arapaho Rd$US75$SB	14.55	3.75	17.24	9.60	5023	4853	5220	15096
21180-4085$US 75 S Collins Blvd TO Arapaho Rd$US75$SB	19.49	2.77	21.05	14.61	5320	5164	5467	15951
180-187$US 75 S Arapaho Rd TO Belt Line Rd$US75$SB	8.13	35.54	20.53	21.08	3618	3368	3361	10347
3279-3291$US 75 S Belt Line Rd TO Spring Valley Rd$US75$SB	25.58	10.27	25.84	20.68	5317	5026	5113	15456
3291-3292$US 75 S Belt Line Rd TO Spring Valley Rd$US75$SB	4.86	28.84	6.63	13.21	3762	3505	3561	10828
3300-3304$US 75 S Spring Valley Rd TO Midpark Rd$US75$SB	10.96	2.80	7.92	5.31	4863	4829	4456	14148
3304-3108$US 75 S Midpark Rd TO Cottonwood Creek$US75$SB	23.77	8.60	18.90	17.26	6407	5953	5973	18333
3138-3140$US 75 S Forest Ln TO Park Central$US75$SB	10.45	30.07	28.35	22.64	3683	3422	3407	10512
3164-586$US 75 S Park Central TO Royal Ln$US75$SB	25.76	28.80	19.71	24.73	4371	4042	4165	12578
21224-588$US 75 S Royal Ln TO Meadow Rd$US75$SB	0.46	3.37	4.97	2.84	5232	4903	4632	14767
588-2139$US 75 S Meadow Rd TO Walnut Hill Ln$US75$SB	24.66	28.77	32.81	28.62	7299	6935	6669	20903
2140-2154$US 75 S Walnut Hill Ln TO Park Ln$US75$SB	13.46	16.44	21.73	17.09	5809	5427	5296	16532
2154-2155$US 75 S Park Ln TO Northpark Dr$US75$SB	11.45	12.24	20.53	14.65	5650	5401	5290	16341
2155-2013$US 75 S Northpark Dr TO Loop 12/Northwest Hwy$US75$SB	20.82	6.01	28.82	18.77	4708	4279	4472	13459
2110-2099$US 75 S Southwestern Blvd TO Lovers Ln$US75$SB	0.41	29.35	0.94	9.13	3929	3182	3287	10398
2059-2058$US 75 S Lovers Ln TO University Blvd$US75$SB	22.12	17.46	15.11	7.34	3350	3385	3733	10468
2090-733$US 75 S Mockingbird Ln TO McCommas Blvd$US75$SB	3.18	0.29	22.50	6.26	3705	3424	3537	10666
733-734$US 75 S Mockingbird Ln TO McCommas Blvd$US75$SB	2.36	15.80	31.96	16.89	3906	4082	4058	12046
All Detectors	13.55	14.66	16.57	14.14	168351	160512	161903	490766

Error Legend	
<=15%	
15-25%	
25-40%	
>=40%	

a) Hourly Traffic Volume Comparison for US 75 Freeway - SB



b) Correlation between Observed and Estimated Traffic Volumes for the US 75 Freeway - SB

Figure 4-2: Hourly Traffic Volume Comparison for US 75 Freeway SB - Cluster I [Source: SMU]

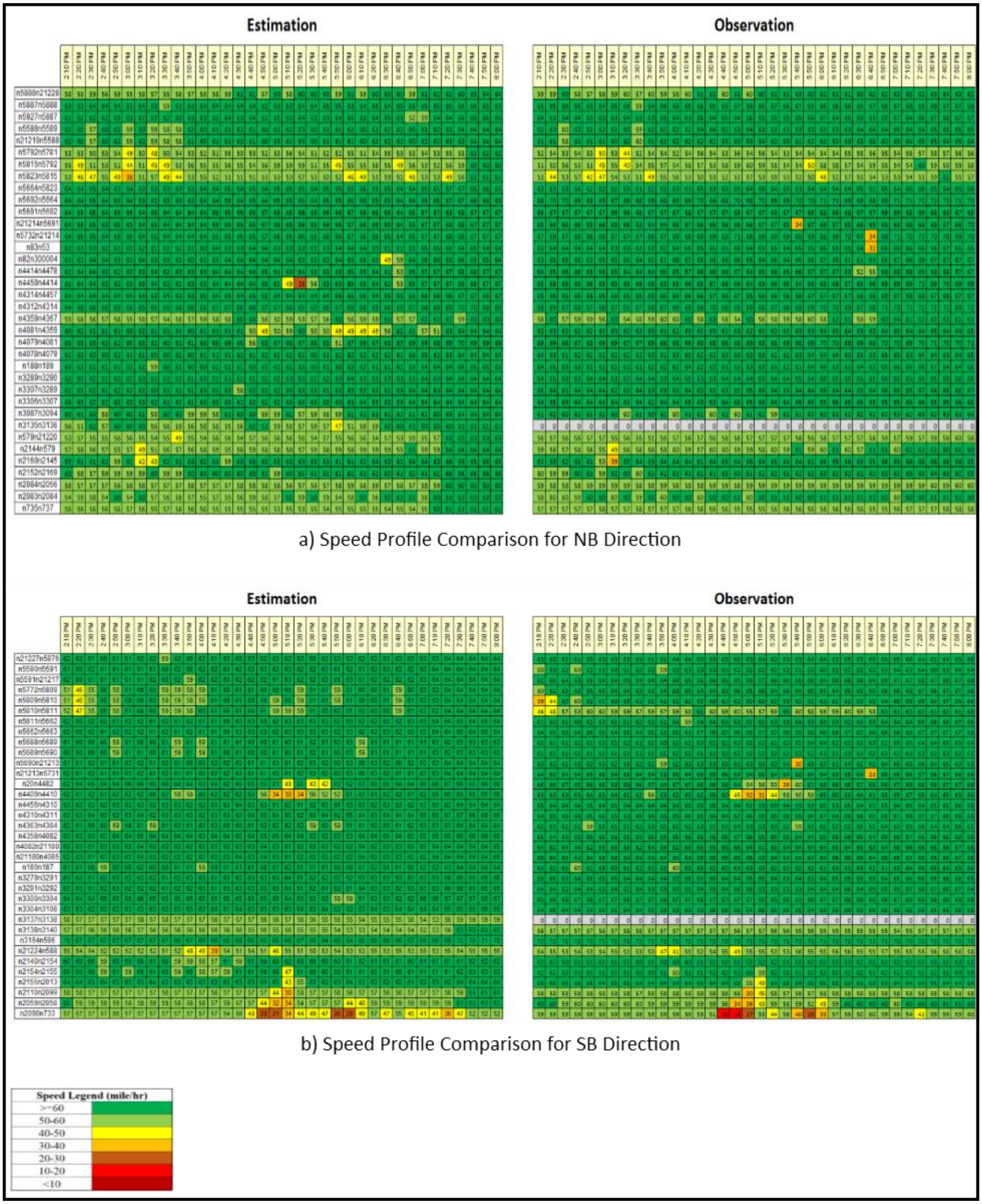


Figure 4-3: Estimated and Observed Time-Dependent Speed Profile for US 75 Freeway - Cluster I [Source: SMU]

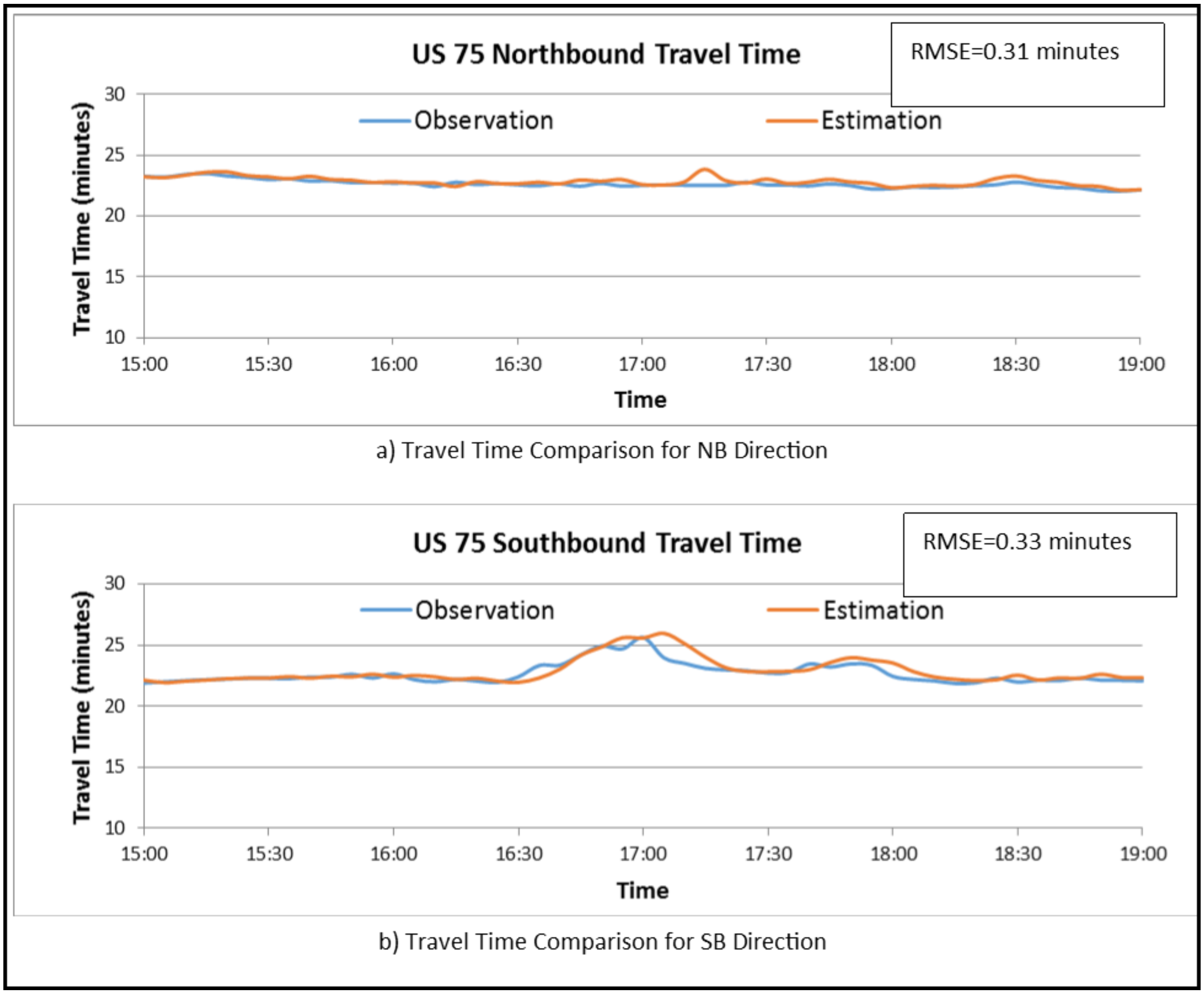


Figure 4-4: Estimated and Observed Travel Time for US 75 Freeway - Cluster I [Source: SMU]

4.3 Calibration Results for Baseline Scenario II

As described earlier, based on the conducted cluster analysis, the operation conditions of Cluster II represent a baseline scenario in which high demand, with minor incident, and wet (precipitation) conditions are considered. A representative peak period that represents this cluster is selected. Figure 4-5 to Figure 4-8 illustrate the model calibration results against the observed traffic pattern for this representative peak period.

Figure 4-5 and Figure 4-6 give the percentage error in the hourly traffic volumes for the US 75 freeway for the NB and SB directions, respectively. As shown in Figure 4-5 a, which provides the percentage error for the NB direction, 62% of the hourly observations have percentage error less than 15%, and 85% of the observations have percentage error that is less than 25%. No hourly observations with error that is greater than 40% have been recorded. Considering the entire peak period, out of the 31 detectors available on the freeway in the NB direction, a percentage error of less than 15% is recorded for 21 detectors, an error that is greater than 15% and less than 25% is recorded for six detectors, and four detectors are recorded with error that is greater than 25% and less than 40%.

Considering all detectors along the NB directions (the last row), the percentage error in the first hour of the peak period (4:00 to 5:00) is recorded at 11.86%. This error is recorded at 13.95% and 12.64% for the second and third hours of the peak period, respectively.

As shown in Figure 4-5 b, the slope of the best-fitting line between the observed and estimated hourly volumes is recorded at 0.956, which indicates that the model is generally capturing the overall demand level along the NB travel direction.

For the SB direction, as illustrated in Figure 4-6 a, 53% of the hourly observations have percentage error hat is less than 15%, and 72% of the observations have percentage error that is less than 25%. No observations with error that is greater than 40% have been recorded. Considering the entire peak period for the SB direction, out of the 35 detectors available along that direction, a percentage error of less than 15% is recorded for 21 detectors, 11 detectors have error that is greater than 15% and less than 25%, and three detectors have an error that is greater than 25% and less than 40%. Considering all detectors along the SB directions, the percentage error is recorded at 15.44% for the first hour, 14.35% for the second hour, and 13.48% for the third hour. As shown in Figure 4-6 b, the slope of the best-fitting line between observed and estimated hourly volumes is recorded at 0.953, which indicates that the model is generally capturing the overall demand level along the SB travel direction.

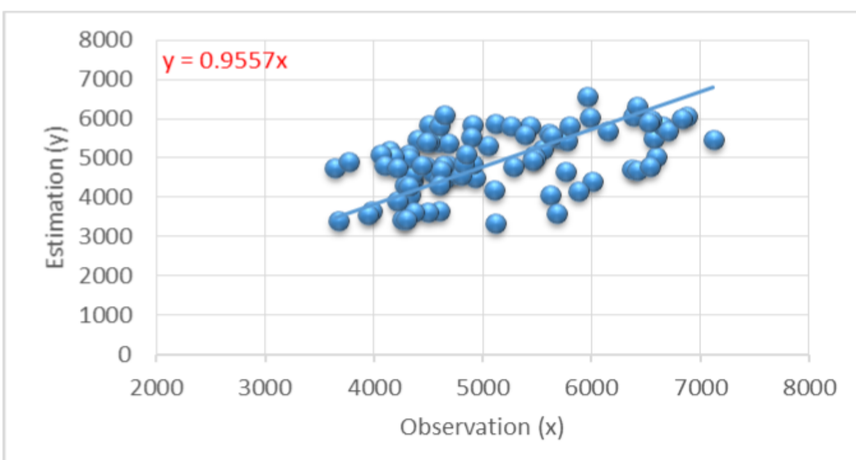
The estimated and observed US 75 speed profiles are given in Figure 4-7 for both NB and SB directions. As mentioned above, the estimated and observed speed is recorded for each detector at 10 minute intervals. The top of the figure gives the speed for the north section of the freeway (City of Plano), while the bottom of the figure gives the speed for the south section (north of downtown Dallas).

As illustrated in these figures, the model is generally replicating the observed speed profile in both directions. For instance, in the NB direction, the model replicates the high reduction in the speed in the south and north sections of the freeway during the period of 3:30 pm to 7:00 pm. The model also replicates the high reduction in speed observed along the SB direction during the period of 4:20 pm to 5:30 pm. Finally, the comparison between for estimated and observed time-varying travel time for both directions is given in Figure 4-8. The figure shows that model generally replicates the travel time along the freeway for both directions. The RMSE between the observed and estimated travel time is less than one minute for the NB direction and about 1.15 minute for the SB direction.

Detector Location	Percentage Errors %				Observed Values			
	4-5 PM	5-6 PM	6-7 PM	All PM	4-5 PM	5-6 PM	6-7 PM	All PM
5888-21228$US 75 N Exchange Pkwy TO Stacy Rd$US75$NB	6.87	17.73	0.56	8.58	4482	4585	4281	13348
5887-5888$US 75 N Allen Dr TO Exchange Pkwy$US75$NB	3.01	14.83	3.50	4.83	4684	4679	4600	13963
5927-5887$US 75 N McDermott Dr TO Allen Dr$US75$NB	5.92	0.69	6.82	0.50	5544	5978	5437	16959
5588-5589$US 75 N Bethany Dr TO McDermott Dr$US75$NB	7.70	5.63	10.80	1.09	5467	5769	5252	16488
21219-5588$US 75 N Bethany Dr TO McDermott Dr$US75$NB	19.29	25.98	0.21	15.36	5755	6370	5796	17921
5792-5781$US 75 N Enterprise Blvd TO Bethany Dr$US75$NB	3.66	8.90	12.70	0.09	4645	4930	4896	14471
5815-5792$US 75 N Chase Oaks Blvd TO Ridgemont Dr$US75$NB	2.49	5.00	26.12	7.68	4624	4804	4601	14029
5823-5815$US 75 N Legacy Dr TO Chase Oaks Blvd$US75$NB	8.45	7.12	30.02	4.39	3974	3679	3644	11297
5664-5823$US 75 N Spring Creek Pkwy TO Legacy Dr$US75$NB	20.72	19.41	1.84	12.58	4594	4260	4612	13466
5692-5664$US 75 N Spring Creek Pkwy TO Legacy Dr$US75$NB	1.26	6.31	20.60	5.00	4351	4326	4179	12856
5691-5692$US 75 N Parker Rd TO Spring Creek Pkwy$US75$NB	27.97	34.64	17.97	26.90	5617	5121	5103	15841
21214-5691$US 75 N Parker Rd TO Spring Creek Pkwy$US75$NB	3.32	19.31	6.20	9.47	4753	4495	4596	13844
5732-21214$US 75 N Parker Rd TO Spring Creek Pkwy$US75$NB	2.12	17.37	0.65	5.22	4536	4365	4320	13221
83-53$US 75 N Park Blvd TO Parker Rd$US75$NB	26.52	36.78	29.55	30.85	6002	5675	5881	17558
82-300004$US 75 N 15th St TO Park Blvd$US75$NB	4.89	3.84	5.02	4.60	5049	4632	4841	14522
4414-4478$US 75 N Plano Pkwy TO 15th St$US75$NB	23.68	27.16	27.00	25.94	6591	6413	6533	19537
4314-4457$US 75 N SH 190/President George Bush TPKE TO Plano Pkwy$US7	3.58	0.20	1.56	1.66	5693	5609	5637	16939
4359-4367$US 75 N Galatyn Pkwy TO Dallas Collin County Line$US75$NB	2.05	15.86	30.43	15.44	4346	4318	3763	12427
4081-4359$US 75 N Campbell Rd TO Galatyn Pkwy$US75$NB	7.35	10.15	1.79	0.21	6148	5962	6421	18531
4079-4081$US 75 N Collins Blvd TO Campbell Rd$US75$NB	23.05	11.86	12.09	15.76	7116	6872	6823	20811
4078-4079$US 75 N Arapaho Rd TO Collins Blvd$US75$NB	16.28	5.08	8.60	10.04	6572	6381	6545	19498
188-189$US 75 N Belt Line Rd TO Arapaho Rd$US75$NB	14.71	18.91	31.53	21.45	5112	4901	4643	14656
3289-3290$US 75 N Spring Valley Rd TO Belt Line Rd$US75$NB	12.50	15.08	9.42	12.36	6657	6697	6521	19875
3306-3307$US 75 N Midpark Rd TO Spring Valley Rd$US75$NB	8.51	9.24	3.74	4.71	5477	5454	5380	16311
579-21220$US 75 N Royal Ln TO Park Central$US75$NB	1.08	4.24	0.24	1.78	5110	5282	4629	15021
2144-579$US 75 N Meadow Rd TO Royal Ln$US75$NB	23.84	29.88	25.70	26.52	4405	4504	4055	12964
2169-2145$US 75 N Walnut Hill Ln TO Meadow Rd$US75$NB	18.36	20.01	8.07	15.47	4313	4503	4438	13254
2152-2169$US 75 N Park Ln TO Walnut Hill Ln$US75$NB	24.88	20.65	17.46	21.00	4148	4484	4101	12733
2084-2056$US 75 N University Blvd TO Lovers Ln$US75$NB	1.37	1.28	9.77	4.33	4667	4904	5282	14853
2083-2084$US 75 N SMU Blvd TO University Blvd$US75$NB	5.42	0.58	12.93	6.04	4357	4819	4215	13391
735-737$US 75 N Mockingbird Ln TO SMU Blvd$US75$NB	9.59	7.58	20.40	12.65	3940	4208	4298	12446
All Detectors	11.86	13.95	12.64	11.18	158729	158979	155323	473031

Error Legend	
<=15%	
15-25%	
25-40%	
>=40%	

a) Hourly Traffic Volume Comparison for US 75 Freeway - NB



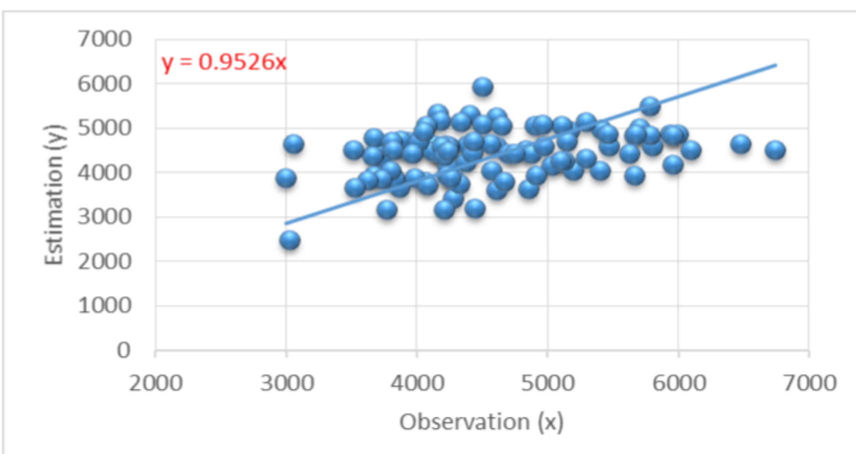
b) Correlation between Observed and Estimated Traffic Volumes for the US 75 Freeway - NB

Figure 4-5: Hourly Traffic Volume Comparison for US 75 Freeway NB - Cluster II [Source: SMU]

Detector Location	Percentage Errors %				Observed Values			
	4-5 PM	5-6 PM	6-7 PM	All PM	4-5 PM	5-6 PM	6-7 PM	All PM
21227-5876$US 75 S Exchange Pkwy TO Allen Dr$US75$SB	9.54	11.53	7.10	3.27	4213	4571	4224	13008
5876-5877$US 75 S Allen Dr TO McDermott Dr$US75$SB	0.20	21.92	19.96	14.45	4608	5188	4906	14702
5877-5917$US 75 S Allen Dr TO McDermott Dr$US75$SB	20.66	4.42	8.63	7.61	4400	5164	4646	14210
5590-5591$US 75 S McDermott Dr TO Bethany Dr$US75$SB	28.22	13.10	18.60	19.77	4153	4497	4333	12983
5591-21217$US 75 S McDermott Dr TO Bethany Dr$US75$SB	13.58	1.06	2.80	4.85	4611	5106	4956	14673
5772-5809$US 75 S Ridgemont Dr TO Chase Oaks Blvd$US75$SB	17.45	25.25	16.42	19.82	5026	5394	5097	15517
5809-5810$US 75 S Ridgemont Dr TO Chase Oaks Blvd$US75$SB	21.25	6.80	19.18	15.51	3802	4161	3936	11899
5810-5811$US 75 S Ridgemont Dr TO Chase Oaks Blvd$US75$SB	5.13	9.01	6.14	0.42	4385	4872	4429	13686
5811-5662$US 75 S Legacy Dr TO Spring Creek Pkwy$US75$SB	1.28	6.20	0.99	1.41	3827	4062	3825	11714
5662-5663$US 75 S Legacy Dr TO Spring Creek Pkwy$US75$SB	9.74	18.59	8.79	12.56	4280	4663	4253	13196
5688-5689$US 75 S Spring Creek Pkwy TO Parker Rd$US75$SB	16.86	8.26	21.91	15.45	3926	4247	3871	12044
5689-5690$US 75 S Spring Creek Pkwy TO Parker Rd$US75$SB	16.12	20.82	8.51	15.39	5465	5803	5148	16416
5690-21213$US 75 S Parker Rd TO Park Blvd$US75$SB	13.23	8.76	17.30	13.02	4020	4233	4011	12264
21213-5731$US 75 S Parker Rd TO Park Blvd$US75$SB	16.19	11.81	23.37	16.97	3904	4124	3804	11832
20-4482$US 75 S Park Blvd TO 15th St$US75$SB	6.52	2.51	6.61	3.44	3773	3984	3797	11554
4409-4410$US 75 S 15th St TO Plano Pkwy$US75$SB	16.64	9.19	19.47	14.87	3726	4115	3662	11503
4456-4310$US 75 S SH 190/President George Bush TPKE TO Renner Rd$US	6.15	9.91	5.57	7.20	4182	4189	4237	12608
4310-4311$US 75 S Renner Rd TO Dallas Collin County Line$US75$SB	21.50	30.34	28.40	26.72	3674	3665	3510	10849
4363-4364$US 75 S Galatyn Pkwy TO Campbell Rd$US75$SB	5.44	7.41	3.52	1.71	3860	3672	3724	11256
4358-4082$US 75 S Campbell Rd TO Collins Blvd$US75$SB	12.12	7.85	3.00	7.77	5701	5404	5292	16397
4082-21180$US 75 S Collins Blvd TO Arapaho Rd$US75$SB	18.01	14.58	11.03	14.64	5940	5658	5459	17057
21180-4085$US 75 S Collins Blvd TO Arapaho Rd$US75$SB	19.04	16.35	14.15	16.56	5998	5775	5667	17440
180-187$US 75 S Arapaho Rd TO Belt Line Rd$US75$SB	2.11	4.33	18.31	7.77	4553	4204	3818	12575
3279-3291$US 75 S Belt Line Rd TO Spring Valley Rd$US75$SB	26.16	29.96	21.24	25.87	6096	5952	5627	17675
3291-3292$US 75 S Belt Line Rd TO Spring Valley Rd$US75$SB	5.68	3.38	12.23	0.53	4699	4376	3957	13032
3300-3304$US 75 S Spring Valley Rd TO Midpark Rd$US75$SB	6.97	16.70	7.52	10.49	4835	5126	4971	14932
3304-3108$US 75 S Midpark Rd TO Cottonwood Creek$US75$SB	28.38	33.19	18.79	27.09	6470	6739	5955	19164
3138-3140$US 75 S Forest Ln TO Park Central$US75$SB	18.07	0.41	29.33	21.13	3027	3057	2997	9081
3164-586$US 75 S Park Central TO Royal Ln$US75$SB	2.36	31.90	21.30	17.18	4238	4496	4051	12785
21224-588$US 75 S Royal Ln TO Meadow Rd$US75$SB	30.53	5.05	18.27	17.86	5666	5781	5292	16739
2155-2013$US 75 S Northpark Dr TO Loop 12/Northwest Hwy$US75$SB	28.17	3.21	8.78	10.82	4438	4897	4078	13413
2110-2099$US 75 S Southwestern Blvd TO Lovers Ln$US75$SB	20.09	23.98	5.81	2.93	4270	4174	3617	12061
2059-2058$US 75 S Lovers Ln TO University Blvd$US75$SB	13.54	24.49	3.97	4.63	4321	4071	3525	11917
2090-733$US 75 S Mockingbird Ln TO McCommas Blvd$US75$SB	21.46	0.27	15.71	12.26	4609	4417	3769	12795
733-734$US 75 S Mockingbird Ln TO McCommas Blvd$US75$SB	24.98	6.49	24.48	18.47	4852	4743	4203	13798
All Detectors	15.44	14.35	13.48	12.67	159548	164580	152647	476775

Error Legend	
<=15%	
15-25%	
25-40%	
>=40%	

a) Hourly Traffic Volume Comparison for US 75 Freeway - SB



b) Correlation between Observed and Estimated Traffic Volumes for the US 75 Freeway - SB

Figure 4-6: Hourly Traffic Volume Comparison for US 75 Freeway SB - Cluster II [Source: SMU]

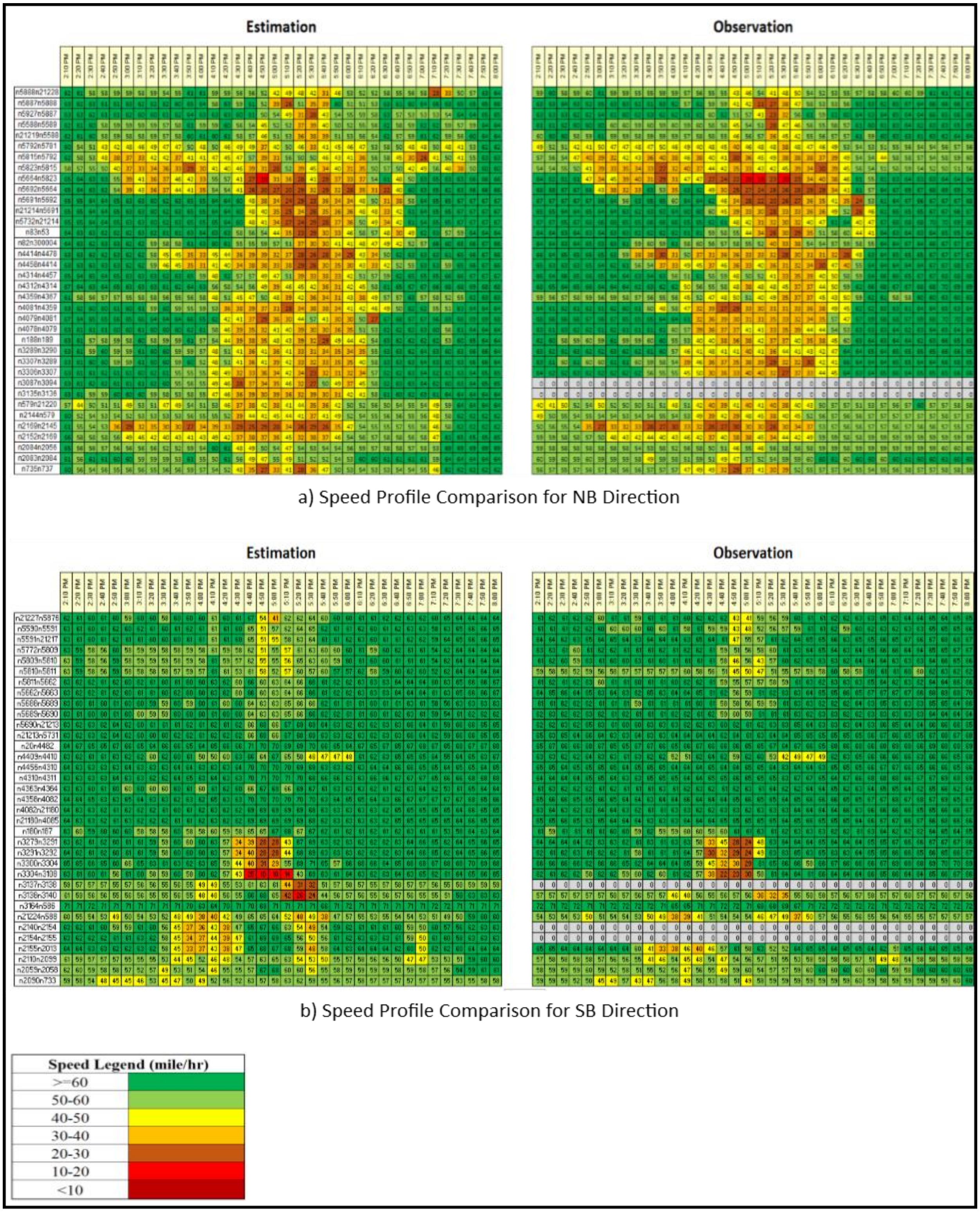
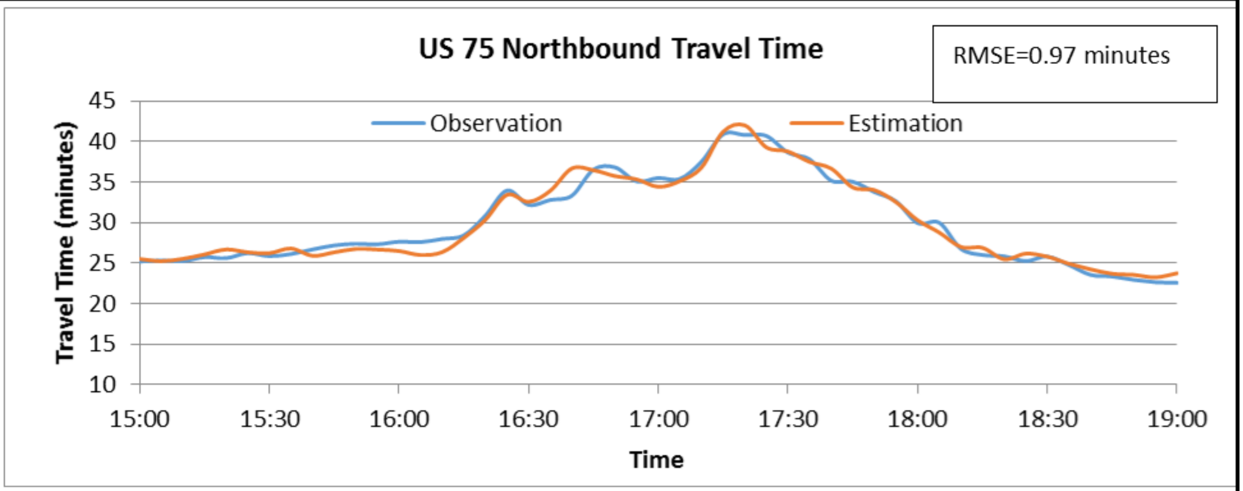
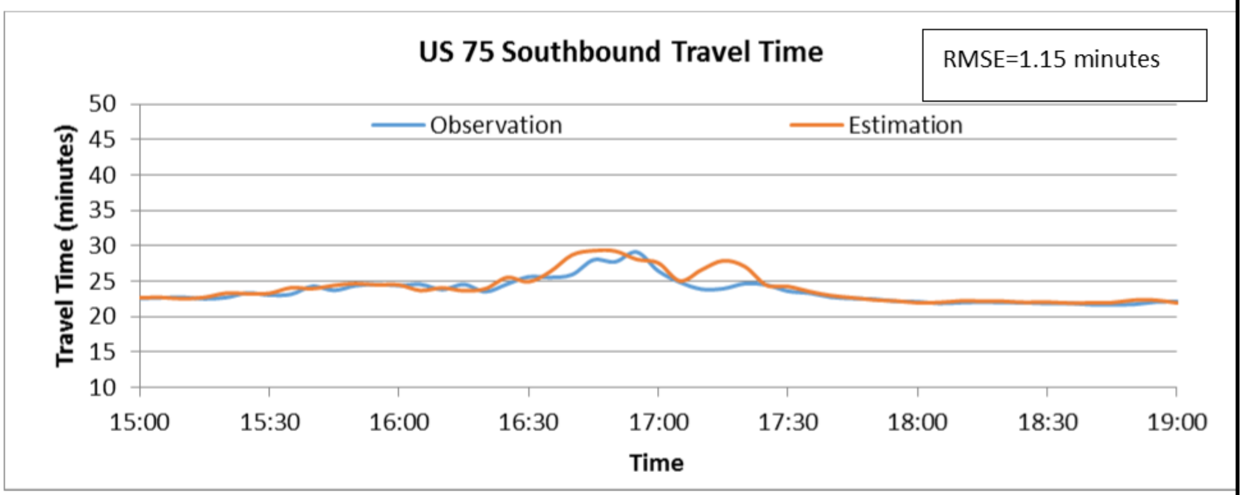


Figure 4-7: Estimated and Observed Time-Dependent Speed Profile for US 75 Freeway - Cluster II [Source: SMU]



a) Travel Time Comparison for NB Direction



b) Travel Time Comparison for SB Direction

Figure 4-8: Estimated and Observed Travel Time for US 75 Freeway - Cluster II [Source: SMU]

4.4 Calibration Results for Baseline Scenario III

As described earlier, based on the conducted cluster analysis, the operation conditions of Cluster III represent a baseline scenario in which high demand, with medium incident, and wet (precipitation) conditions are considered. A representative peak period that represents this cluster is selected. Figure 4-9 to Figure 4-12 illustrate the model calibration results against the observed traffic pattern for this representative peak period.

Figure 4-9 and Figure 4-10 give the percentage error in the hourly traffic volumes for the US 75 freeway for the NB and SB directions, respectively. As shown in Figure 4-9 a, which provides the percentage error for the NB direction, 56% of the hourly observations have percentage error less than 15%, and 82% of the observations have percentage error that is less than 25%. 3% of the hourly observations have percentage error greater than 40%. Considering the entire peak period, out of the 35 detectors available on the freeway in the NB direction, a percentage error of less than 15% is recorded for 24 detectors, an error that is greater than 15% and less than 25% is recorded for eight detectors, and three detectors are recorded with error that is greater than 25% and less than 40%.

Considering all detectors along the NB directions (the last row), the percentage error in the first hour of the peak period (4:00 to 5:00) is recorded at 14.67%. This error is recorded at 14.29% and 10.35% for the second and third hours of the peak period, respectively.

As shown in Figure 4-9 b, the slope of the best-fitting line between the observed and estimated hourly volumes is recorded at 1.019, which indicates that the model is generally capturing the overall demand level along the NB travel direction.

For the SB direction, as illustrated in Figure 4-10 a, 64% of the hourly observations have percentage error hat is less than 15%, and 91% of the observations have percentage error that is less than 25%. No observations with error that is greater than 40% have been recorded. Considering the entire peak period for the SB direction, out of the 39 detectors available along that direction, a percentage error of less than 15% is recorded for 27 detectors, 12 detectors have error that is greater than 15% and less than 25%, and No detector has an error that is greater than 25% and less than 40%. Considering all detectors along the SB directions, the percentage error is recorded at 11.59% for the first hour, 11.71% for the second hour, and 12.78% for the third hour. As shown in Figure 4-10 b, the slope of the best-fitting line between observed and estimated hourly volumes is recorded at 0.964, which indicates that the model is generally capturing the overall demand level along the SB travel direction.

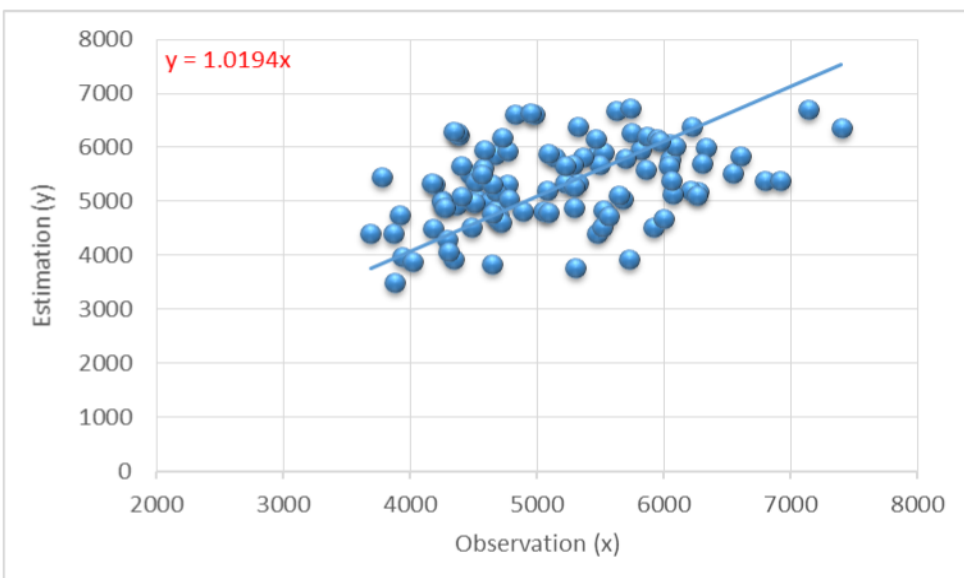
The estimated and observed US 75 speed profiles are given in Figure 4-11 for both NB and SB directions. As mentioned above, the estimated and observed speed is recorded for each detector at 10 minute intervals. The top of the figure gives the speed for the north section of the freeway (City of Plano), while the bottom of the figure gives the speed for the south section (north of downtown Dallas).

As illustrated in these figures, the model is generally replicating the observed speed profile in both directions. For instance, in the NB direction, the model replicates the high reduction in the speed in the south and north sections of the freeway during the period of 3:20 pm to 7:00 pm. The model also replicates the high reduction in speed observed along the SB direction during the period of 5:10 pm to 7:00 pm. Finally, the comparison between for estimated and observed time-varying travel time for both directions is given in Figure 4-12. The figure shows that model generally replicates the travel time along the freeway for both directions. The RMSE between the observed and estimated travel time is less than two minute for the NB direction and less than one minute for the SB direction.

Detector Location	Percentage Errors %				Observed Values			
	4-5 PM	5-6 PM	6-7 PM	All PM	4-5 PM	5-6 PM	6-7 PM	All PM
5888-21228$US 75 N Exchange Pkwy TO Stacy Rd$US75$NB	12.92	3.38	17.88	11.15	4364	4675	4245	13284
5887-5888$US 75 N Allen Dr TO Exchange Pkwy$US75$NB	9.95	5.80	14.88	5.99	4735	5084	4638	14457
5927-5887$US 75 N McDermott Dr TO Allen Dr$US75$NB	18.75	2.88	17.33	12.67	5622	6215	5731	17568
5588-5589$US 75 N Bethany Dr TO McDermott Dr$US75$NB	19.97	0.48	3.35	7.57	5322	6045	5486	16853
21219-5588$US 75 N Bethany Dr TO McDermott Dr$US75$NB	2.25	15.47	15.22	9.80	5817	6541	6069	18427
5792-5781$US 75 N Enterprise Blvd TO Bethany Dr$US75$NB	22.88	11.44	0.28	11.18	4476	4762	4685	13923
5815-5792$US 75 N Chase Oaks Blvd TO Ridgemont Dr$US75$NB	25.52	24.35	2.27	15.86	4667	4767	4718	14152
5823-5815$US 75 N Legacy Dr TO Chase Oaks Blvd$US75$NB	21.41	44.28	0.89	21.90	3918	3778	3935	11631
5664-5823$US 75 N Spring Creek Pkwy TO Legacy Dr$US75$NB	0.83	18.82	17.05	0.70	4478	4511	4638	13627
5692-5664$US 75 N Spring Creek Pkwy TO Legacy Dr$US75$NB	18.31	41.93	0.16	20.30	4244	4381	4288	12913
5691-5692$US 75 N Parker Rd TO Spring Creek Pkwy$US75$NB	19.46	0.40	28.84	15.99	5469	5315	5302	16086
21214-5691$US 75 N Parker Rd TO Spring Creek Pkwy$US75$NB	11.35	22.71	9.46	8.49	4492	4576	4343	13411
5732-21214$US 75 N Parker Rd TO Spring Creek Pkwy$US75$NB	16.36	28.44	3.26	14.34	4254	4405	4016	12675
83-53$US 75 N Park Blvd TO Parker Rd$US75$NB	17.37	4.68	31.29	17.53	6265	6049	5727	18041
82-300004$US 75 N 15th St TO Park Blvd$US75$NB	13.04	32.78	2.84	16.49	5137	4975	4643	14755
4458-4414$US 75 N Plano Pkwy TO 15th St$US75$NB	15.85	34.12	5.98	18.78	5084	4950	4769	14803
4314-4457$US 75 N SH 190/President George Bush TPKE TO Plano Pkwy$US75$NB	11.31	2.09	7.77	5.83	5677	5222	5291	16190
4312-4314$US 75 N Renner Rd TO SH 190/President George Bush TPKE$US75$NB	11.69	28.09	14.46	17.88	4524	4169	4268	12961
4359-4367$US 75 N Galatyn Pkwy TO Dallas Collin County Line$US75$NB	9.57	7.88	5.41	2.23	3876	4175	4303	12354
4081-4359$US 75 N Campbell Rd TO Galatyn Pkwy$US75$NB	12.23	12.92	3.58	1.44	5517	5464	5943	16924
4079-4081$US 75 N Collins Blvd TO Campbell Rd$US75$NB	23.59	5.12	11.42	13.13	5919	6327	6600	18846
4078-4079$US 75 N Arapaho Rd TO Collins Blvd$US75$NB	18.19	5.99	6.49	5.99	5515	5861	6040	17416
188-189$US 75 N Belt Line Rd TO Arapaho Rd$US75$NB	19.63	43.61	20.48	28.25	3688	4375	4561	12624
3289-3290$US 75 N Spring Valley Rd TO Belt Line Rd$US75$NB	4.70	1.67	11.20	4.88	5047	5692	6055	16794
3307-3289$US 75 N Spring Valley Rd TO Belt Line Rd$US75$NB	26.76	44.90	30.19	33.96	4193	4339	4578	13110
3306-3307$US 75 N Midpark Rd TO Spring Valley Rd$US75$NB	8.13	11.01	2.50	7.08	4625	4676	5072	14373
3087-3094$US 75 N Cottonwood Creek TO Midpark Rd$US75$NB	4.39	0.40	9.44	5.00	5858	5288	6303	17449
3135-3136$US 75 N Coit Rd TO Churchill Way$US75$NB	9.26	10.55	8.59	9.40	5744	4503	5357	15604
579-21220$US 75 N Royal Ln TO Park Central$US75$NB	37.45	15.70	31.10	28.43	4820	4400	4721	13941
2144-579$US 75 N Meadow Rd TO Royal Ln$US75$NB	6.17	16.03	13.87	11.87	7135	6208	7396	20739
2169-2145$US 75 N Walnut Hill Ln TO Meadow Rd$US75$NB	6.79	0.94	0.89	2.22	5460	4690	6087	16237
2152-2169$US 75 N Park Ln TO Walnut Hill Ln$US75$NB	7.14	1.43	2.35	2.84	5519	4881	5964	16364
2084-2056$US 75 N University Blvd TO Lovers Ln$US75$NB	20.68	18.42	7.46	11.81	6798	6260	5281	18339
2083-2084$US 75 N SMU Blvd TO University Blvd$US75$NB	21.95	9.47	8.39	9.08	6911	5647	5223	17781
735-737$US 75 N Mockingbird Ln TO SMU Blvd$US75$NB	15.02	13.73	21.80	10.44	5565	3868	5992	15425
All Detectors	14.67	14.29	10.35	11.29	180735	177074	182268	540077

Error Legend	
<=15%	
15-25%	
25-40%	
>=40%	

a) Hourly Traffic Volume Comparison for US 75 Freeway - NB



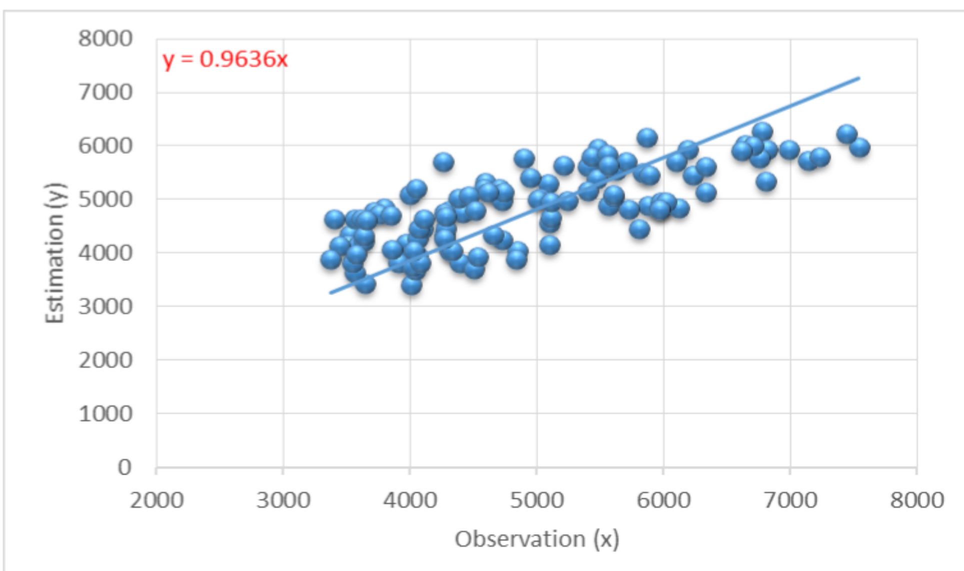
b) Correlation between Observed and Estimated Traffic Volumes for the US 75 Freeway – NB

Figure 4-9: Hourly Traffic Volume Comparison for US 75 Freeway NB - Cluster III [Source: SMU]

Detector Location	Percentage Errors %				Observed Values			
	4-5 PM	5-6 PM	6-7 PM	All PM	4-5 PM	5-6 PM	6-7 PM	All PM
21227-5876$US 75 S Exchange Pkwy TO Allen Dr$US75$SB	3.69	6.70	2.88	2.14	3899	4328	4057	12284
5876-5877$US 75 S Allen Dr TO McDermott Dr$US75$SB	6.47	16.56	13.13	12.24	4313	4844	4531	13688
5877-5917$US 75 S Allen Dr TO McDermott Dr$US75$SB	11.04	5.42	13.48	9.88	4312	4725	4465	13502
5590-5591$US 75 S McDermott Dr TO Bethany Dr$US75$SB	27.28	14.82	28.37	23.18	3794	4380	4050	12224
5591-21217$US 75 S McDermott Dr TO Bethany Dr$US75$SB	7.48	0.20	8.61	5.14	4414	5002	4738	14154
5772-5809$US 75 S Ridgemont Dr TO Chase Oaks Blvd$US75$SB	12.89	19.58	7.02	13.25	4390	4836	4656	13882
5809-5810$US 75 S Ridgemont Dr TO Chase Oaks Blvd$US75$SB	23.24	5.10	25.85	17.61	3524	4057	3757	11338
5810-5811$US 75 S Ridgemont Dr TO Chase Oaks Blvd$US75$SB	1.64	10.15	11.37	0.57	4270	4720	4265	13255
5811-5662$US 75 S Legacy Dr TO Spring Creek Pkwy$US75$SB	5.65	8.68	7.67	2.53	3643	4034	3545	11222
5662-5663$US 75 S Legacy Dr TO Spring Creek Pkwy$US75$SB	15.05	17.96	6.40	13.28	4007	4499	4080	12586
5688-5689$US 75 S Spring Creek Pkwy TO Parker Rd$US75$SB	18.50	8.73	30.33	18.69	3508	4102	3564	11174
5689-5690$US 75 S Spring Creek Pkwy TO Parker Rd$US75$SB	18.50	23.14	9.08	17.17	5096	5800	5110	16006
5690-21213$US 75 S Parker Rd TO Park Blvd$US75$SB	15.39	4.07	28.43	15.27	3587	4278	3613	11478
21213-5731$US 75 S Parker Rd TO Park Blvd$US75$SB	20.19	9.53	36.42	21.27	3437	4072	3399	10908
20-4482$US 75 S Park Blvd TO 15th St$US75$SB	1.99	6.47	11.22	1.90	3565	4017	3575	11157
4409-4410$US 75 S 15th St TO Plano Pkwy$US75$SB	15.39	0.19	18.82	10.74	3372	4271	3634	11277
4456-4310$US 75 S SH 190/President George Bush TPKE TO Renner Rd$US	5.43	13.03	9.32	9.30	3962	4107	4283	12352
4310-4311$US 75 S Renner Rd TO Dallas Collin County Line$US75$SB	16.21	28.19	22.44	22.33	3633	3717	3841	11191
4363-4364$US 75 S Galatyn Pkwy TO Campbell Rd$US75$SB	2.43	5.71	0.45	1.21	3906	3855	4031	11792
4358-4082$US 75 S Campbell Rd TO Collins Blvd$US75$SB	16.76	9.99	9.00	12.00	5877	5603	5600	17080
4082-21180$US 75 S Collins Blvd TO Arapaho Rd$US75$SB	18.92	17.22	19.31	18.48	5994	5977	5965	17936
21180-4085$US 75 S Collins Blvd TO Arapaho Rd$US75$SB	20.94	17.45	19.35	19.26	6117	6012	5969	18098
180-187$US 75 S Arapaho Rd TO Belt Line Rd$US75$SB	9.15	15.70	6.27	10.39	4686	4592	4515	13793
3279-3291$US 75 S Belt Line Rd TO Spring Valley Rd$US75$SB	21.58	14.61	18.93	18.37	6799	6757	6328	19884
3291-3292$US 75 S Belt Line Rd TO Spring Valley Rd$US75$SB	4.29	18.07	11.07	11.05	5087	4892	4617	14596
3300-3304$US 75 S Spring Valley Rd TO Midpark Rd$US75$SB	5.86	8.67	1.61	0.27	5833	5480	5472	16785
3304-3108$US 75 S Midpark Rd TO Cottonwood Creek$US75$SB	20.70	16.21	19.77	18.89	7536	7438	7142	22116
3137-3138$US 75 S Coit Rd TO Forest Ln$US75$SB	12.21	13.24	3.07	1.50	5563	4586	5109	15258
3138-3140$US 75 S Forest Ln TO Park Central$US75$SB	15.84	10.56	4.87	4.25	5727	4699	5240	15666
3164-586$US 75 S Park Central TO Royal Ln$US75$SB	7.29	9.46	10.51	9.07	6774	6641	6611	20026
21224-588$US 75 S Royal Ln TO Meadow Rd$US75$SB	3.97	34.01	1.44	11.46	5397	4264	5559	15220
588-2139$US 75 S Meadow Rd TO Walnut Hill Ln$US75$SB	12.88	10.62	19.83	14.57	6810	6702	7230	20742
2140-2154$US 75 S Walnut Hill Ln TO Park Ln$US75$SB	1.35	0.18	11.45	4.48	5621	5699	6331	17651
2154-2155$US 75 S Park Ln TO Northpark Dr$US75$SB	8.27	6.86	6.57	2.40	5211	5426	6099	16736
2155-2013$US 75 S Northpark Dr TO Loop 12/Northwest Hwy$US75$SB	10.58	27.62	26.39	11.99	5094	3994	3653	12741
2110-2099$US 75 S Southwestern Blvd TO Lovers Ln$US75$SB	0.02	5.08	4.44	0.26	5030	5554	5405	15989
2059-2058$US 75 S Lovers Ln TO University Blvd$US75$SB	9.41	5.15	6.75	6.99	4942	5866	4768	15576
2090-733$US 75 S Mockingbird Ln TO McCommas Blvd$US75$SB	7.49	4.14	11.12	7.41	5884	6190	5353	17427
733-734$US 75 S Mockingbird Ln TO McCommas Blvd$US75$SB	12.51	15.20	25.99	17.89	6225	6988	6444	19657
All Detectors	11.59	11.71	12.78	10.60	190839	197004	190604	578447

Error Legend	
<=15%	
15-25%	
25-40%	
>=40%	

a) Hourly Traffic Volume Comparison for US 75 Freeway - SB



b) Correlation between Observed and Estimated Traffic Volumes for the US 75 Freeway – SB

Figure 4-10: Hourly Traffic Volume Comparison for US 75 Freeway SB - Cluster III [Source: SMU]

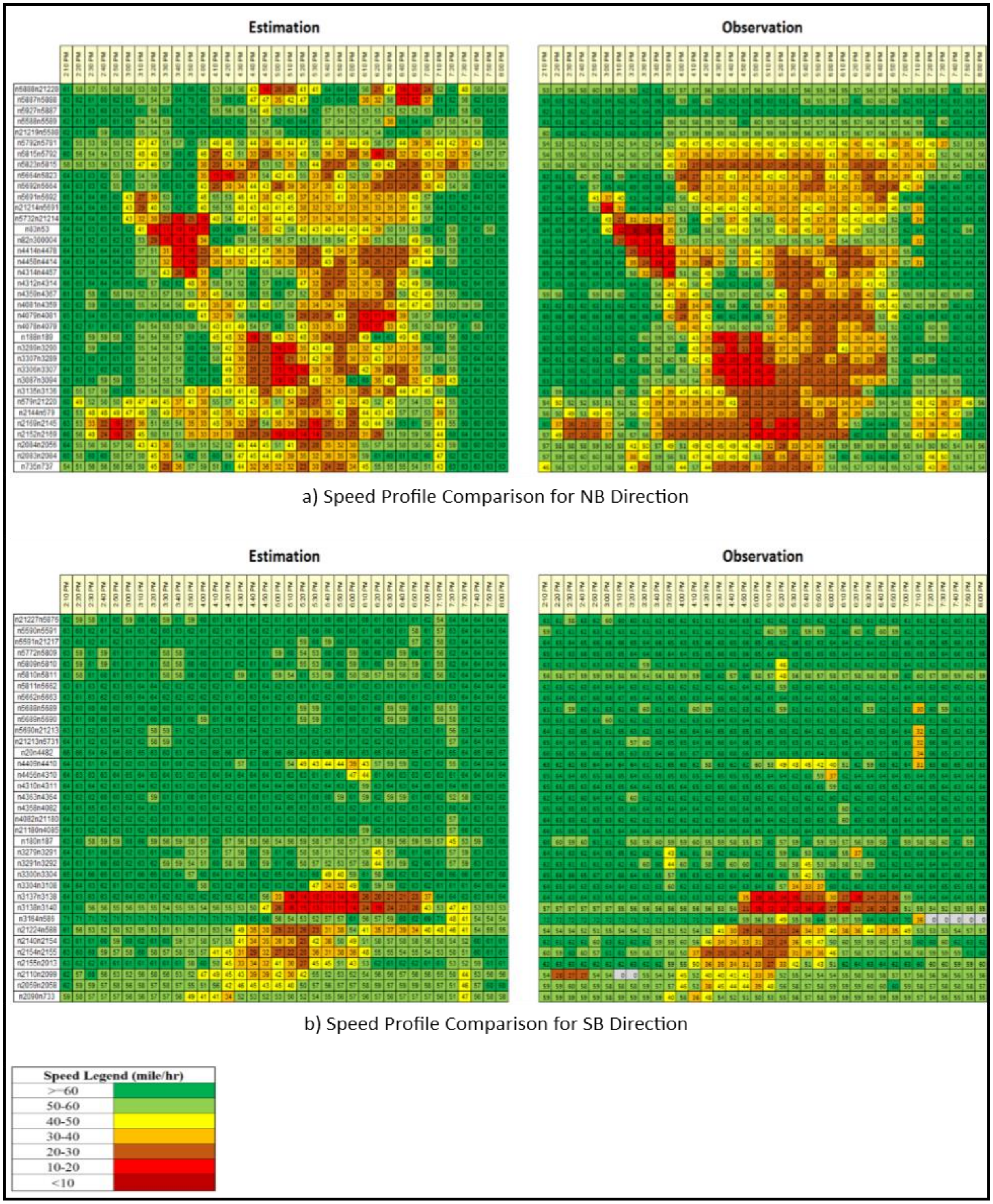


Figure 4-11: Estimated and Observed Time-Dependent Speed Profile for US 75 Freeway - Cluster III [Source: SMU]

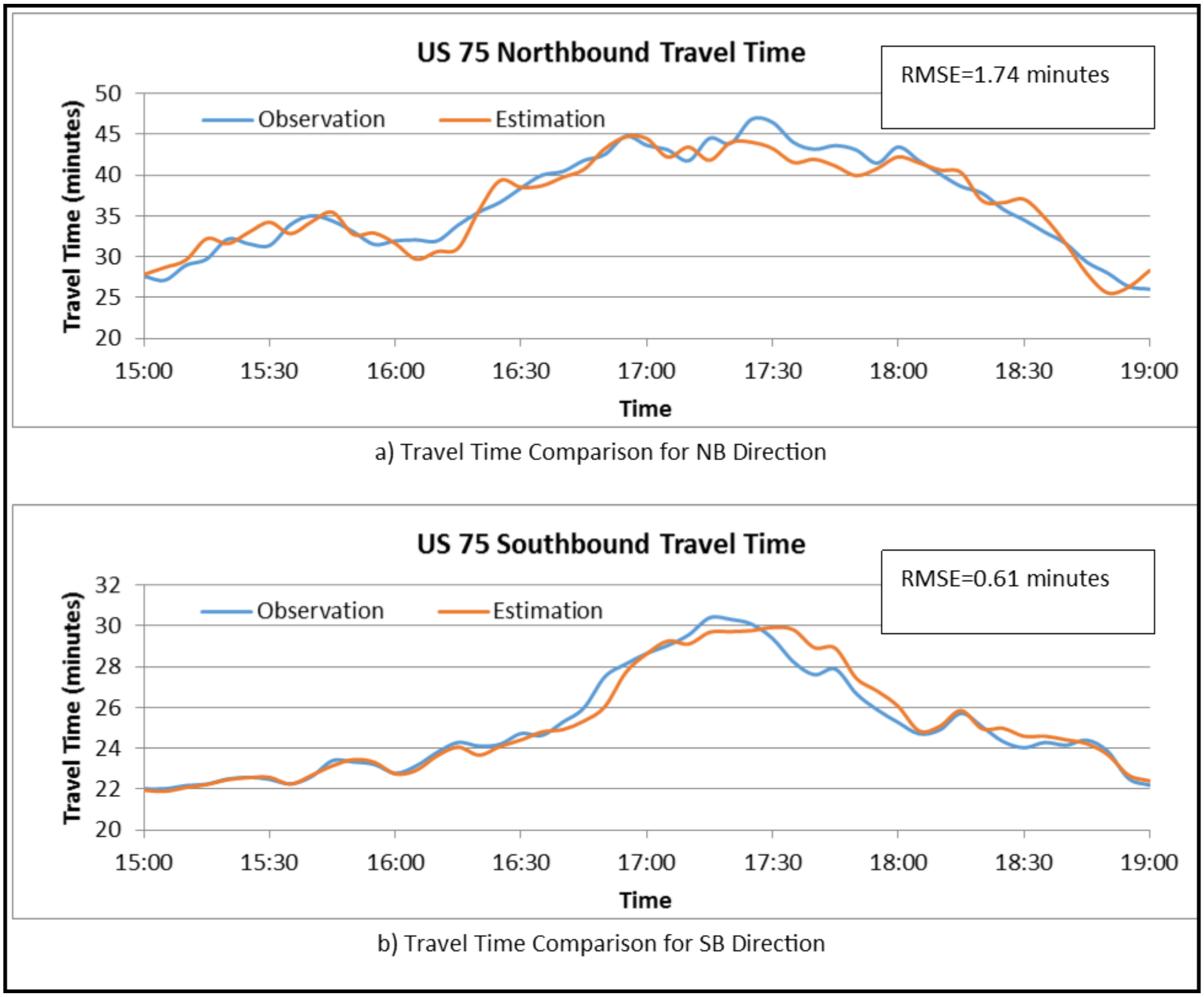


Figure 4-12: Estimated and Observed Travel Time for US 75 Freeway - Cluster III [Source: SMU]

4.5 Calibration Results for Baseline Scenario IV

As described earlier, based on the conducted cluster analysis, the operation conditions of Cluster IV represent a baseline scenario in which high demand, with major incident, and dry conditions are considered. A representative peak period that represents this cluster is selected. Figure 4-13 to Figure 4-16 illustrate the model calibration results against the observed traffic pattern for this representative peak period.

Figure 4-13 and Figure 4-14 give the percentage error in the hourly traffic volumes for the US 75 freeway for the NB and SB directions, respectively. As shown in Figure 4-13 a, which provides the percentage error for the NB direction, 54% of the hourly observations have percentage error less than 15%, and 81% of the observations have percentage error that is less than 25%. 2% of the hourly observations with error that is greater than 40% have been recorded. Considering the entire peak period, out of the 35 detectors available on the freeway in the NB direction, a percentage error of less than 15% is recorded for 21 detectors, an error that is greater than 15% and less than 25% is recorded for ten detectors, and four detectors are recorded with error that is greater than 25% and less than 40%.

Considering all detectors along the NB directions (the last row), the percentage error in the first hour of the peak period (4:00 to 5:00) is recorded at 16.48%. This error is recorded at 18.62% and 15.87% for the second and third hours of the peak period, respectively.

As shown in Figure 4-13 b, the slope of the best-fitting line between the observed and estimated hourly volumes is recorded at 0.900, which indicates that the model is generally capturing the overall demand level along the NB travel direction.

For the SB direction, as illustrated in Figure 4-14 a, 65% of the hourly observations have percentage error that is less than 15%, and 89% of the observations have percentage error that is less than 25%. No observations with error is greater than 40% have been recorded. Considering the entire peak period for the SB direction, out of the 38 detectors available along that direction, a percentage error of less than 15% is recorded for 30 detectors, eight detectors have error that is greater than 15% and less than 25%, and one detector have an error that is greater than 25% and less than 40%. Considering all detectors along the SB directions, the percentage error is recorded at 16.01% for the first hour, 13.23% for the second hour, and 16.91% for the third hour. As shown in Figure 4-14 b, the slope of the best-fitting line between observed and estimated hourly volumes is recorded at 0.962, which indicates that the model is generally capturing the overall demand level along the SB travel direction.

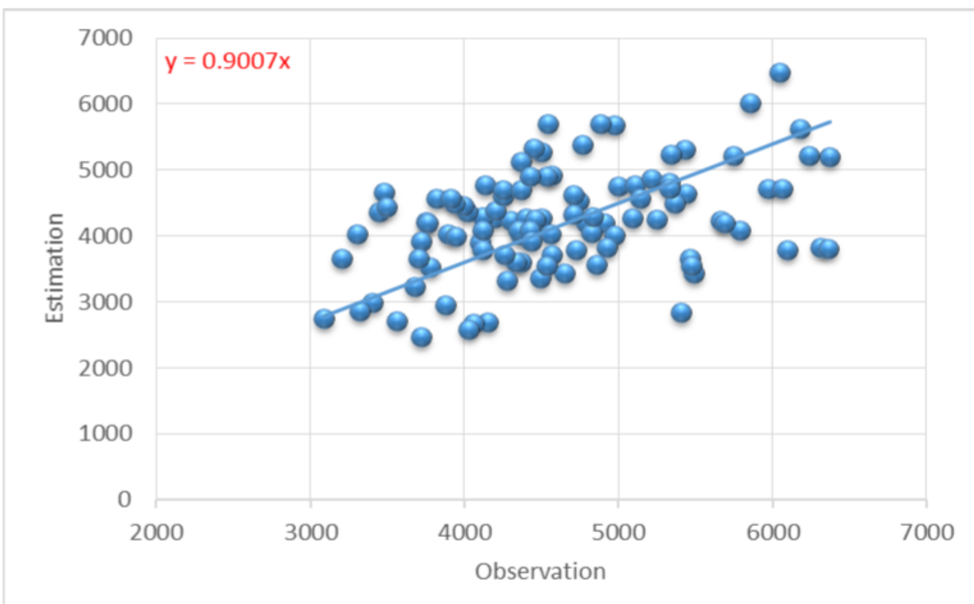
The estimated and observed US 75 speed profiles are given in Figure 4-15 for both NB and SB directions. As mentioned above, the estimated and observed speeds are recorded for each detector at 10 minute intervals. The top of the figure gives the speed for the north section of the freeway (City of Plano), while the bottom of the figure gives the speed for the south section (north of downtown Dallas).

As illustrated in these figures, the model is generally replicating the observed speed profile in both directions. For instance, in the NB direction, the model replicates the high reduction in the speed in the south and north sections of the freeway during the period of 4:00 pm to 8:00 pm. The model also replicates the high reduction in speed observed along the SB direction during the period of 4:50 pm to 6:50 pm. Finally, the comparison between for estimated and observed time-varying travel time for both directions is given in Figure 4-16. The figure shows that model generally replicates the travel time along the freeway for both directions. The RMSE between the observed and estimated travel time is around two minutes for both directions.

Detector Location	Percentage Errors %				Observed Values			
	4-5 PM	5-6 PM	6-7 PM	All PM	4-5 PM	5-6 PM	6-7 PM	All PM
5888-21228$US 75 N Exchange Pkwy TO Stacy Rd$US75$NB	1.77	25.50	0.70	9.36	4190	4537	4118	12845
5887-5888$US 75 N Allen Dr TO Exchange Pkwy$US75$NB	4.87	14.33	7.66	1.12	4497	4976	4423	13896
5927-5887$US 75 N McDermott Dr TO Allen Dr$US75$NB	14.44	7.28	2.08	2.71	5438	6045	5429	16912
5588-5589$US 75 N Bethany Dr TO McDermott Dr$US75$NB	16.30	2.77	1.80	4.89	5367	5856	5335	16558
21219-5588$US 75 N Bethany Dr TO McDermott Dr$US75$NB	29.53	8.81	9.17	15.70	5791	6174	5748	17713
5792-5781$US 75 N Enterprise Blvd TO Bethany Dr$US75$NB	12.30	12.77	7.77	2.66	4789	4769	4566	14124
5815-5792$US 75 N Chase Oaks Blvd TO Ridgemont Dr$US75$NB	4.33	16.75	8.14	6.93	4737	4878	4533	14148
5823-5815$US 75 N Legacy Dr TO Chase Oaks Blvd$US75$NB	6.33	8.61	5.19	2.61	3775	4017	3719	11511
5664-5823$US 75 N Spring Creek Pkwy TO Legacy Dr$US75$NB	26.38	7.92	11.73	15.53	4853	4710	4433	13996
5692-5664$US 75 N Spring Creek Pkwy TO Legacy Dr$US75$NB	4.75	15.49	11.89	7.44	4102	4133	3759	11994
5691-5692$US 75 N Parker Rd TO Spring Creek Pkwy$US75$NB	37.56	25.37	22.13	28.54	5490	5665	4926	16081
21214-5691$US 75 N Parker Rd TO Spring Creek Pkwy$US75$NB	8.13	8.50	11.50	3.69	4366	4249	3992	12607
5732-21214$US 75 N Parker Rd TO Spring Creek Pkwy$US75$NB	3.70	19.80	27.38	16.56	3896	3819	3492	11207
83-53$US 75 N Park Blvd TO Parker Rd$US75$NB	32.88	26.09	16.08	25.38	5466	5689	4827	15982
82-300004$US 75 N 15th St TO Park Blvd$US75$NB	1.61	10.73	14.20	7.58	4296	4249	3938	12483
4458-4414$US 75 N Plano Pkwy TO 15th St$US75$NB	3.07	1.68	7.81	0.94	4400	4704	4366	13470
4314-4457$US 75 N SH 190/President George Bush TPKE TO Plano Pkwy$US75$NB	17.32	19.20	10.96	15.71	4364	4969	5136	14469
4312-4314$US 75 N Renner Rd TO SH 190/President George Bush TPKE$US75$NB	14.25	1.29	17.06	10.62	3199	3943	3905	11047
4359-4367$US 75 N Galatyn Pkwy TO Dallas Collin County Line$US75$NB	12.07	23.48	16.97	17.54	3406	3556	4331	11293
4081-4359$US 75 N Campbell Rd TO Galatyn Pkwy$US75$NB	4.08	25.05	6.54	9.39	4119	4491	5215	13825
4079-4081$US 75 N Collins Blvd TO Campbell Rd$US75$NB	11.58	35.18	22.01	22.49	4559	4153	6061	14773
4078-4079$US 75 N Arapaho Rd TO Collins Blvd$US75$NB	6.19	34.04	9.59	15.74	4347	4060	5331	13738
188-189$US 75 N Belt Line Rd TO Arapaho Rd$US75$NB	12.59	11.15	17.58	7.99	3748	3085	4364	11197
3289-3290$US 75 N Spring Valley Rd TO Belt Line Rd$US75$NB	14.49	35.68	11.36	19.30	4908	4028	5328	14264
3307-3289$US 75 N Spring Valley Rd TO Belt Line Rd$US75$NB	4.36	13.92	10.76	1.65	4202	3318	4425	11945
3306-3307$US 75 N Midpark Rd TO Spring Valley Rd$US75$NB	18.70	33.69	19.57	23.30	4566	3719	4722	13007
3087-3094$US 75 N Cottonwood Creek TO Midpark Rd$US75$NB	37.71	47.28	39.52	41.26	6096	5406	6314	17816
3135-3136$US 75 N Coit Rd TO Churchill Way$US75$NB	35.20	22.24	22.01	16.35	5468	3300	4275	13043
579-21220$US 75 N Royal Ln TO Park Central$US75$NB	8.16	33.85	12.56	2.59	4117	3480	4259	11856
2144-579$US 75 N Meadow Rd TO Royal Ln$US75$NB	20.88	19.05	40.14	27.31	5968	5244	6362	17574
2169-2145$US 75 N Walnut Hill Ln TO Meadow Rd$US75$NB	17.09	23.75	25.99	10.45	4499	3878	4651	13028
2152-2169$US 75 N Park Ln TO Walnut Hill Ln$US75$NB	19.93	11.78	21.65	4.17	4445	3675	4531	12651
2084-2056$US 75 N University Blvd TO Lovers Ln$US75$NB	18.28	4.74	11.18	11.98	6369	4996	4831	16196
2083-2084$US 75 N SMU Blvd TO University Blvd$US75$NB	16.25	6.66	15.93	13.17	6239	5106	5085	16430
735-737$US 75 N Mockingbird Ln TO SMU Blvd$US75$NB	4.53	26.60	0.97	5.84	4460	3443	3699	11602
All Detectors	16.48	18.62	15.87	13.92	164532	156320	164429	485281

Error Legend	
<=15%	
15-25%	
25-40%	
>=40%	

a) Hourly Traffic Volume Comparison for US 75 Freeway - NB



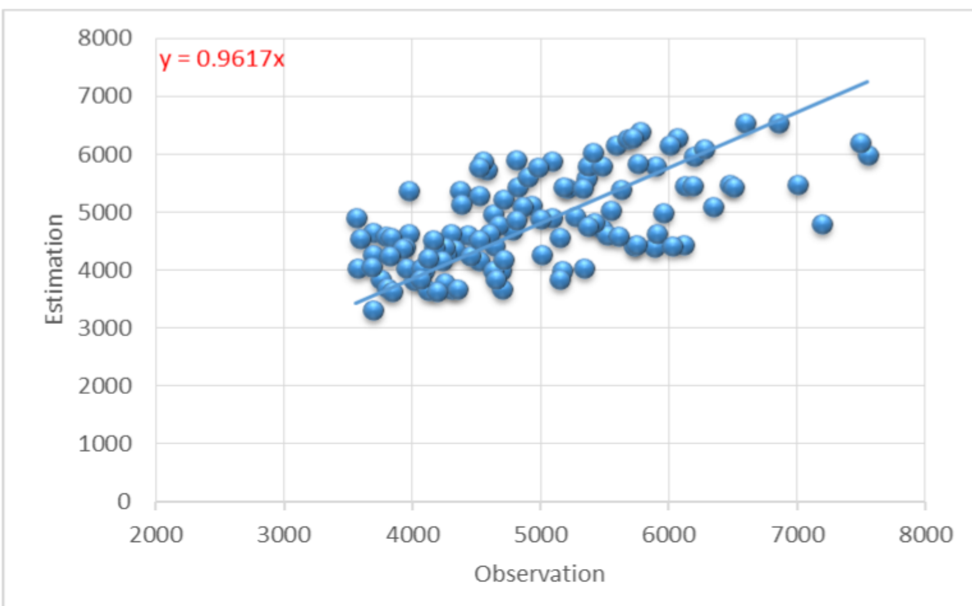
b) Correlation between Observed and Estimated Traffic Volumes for the US 75 Freeway – NB

Figure 4-13: Hourly Traffic Volume Comparison for US 75 Freeway NB - Cluster IV [Source: SMU]

Detector Location	Percentage Errors %				Observed Values			
	4-5 PM	5-6 PM	6-7 PM	All PM	4-5 PM	5-6 PM	6-7 PM	All PM
21227-5876$US 75 S Exchange Pkwy TO Allen Dr$US75$SB	16.29	14.70	2.30	1.07	3971	4688	4094	12753
5876-5877$US 75 S Allen Dr TO McDermott Dr$US75$SB	3.92	22.57	13.53	11.37	4434	5166	4628	14228
5877-5917$US 75 S Allen Dr TO McDermott Dr$US75$SB	22.68	3.79	2.44	6.46	4373	5091	4671	14135
5590-5591$US 75 S McDermott Dr TO Bethany Dr$US75$SB	35.11	7.03	17.59	19.18	3970	4634	4377	12981
5591-21217$US 75 S McDermott Dr TO Bethany Dr$US75$SB	16.74	6.55	5.04	4.48	4523	5268	4858	14649
5772-5809$US 75 S Ridgemont Dr TO Chase Oaks Blvd$US75$SB	8.00	25.39	17.13	17.22	4524	5148	4646	14318
5809-5810$US 75 S Ridgemont Dr TO Chase Oaks Blvd$US75$SB	25.79	0.14	10.75	11.62	3692	4262	3825	11779
5810-5811$US 75 S Ridgemont Dr TO Chase Oaks Blvd$US75$SB	7.66	14.76	4.76	4.53	4296	5013	4453	13762
5811-5662$US 75 S Legacy Dr TO Spring Creek Pkwy$US75$SB	2.45	14.31	5.44	6.15	3749	4299	3845	11893
5662-5663$US 75 S Legacy Dr TO Spring Creek Pkwy$US75$SB	4.57	21.82	13.23	13.67	4007	4703	4189	12899
5688-5689$US 75 S Spring Creek Pkwy TO Parker Rd$US75$SB	20.81	3.34	2.15	8.47	3792	4253	3949	11994
5689-5690$US 75 S Spring Creek Pkwy TO Parker Rd$US75$SB	11.08	25.45	24.33	20.57	5144	5889	5335	16368
5690-21213$US 75 S Parker Rd TO Park Blvd$US75$SB	18.84	5.33	0.71	7.58	3833	4168	4072	12073
21213-5731$US 75 S Parker Rd TO Park Blvd$US75$SB	26.56	11.70	9.85	15.85	3588	3923	3686	11197
20-4482$US 75 S Park Blvd TO 15th St$US75$SB	12.69	2.94	10.34	0.37	3571	3807	3696	11074
4409-4410$US 75 S 15th St TO Plano Pkwy$US75$SB	15.48	1.46	5.22	2.48	3694	4234	4065	11993
4456-4310$US 75 S SH 190/President George Bush TPKE TO Renner Rd$US	0.51	4.74	11.21	5.31	4329	4644	4711	13684
4310-4311$US 75 S Renner Rd TO Dallas Collin County Line$US75$SB	11.32	8.55	1.79	7.16	3941	4164	4125	12230
4363-4364$US 75 S Galatyn Pkwy TO Campbell Rd$US75$SB	11.39	11.09	15.72	12.77	4125	4246	4346	12717
4358-4082$US 75 S Campbell Rd TO Collins Blvd$US75$SB	13.75	2.32	11.08	9.24	5476	5002	5414	15892
4082-21180$US 75 S Collins Blvd TO Arapaho Rd$US75$SB	27.39	21.80	26.75	25.35	6111	5908	6027	18046
21180-4085$US 75 S Collins Blvd TO Arapaho Rd$US75$SB	22.87	16.70	22.88	20.87	5727	5521	5748	16996
180-187$US 75 S Arapaho Rd TO Belt Line Rd$US75$SB	1.99	11.07	0.52	3.20	4779	4706	4599	14084
3279-3291$US 75 S Belt Line Rd TO Spring Valley Rd$US75$SB	19.73	11.66	18.27	16.53	6347	6182	5604	18133
3291-3292$US 75 S Belt Line Rd TO Spring Valley Rd$US75$SB	3.63	12.46	0.13	5.51	4929	4824	4519	14272
3300-3304$US 75 S Spring Valley Rd TO Midpark Rd$US75$SB	15.32	3.73	11.41	10.17	6474	6200	5372	18046
3304-3108$US 75 S Midpark Rd TO Cottonwood Creek$US75$SB	20.57	17.34	33.34	23.61	7548	7493	7192	22233
3137-3138$US 75 S Coit Rd TO Forest Ln$US75$SB	9.49	5.00	0.94	1.44	5552	5178	4810	15540
3138-3140$US 75 S Forest Ln TO Park Central$US75$SB	16.33	4.16	37.54	0.85	5960	5628	3559	15147
21224-588$US 75 S Royal Ln TO Meadow Rd$US75$SB	10.14	10.54	25.23	14.65	5584	5674	4581	15839
588-2139$US 75 S Meadow Rd TO Walnut Hill Ln$US75$SB	0.70	4.68	2.95	2.80	6595	6852	6274	19721
2140-2154$US 75 S Walnut Hill Ln TO Park Ln$US75$SB	3.68	2.63	15.69	6.88	6062	6001	5091	17154
2154-2155$US 75 S Park Ln TO Northpark Dr$US75$SB	10.70	9.80	22.68	13.92	5775	5716	4811	16302
2155-2013$US 75 S Northpark Dr TO Loop 12/Northwest Hwy$US75$SB	3.76	7.91	14.55	8.62	5210	5370	4901	15481
2110-2099$US 75 S Southwestern Blvd TO Lovers Ln$US75$SB	4.01	1.60	29.25	10.45	5360	5752	4547	15659
2059-2058$US 75 S Lovers Ln TO University Blvd$US75$SB	1.83	5.84	11.45	4.95	5899	5479	5408	16786
2090-733$US 75 S Mockingbird Ln TO McCommas Blvd$US75$SB	10.79	1.69	27.56	4.22	6126	5331	4521	15978
733-734$US 75 S Mockingbird Ln TO McCommas Blvd$US75$SB	21.92	16.42	16.14	9.74	7002	6505	4976	18483
All Detectors	16.01	13.23	16.91	13.53	190072	196922	179525	566519

Error Legend	
<=15%	
15-25%	
25-40%	
>=40%	

a) Hourly Traffic Volume Comparison for US 75 Freeway - SB



b) Correlation between Observed and Estimated Traffic Volumes for the US 75 Freeway – SB

Figure 4-14: Hourly Traffic Volume Comparison for US 75 Freeway SB - Cluster IV [Source: SMU]

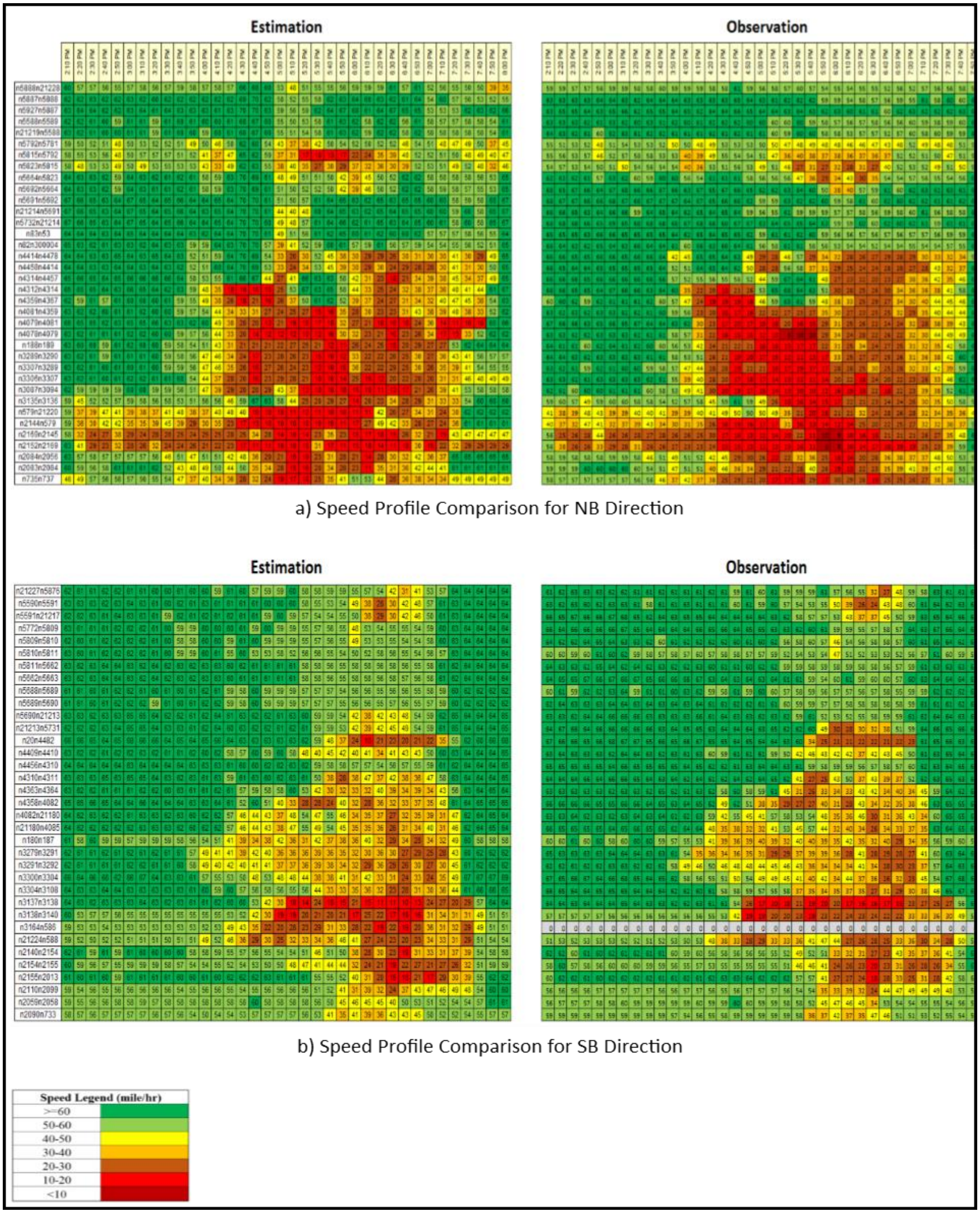
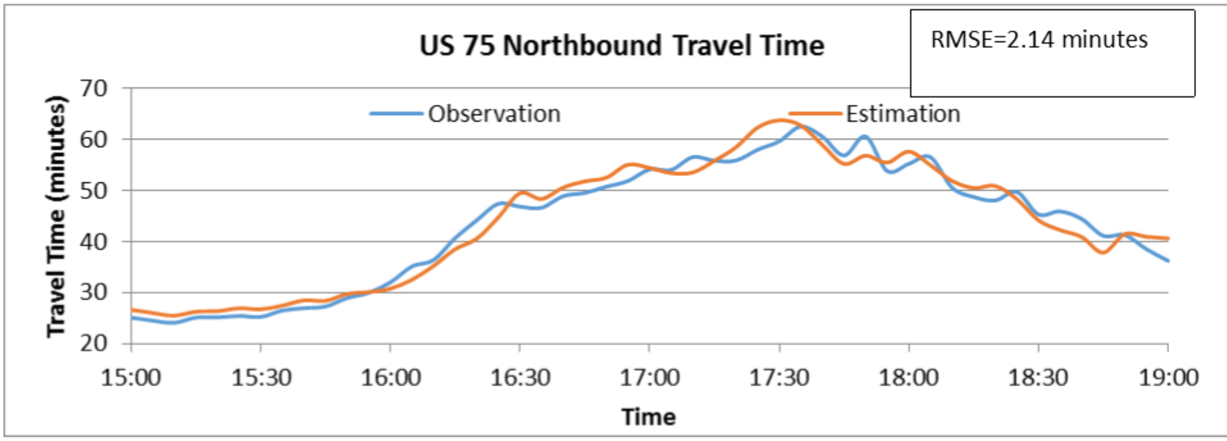
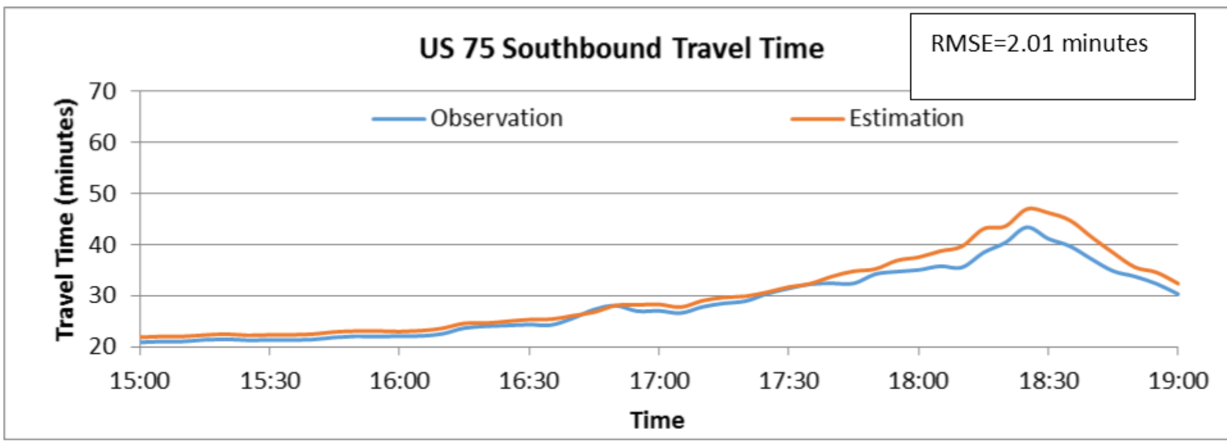


Figure 4-15: Estimated and Observed Time-Dependent Speed Profile for US 75 Freeway - Cluster IV [Source: SMU]



a) Travel Time Comparison for NB Direction



b) Travel Time Comparison for SB Direction

Figure 4-16: Estimated and Observed Travel Time for US 75 Freeway - Cluster IV [Source: SMU]

4.6 Comparison against the Calibration Criteria

This section provides a summary of the calibration criteria targeted in this analysis. In addition, it compares the calibration results, presented in the previous four subsections for the different operational scenarios, against these criteria. As illustrated in Table 4-1, four main criteria are targeted. The first criterion compares the aggregated traffic volume estimated by the model and its corresponding observed one. The second criterion pertains to limiting the difference between the estimated and observed hourly volumes to less than 15% for at least 85% of the hourly volume observations. The third criterion ensures that the model accurately replicates the observed travel time. Finally, visual audit criteria are considered to compare the observed and estimated bottleneck patterns.

Table 4-2 and Table 4-3 compare the results obtained for the different operational condition scenarios against these two criteria. As illustrated in Table 4-2, the percentage error between the aggregated observed and estimated traffic volumes is less than 5% for all cases, which indicates that the model captures the overall congestion level in the network. Table 4-3 provides the comparison for the hourly volumes in criterion 2. The percentage of detector observations that satisfy a threshold error of 15%, 20% and 25% are given in Table 4-3 a to Table 4-3 c, respectively. As shown in the tables, at 15% error threshold, the percentage of detectors that satisfy such threshold of is less than 85%. However, as this error threshold is relaxed to 20%, the percentage of links increased to close to the targeted percentage of 85%. As the error is further relaxed to 25%, a high percentage of the links meet such error threshold. For criterion 3, Figure 4-17 to Figure 4-20 show the percentage error between the observed and estimated time-varying travel time during the peak period. As shown in the figure, the error is less than 15% for almost all observations. Finally, based on the visual audits of the bottlenecks given in the previous subsection, the model replicates the tempo-spatial congestion patterns along the NB and SB directions of the US 75 freeway at a satisfactory level.

Table 4-1: Target Calibration Criteria Used in the Analysis

Calibration Criteria and Measures	Calibration Acceptance Targets
1. Sum of all link flows	Within 5% of sum of all link counts
2. Traffic flows within 15% of observed volumes for links with peak-period volumes greater than 2,000 vph	For 85% of cases for links with peak-period volumes greater than 2,000 vph
3. Travel Time Error is within 15%	For 85% of cases
Visual Audits *Individual Link Speeds: Visually Acceptable Speed-Flow Relationship*	To analyst's satisfaction
Visual Audits *Bottlenecks: Visually Acceptable Queuing*	To analyst's satisfaction

Table 4-2: Comparison of Aggregated Traffic Volume

Operational Conditions (Cluster)	US 75 Northbound			US 75 Southbound		
	Estimated sum of hourly volumes for all detectors	Observed sum of hourly volumes for all detectors	% Error	Estimated sum of hourly volumes for all detectors	Observed sum of hourly volumes for all detectors	% Error
1	403,745	405,080	0.33%	472,058	490,766	3.81%
2	456,549	473,031	3.48%	464,155	476,775	2.65%
3	559,191	540,077	3.54%	568,188	578,447	1.77%
4	463,867	485,281	4.41%	553,096	566,519	2.37%

Table 4-3: Percentage of Detector Observations that meet a Certain Percentage Error

a) Percentage Error between Estimated and Observed Hourly volumes: 15%

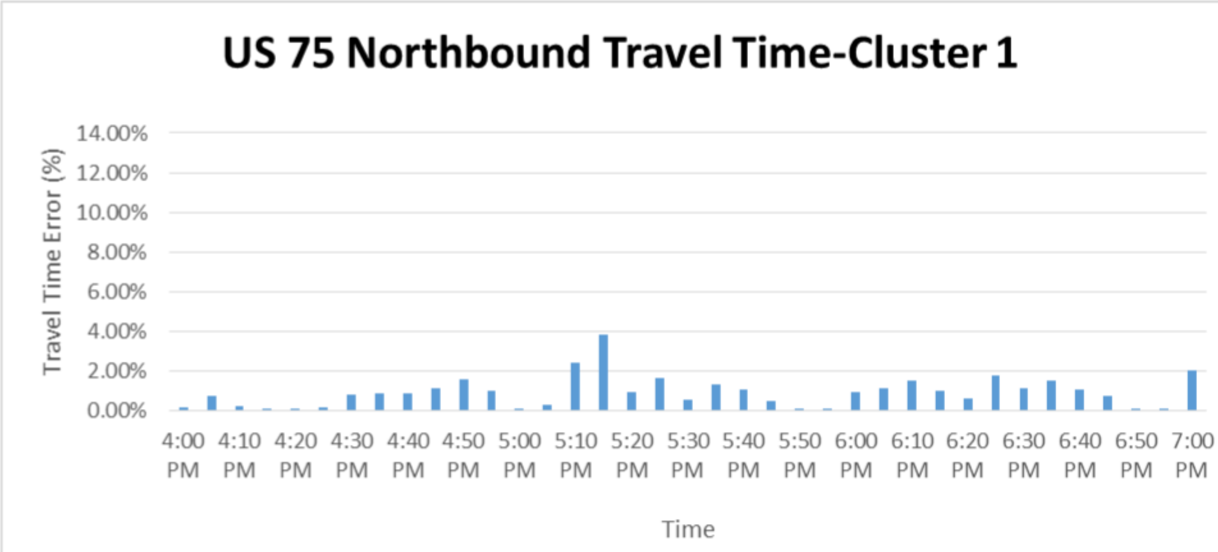
Operational Conditions (Cluster)	US 75 Northbound			US 75 Southbound		
	Total number of detectors	Number of detectors with <15% error	% of detectors with <15% error	Total number of detectors	Number of detectors with <15% error	% of detectors with <15% error
1	30	21	70.00%	38	22	57.89%
2	31	21	67.74%	35	21	60.00%
3	35	23	65.71%	39	27	69.23%
4	35	22	62.86%	38	30	78.95%

b) Percentage Error between Estimated and Observed Hourly Volumes: 20%

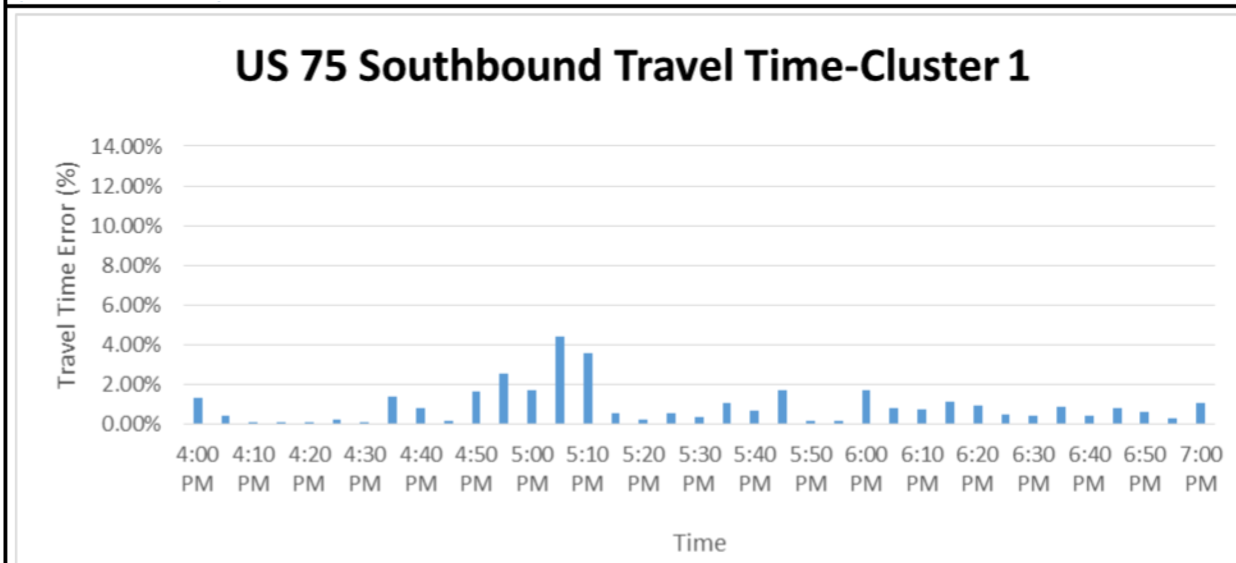
Operational Conditions (Cluster)	US 75 Northbound			US 75 Southbound		
	Total number of detectors	Number of detectors with <20% error	% of detectors with <20% error	Total number of detectors	Number of detectors with <20% error	% of detectors with <20% error
1	30	23	76.67%	38	30	78.95%
2	31	25	80.65%	35	31	88.57%
3	35	30	85.71%	39	36	92.31%
4	35	29	82.86%	38	34	89.47%

c) Percentage Error between Estimated and Observed Hourly Volumes: 25%

Operational Conditions (Cluster)	US 75 Northbound			US 75 Southbound		
	Total number of detectors	Number of detectors with <25% error	% of detectors with <25% error	Total number of detectors	Number of detectors with <25% error	% of detectors with <25% error
1	30	24	80.00%	38	37	97.37%
2	31	27	87.10%	35	32	91.43%
3	35	32	91.43%	39	39	100.00%
4	35	31	88.57%	38	37	97.37%

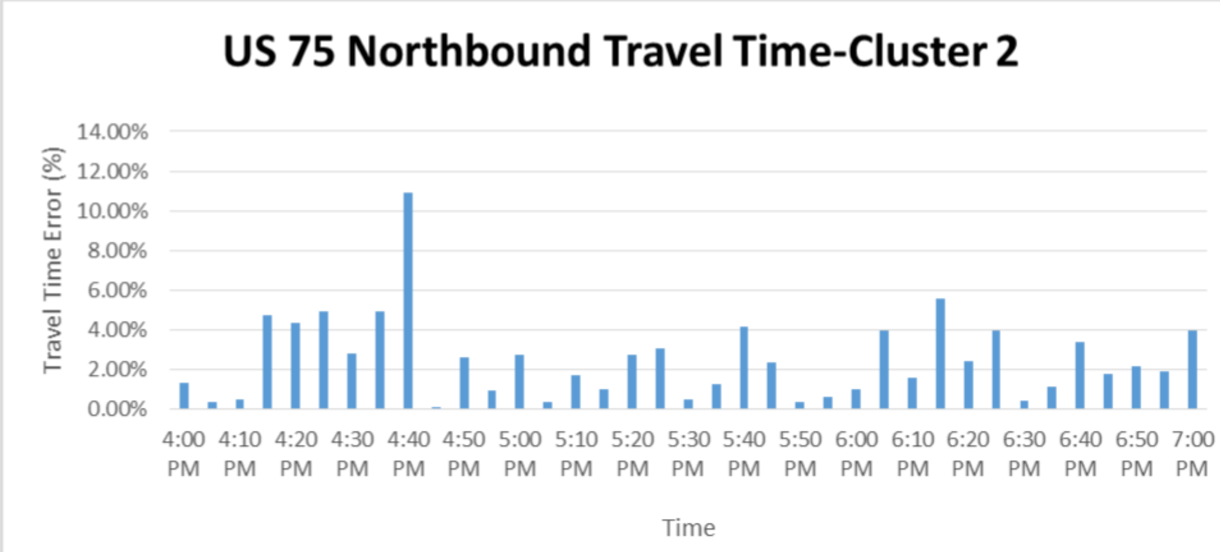


a) Travel Time Comparison for the US 75 NB Direction

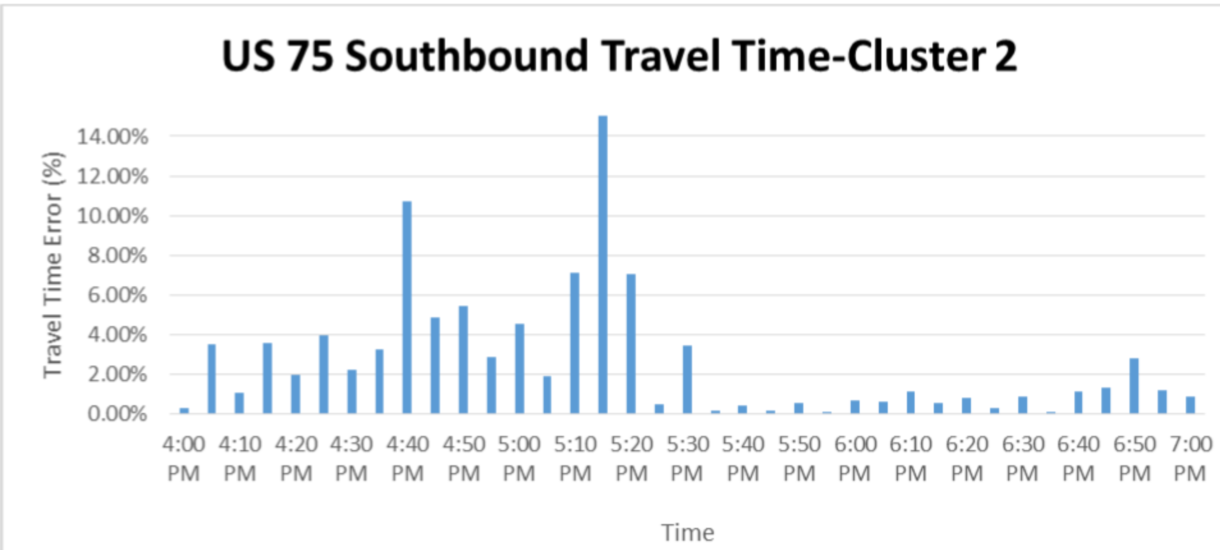


b) Travel Time Comparison for the US 75 SB Direction

Figure 4-17: Percentage Error between Estimated and Observed Time Varying Travel Time - Cluster I [Source: SMU]

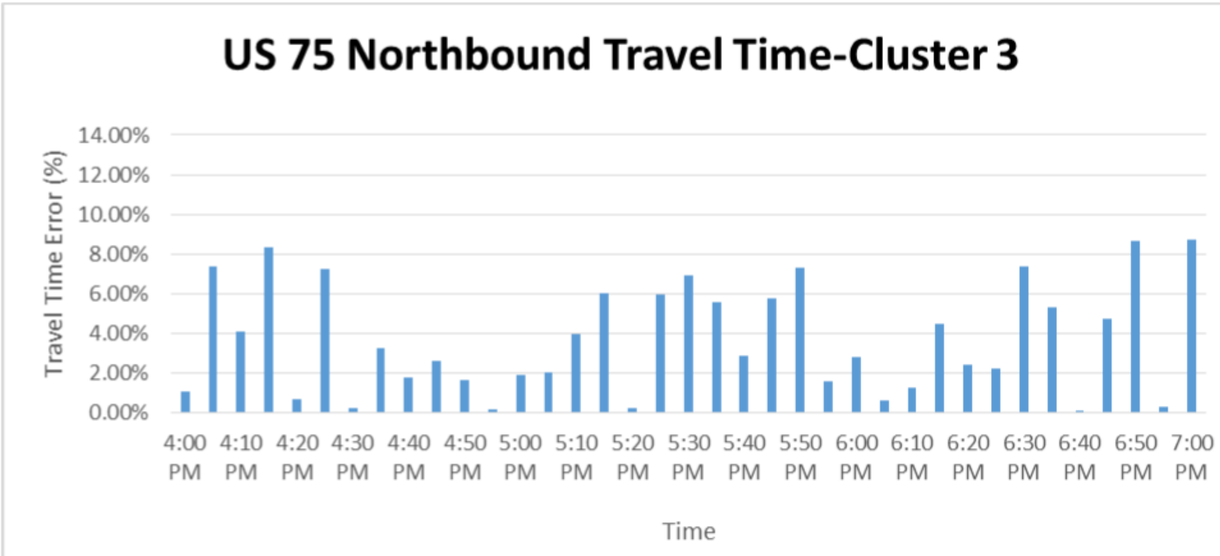


a) Travel Time Comparison for the US 75 NB Direction

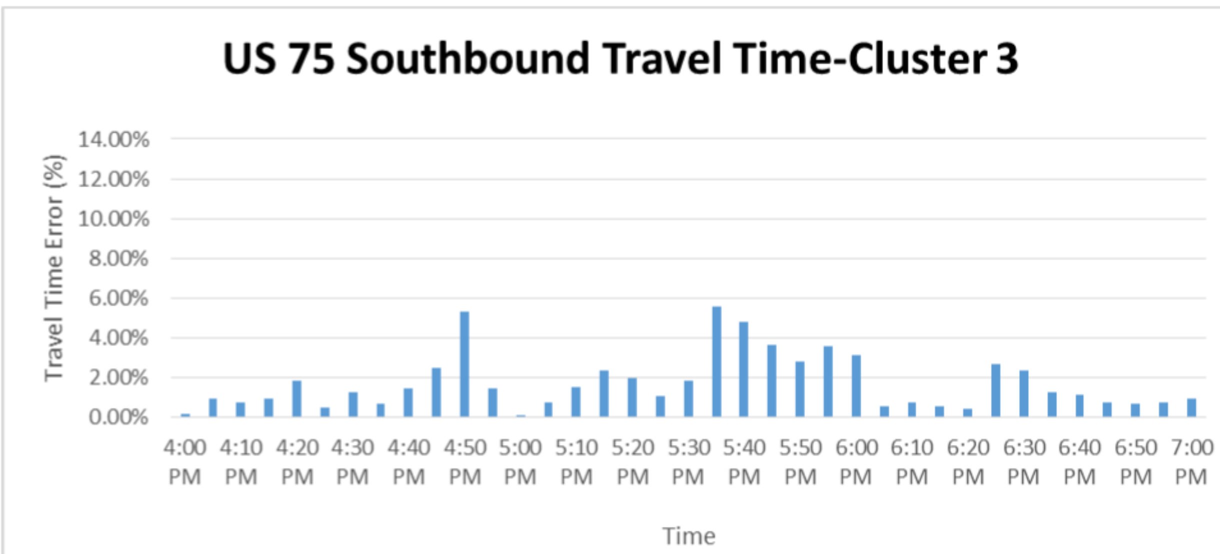


b) Travel Time Comparison for the US 75 SB Direction

Figure 4-18: Percentage Error between Estimated and Observed Time Varying Travel Time - Cluster II [Source: SMU]

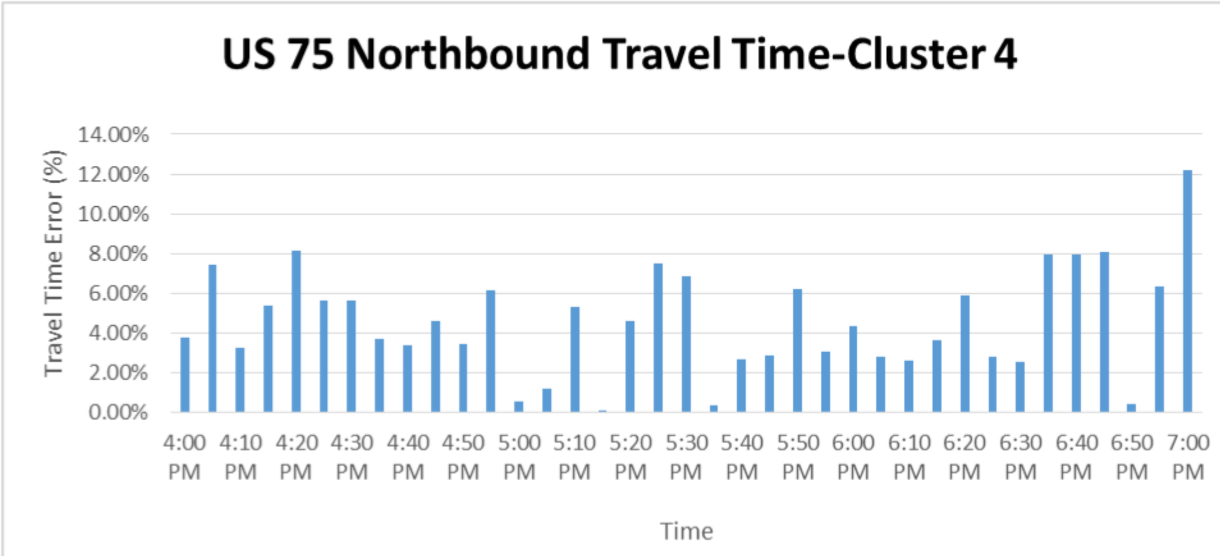


a) Travel Time Comparison for the US 75 NB Direction

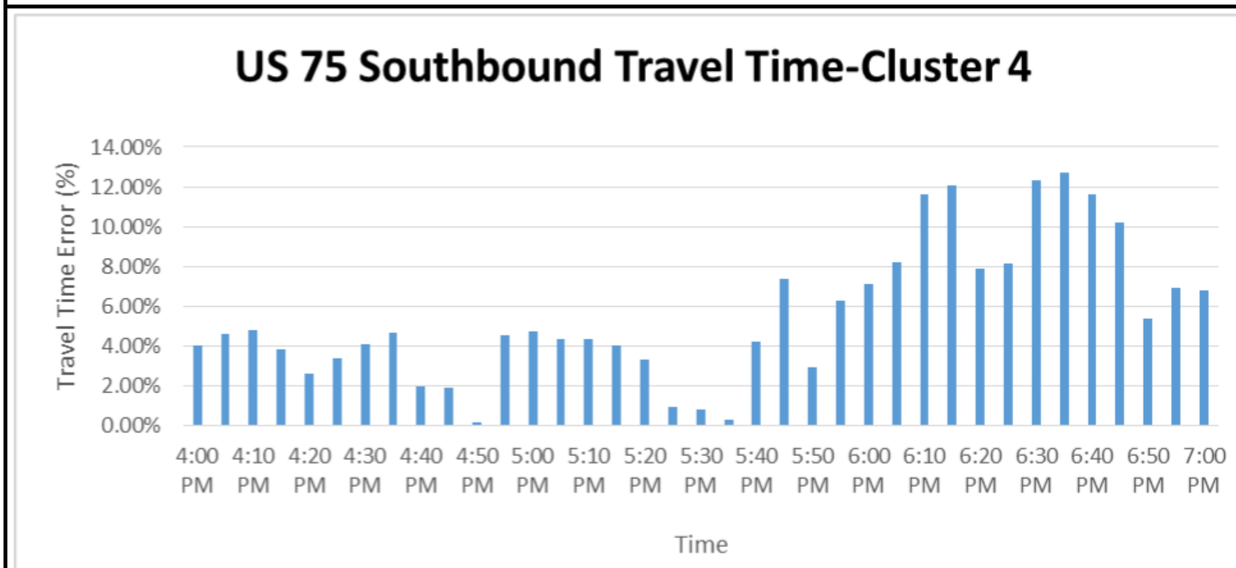


b) Travel Time Comparison for the US 75 SB Direction

Figure 4-19: Percentage Error between Estimated and Observed Time Varying Travel Time - Cluster III [Source: SMU]



a) Travel Time Comparison for the US 75 NB Direction



b) Travel Time Comparison for the US 75 SB Direction

Figure 4-20: Percentage Error between Estimated and Observed Time Varying Travel Time - Cluster IV [Source: SMU]

4.7 Summary

This report presents the methodology used to calibrate the DIRECT model for the baseline scenarios that were identified to examine the effectiveness of the different ATDM strategies in the ICM Dallas Testbed. The calibration methodology involves simultaneously adjusting the time-dependent demand pattern and the flow propagation models for the different links in order to replicate the observed traffic congestion pattern for these baseline scenarios. Based on the calibration effort conducted in this study, a set of results that illustrate the estimated and observed time-varying link flows as well as the speed and travel time profiles are presented.

It is worth mentioning that the calibration of such large-scale simulation models is a challenging task. The large number of model parameters and the lack of a comprehensive data require the analyst to apply her own judgment in the process. In addition, models generally have limited degrees of freedom compared to their real-world systems. These limited degrees of freedom are due to the simplification/assumption used to model many of the complex phenomena inherited in these systems (e.g., travel behavior, flow propagation, etc.).

Completing the calibration of the baseline scenarios is a significant milestone for this project. The next steps involve finalizing the experimental design and perform the simulation experiments to answer the research questions defined as part of this project.

U.S. Department of Transportation
ITS Joint Program Office-HOIT
1200 New Jersey Avenue, SE
Washington, DC 20590

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