FIELD APPLICATIONS OF CORSIM:
I-40 FREEWAY DESIGN EVALUATION, OKLAHOMA CITY, OK

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ABSTRACT

Simulation of traffic flow is an effective tool for evaluating alternative roadway designs, particularly in congested urban areas. CORSIM, a traffic simulation model with detailed representation of vehicles and their interactions, was used to study the performance of two alternatives for a freeway reconstruction project in Oklahoma City. The simulation identified problem areas in the two freeway design alternatives and assisted transportation professionals in selecting a preferred alternative.

1 INTRODUCTION

Traffic congestion has become one of the most serious problems affecting urban areas. Excessive traffic demand or the effects of overlapping bottleneck locations often results in significant traffic congestion. The increase in traffic volumes, coupled with short distances between intersections/interchanges, heavy turning movements, closely spaced on/off ramps and increased cross street traffic demand, requires the transportation professional to conduct a "systems analysis" approach to properly address traffic congestion. In doing so, the impacts of potential design and traffic control improvements along the roadway corridor can be fully evaluated.

For this reason, the transportation professional must perform a "systems approach", relying on new techniques such as, the CORSIM Simulation model which is fully capable of properly evaluating these types of transportation conditions. CORSIM is a very powerful microscopic simulation model designed to simulate traffic flow on freeways and surface streets. In addition to sound theoretical logic within CORSIM, it can provide a "movie" animation of individual vehicles moving throughout the network in real time.

CORSIM simulates the traffic behavior at a microscopic level and with detailed representation of individual vehicles and their interaction with their physical environment and other vehicles. Driver behavior (varying driver types, ranging from passive to aggressive) of individual vehicles (auto, carpool, bus or truck) are represented in the model through interaction with its surrounding environment, which includes the geometry, the traffic control devices, incidents and other vehicles. Each time a vehicle is moved, its position (both lateral and longitudinal) along the roadway and its relationship to other vehicles nearby are recalculated, as are its speed, acceleration, and status. As a result, each vehicle's behavior can be simulated in a manner reflecting real-world situations. The purpose of this paper is to describe why the CORSIM simulation model was applied to a real-world freeway reconstruction project in Oklahoma City, OK and describe how the simulation results were used to assist Oklahoma Department of Transportation (ODOT) select a preferred freeway design.

2 CASE STUDY - I-40, OKLAHOMA CITY

Interstate 40 in Oklahoma City, OK stretches across Oklahoma City's downtown, handling more than 100,000 vehicles each day, including a high percentage of truck traffic. The study area extends for three miles, bypasses downtown and connects two major freeway systems; I-35 and I-44. Therefore the study area is called the "Cross-town Expressway" as shown in Figure 1. Due to existing traffic congestion problems, high percentage of traffic growth and failing roadway structures, the Cross-town Expressway requires major reconstruction.

Proposing a new freeway design is difficult because a majority of the freeway exists as a bridge structure. ODOT reviewed numerous design alternatives and finally, based on a rigorous review and panel selection, two design alternatives were selected for final consideration. The two designs vary from replacing the existing bridge to relocating the expressway south of the existing structure. Reconstruction of the roadway prices the project from $250 million to $550 million. Renovating the existing bridge will be even more costly. The objective of the study was to analyze the traffic operations on two of the
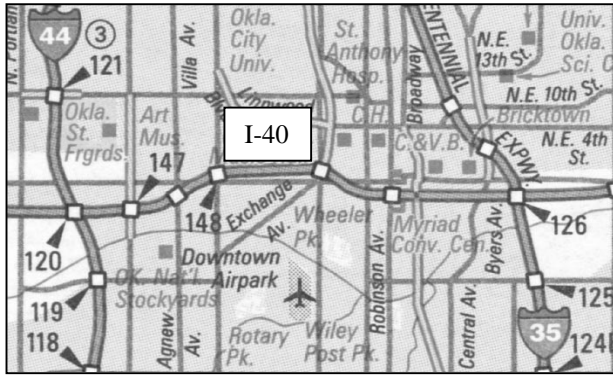
Figure 1: I-40 "Cross-Town" Study Area

preferred freeway design alternatives. Three critical issues needed to be addressed: 1) conduct a systems analyses over the entire freeway system, 2) evaluate the impact of high ramp traffic entering and exiting the freeway system, and 3) display the operational and animation results to the public. The only simulation model that can properly address and evaluate the I-40 project issues is CORSIM.

The CORSIM simulation model was used as a design/evaluation tool for the I-40 reconstruction study conducted by Oklahoma DOT. FHWA assisted ODOT to simulate the I-40 freeway system between I-35 and I-44 in both eastbound and westbound directions. The two proposed alternative designs that were to be evaluated with CORSIM were Alternative B3 and Alternative D.

3 MODELING APPROACH

3.1 Data Collection

The data collection process for CORSIM requires the gathering of peak hour volume data, geometric distances and traffic flow data for the study area. The study area extended along I-40 between the I-35 and I-44 freeway system interchanges, encompassing six ramp locations per direction of freeway. ODOT provided FHWA with geometric drawings, Average Annual Daily Traffic (AADT) volumes (Year 2020) for the freeway and ramps, truck percentages and design speeds. The data was collected for the freeway mainline sections along I-40 and the adjoining ramp locations. Modeling of the adjacent intersections and surface streets were not included as part of this analysis.

The I-40 design drawings were used to measure the roadway geometric information. The CORSIM simulation model is sensitive to geometric distances such as, ramp spacing and acceleration/deceleration taper distances. The lane geometrics and ramp gore distances in the eastbound and westbound directions for Alternative B3 are shown in Figure 2 and Figure 3. Spacing between ramps could be measured from the design drawings, however, spacing for

ramp acceleration and deceleration lanes had to be approximated. Proper ramp acceleration and deceleration distances are critical to ensure that the ramps will operate at sufficient speeds. The design speed for the freeway is 65 mph. The number of lanes is also required input. The proposed freeway design specifies five lanes per direction for both alternatives. On and off ramps are designed as one-lane facilities.

Traffic volumes for CORSIM are input as peak hour volumes. The peak hour volumes were computed from the given AADT volumes and applied a peak hour factor (PHF), directional distribution factor (D), and 30th highest annual factor (K). ODOT provided the factors used in the peak hour computations: PHF-0.95, D-0.55 and K-0.095. The Year 2020 peak hour volumes for the study area are shown on Figure 4 for Alternative B3. Vehicle composition was provided by ODOT, which specified heavy truck percentage as 8% along the mainline.

The average mainline peak hour volumes for both alternatives ranged from 4800 to 6800 vehicles per hour (vph). Due to five lanes on the mainline, the projected mainline demand volumes will have adequate capacity. The average peak hour volume for Alternative B3 on the mainline was 1200 vehicles per hour per lane (vphpl), while the maximum was 1500 vphpl. High ramp volumes in Alternative B3, greater than 1500 vph, were observed to occur on four out of eleven ramps within the study area. For Alternative D, the average peak hour volume on the mainline was 1150 vphpl, while the maximum was 1235 vphpl. Most of the ramp volumes in Alternative D were under capacity. The high volume ramp locations will be analyzed closely to see if problems occur. It should be noted that the peak hour volumes for Alternative D are lower because the existing I-40 freeway will be used as a parallel facility to accommodate part of the demand.

After the data collection effort was complete the next step was to input the data into the CORSIM model. CORSIM uses a link-node representation to model freeways and surface streets. ITRAF, a graphical input editor developed by FHWA and Oak Ridge National Labs (ORNL), was used to set up the link-node input file.

Detectors were placed on several freeway and ramp links to generate detector output or point processing output in CORSIM. Detector output is very helpful when analyzing volumes and speeds per lane at a given location.

4 CALIBRATION OF DATA

The I-40 freeway system was simulated for one hour in CORSIM and the results were analyzed. The first step, before reporting the CORSIM results, is to ensure the output results are replicating the real world traffic conditions and behaviors. This step is called Calibration. If unexpected problems or unrealistic traffic behaviors occur, internal parameters in CORSIM can be modified.
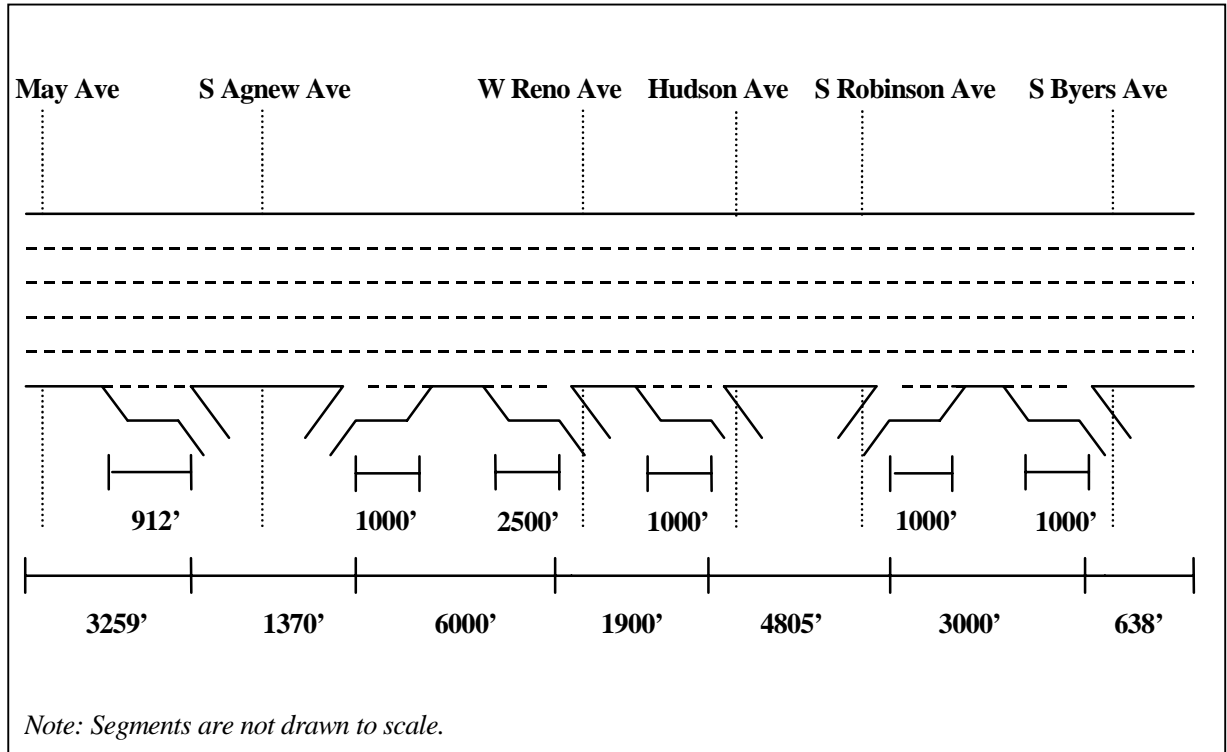
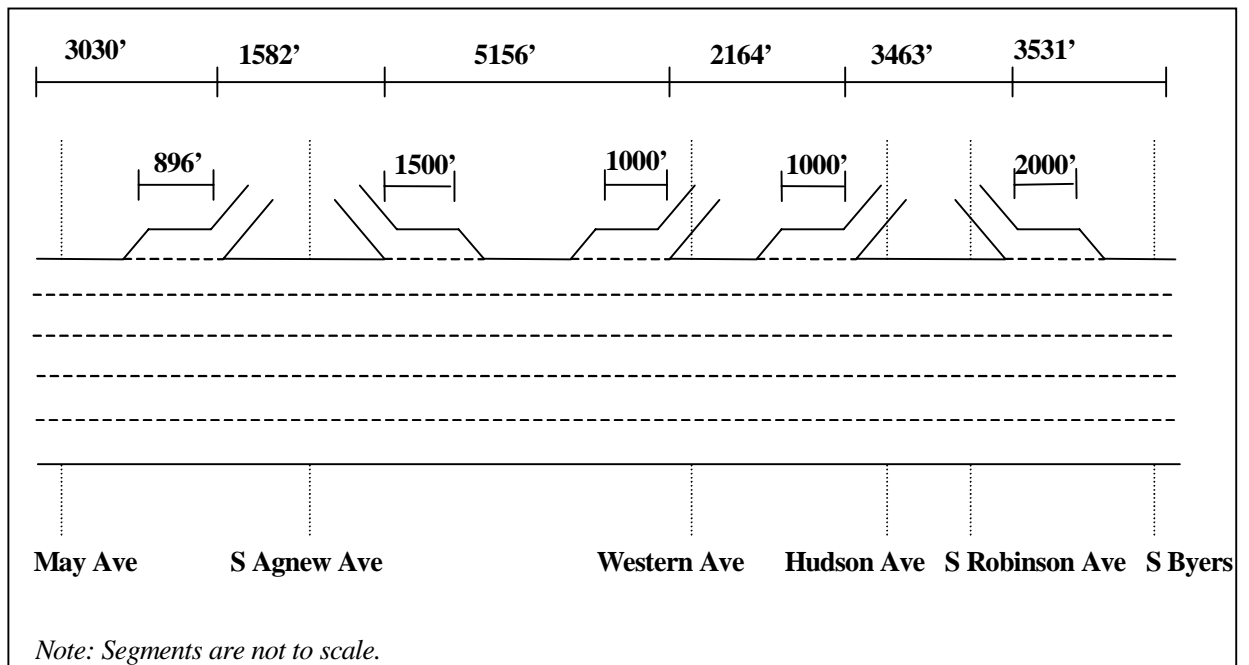Figure 2: Alternative B3 - Eastbound I-40- Freeway Geometry

Figure 3: Alternative B3 - Westbound I-40- Freeway Geometry

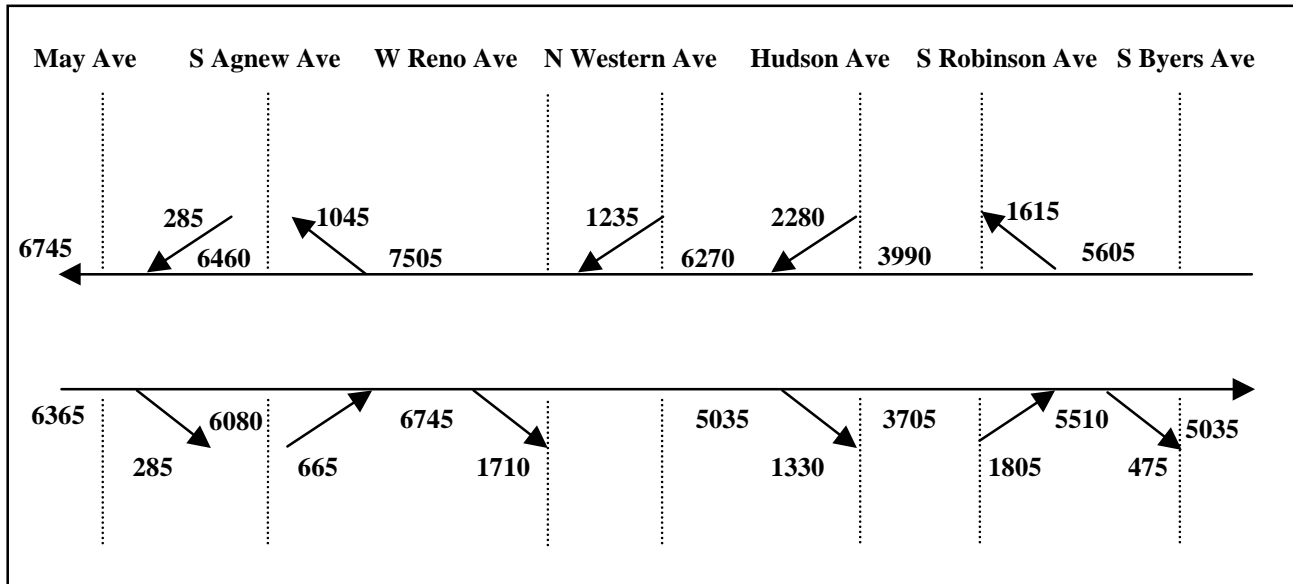| May Ave | S Agnew Ave | W Reno Ave | N Western Ave | Hudson Ave | S Robinson Ave | S Byers Ave |

Figure 4: Alternative B3 – Peak Hour Volumes – Year 2000

The simulated off-ramp volumes and freeway mainline speeds near the ramps were very low. Inadequate or short ramp acceleration and deceleration lengths caused slow speeds or queue spillbacks because vehicles could not find gaps to merge. To improve these results and further calibrate the model, the following variables were adjusted:

- Increased acceleration and deceleration lanes at high ramp volume locations.
- Increased the warning sign location for off-ramps and lane drops.
- Adjusted the free flow speed to 70 mph on freeway mainline links.
- Changed the duration of a lane-change maneuver time from the default value of 3 sec to 1 sec.
- Adjusted the percentage of drivers who co-operate with a lane-changer from the default value of 50% to 70%.

5 TRAFFIC OPERATIONAL RESULTS

After the model is calibrated, the final input data files were run and analyzed. CORSIM provided a wide array of traffic operational output measures. The most important measure to be used in the evaluation process include: average speed of vehicles (mph), density (number of vehicles per lane per mile) and simulated throughput volume (vph). These measures of effectiveness are given on an average link basis. In addition, detectors were placed within the network to provide output on a per lane basis. Detector output provided throughput volumes and speeds per lane for freeway sections and on-ramp locations. Due to high on-ramp volumes, the outside

freeway lane, receiving the on-ramp traffic, was of concern.

5.1 Alternative B3

The CORSIM results are summarized and shown in Table 1. Comparisons of simulated throughput volumes to demand volumes and input speeds to simulated speeds for Alternative B3 are listed in Table 1. The results are shown for eastbound and westbound freeway and ramp segments and specified on a link basis across all lanes. Summaries of the findings are discussed below.

- Eastbound and westbound sections along I-40 operate at speeds close to the desired speed of 65 mph.
- Slow speeds, 54 mph, occur after the EB I-40 S Byers Avenue on-ramp. The slow speeds are due to a freeway lane drop from five to four lanes.
- Slow speeds occur on the S Robinson Avenue off-ramp. Due to a traffic signal at the end of the off-ramp, optimal signal timing plans are critical to prevent the ramp traffic from backing up onto the freeway.
- The actual demand volume of 2280 vph could not be accommodated at the I-40 WB Hudson Ave on-ramp. The ramp could accommodate a maximum of 1850 vph; therefore, a shortfall of 430 vph occurred. The simulated ramp volume is replicating reality, because the AASHTO design guides state the maximum volume for a one lane ramp is approximately 1900 vph.

To look closer at output measures by lane, detectors were input to gather volumes and speed by lane. Figures 6 and 7

depict the average speeds by lane at on-ramp locations. The following problem areas were identified:

- Slow speeds occur in Lane 1 at the I-40 WB on-ramp from S. Robinson Avenue due to a high ramp volume of 2280 vph.
- Slow speeds occur in Lane 1 at the I-40 EB on-ramp from S. Robinson Ave due to a high ramp volume of 1805 vph.

5.2 Alternative D

Comparisons of simulated throughput volumes to demand volumes and input speeds to simulated speeds were also performed for Alternative D. Summaries of the findings are discussed below.

- Mainline traffic operated at average speeds greater than 65 mph.
- The off-ramp to Shields Boulevard had a very low speed of 19 mph. As was seen for Alternative B3, the problem was caused by a traffic signal right at the end of the off-ramp.
- Slow speeds occur in the eastbound direction in Lane 1 at the Shields Boulevard off and on-ramp locations.

Overall, there were minimal problems and acceptable traffic operations for Alternative D.

5.3 Summary of Results

Comparing the two alternatives, the freeway travel speeds were higher for Alternative D. Since the demand volumes for Alternative D are lower this observation seems realistic. For both alternatives, the freeway mainline sections operated at acceptable and high speeds of 65 mph due to adequate mainline capacity.

As for ramp operations, Alternative B3 experienced higher demand volumes at several on-ramp locations. With five high on-ramp volume locations, four experienced slow vehicle speeds. Alternative D had two high on-ramp locations, but only one experienced slow speeds at the freeway ramp merge area. In addition, it was not possible to evaluate the traffic operations on the adjacent surface streets. The high ramp volumes indicate there could be potential problems at the intersections due to the high demand of vehicles trying to enter onto and exit the freeway. Queue spillbacks from the freeway or poor signal control timings could severely impact intersection operations. Adjacent intersections in Alternative B3 have the potential to experience serious congestion problems.

6 CONCLUSION

The CORSIM analysis for the I-40 Cross-town Expressway freeway design evaluation was a success. CORSIM provided ODOT with a "system analyses" of results for both design alternatives with future volumes along I-40.

The CORSIM results identified problem locations at freeway-ramp locations and also identified future problem locations at nearby intersections. Comparison of the operational results between the two preferred alternatives helped ODOT identify and recommend a preferred freeway design. In addition, the animation results for both alternatives were displayed at the public meetings. The "movie" animation helped ODOT discuss the traffic operations and answer questions from the public. This study was conducted in less than two months.

With the simulation files complete, testing new design alternatives or expanding the network can be accomplished with little effort. FHWA conducted a CORSIM technical assistance workshop with the intent for ODOT to pick up and continue to use the CORSIM files. ODOT is planning to include and analyze the operations of the arterial streets and intersections. Testing different work zone strategies and the impact on traffic operations is also being evaluated. CORSIM provided ODOT with the necessary information on the I-40 design to make a preferred design recommendation. Overall, ODOT has gained valuable insight and knowledge based on the capabilities of CORSIM.
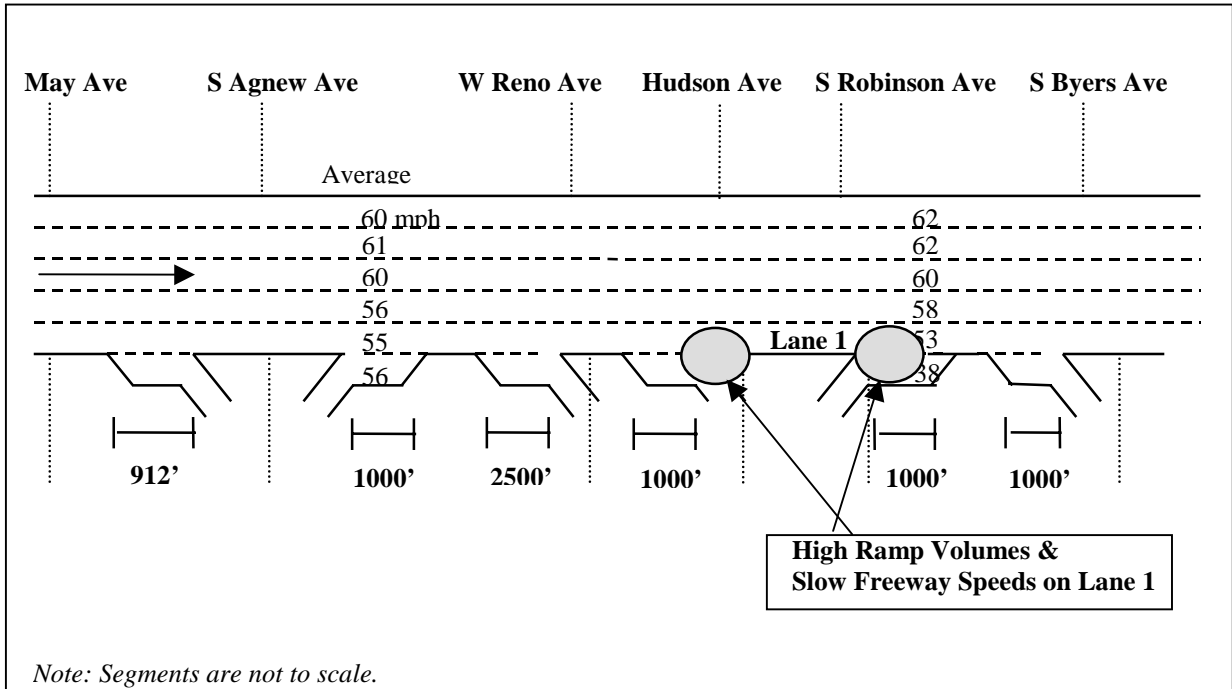
May Ave   S Agnew Ave   W Reno Ave   Hudson Ave   S Robinson Ave   S Byers Ave

Average

60 mph   62
61   62
60   60
56   58
55   Lane 1   53
56   38

912'   1000'   2500'   1000'   1000'   1000'

**High Ramp Volumes &
Slow Freeway Speeds on Lane 1**

Note: Segments are not to scale.

Figure 6: Alternative B3 – I-40 Eastbound - Output Results – Speeds by Lane

**High Ramp Volumes &
Slow Freeway Speeds on Lane 1**

896'   1500'   1000'   1000'   2000'

52   54   42
59   55   52   Lane 1
57   56   58
59   60   60
61   61   61
60 mph   60   60

Average

May Ave   S Agnew Ave   N Western Ave   Hudson Ave   S Robinson Ave   S Byers
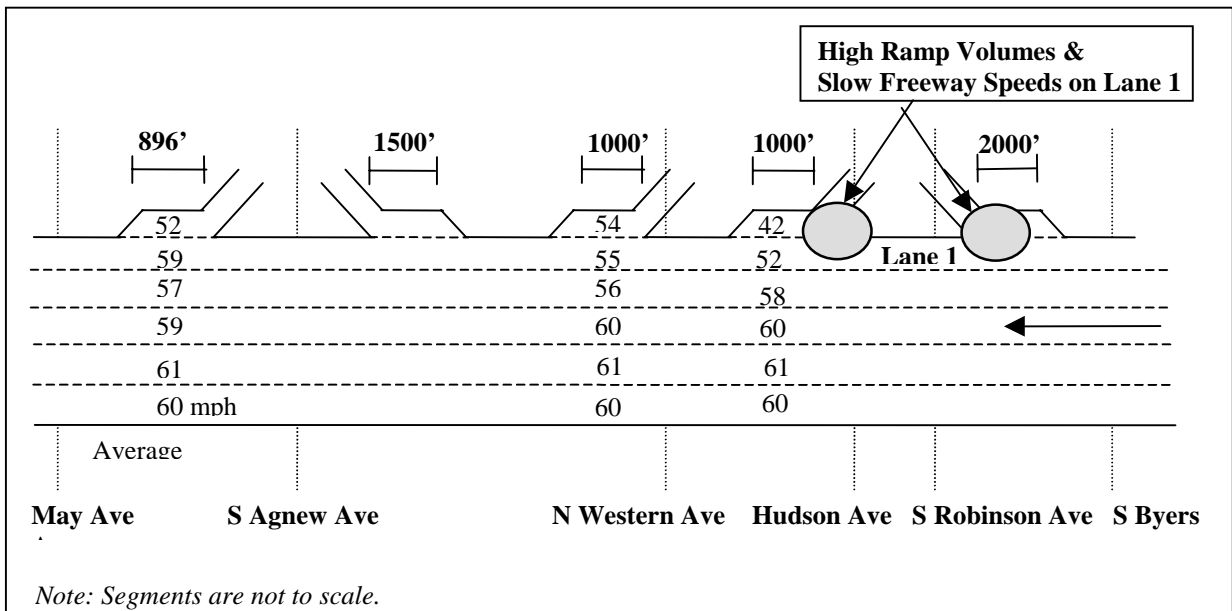
Note: Segments are not to scale.

Figure 7: Alternative B3 – I-40 Westbound - Output Results – Speeds by Lane

Table 1: Alternative B3 - Comparison of Link Throughput Volumes and Average Speeds

ALTERNATIVE B3 EASTBOUND DIRECTION	Input Volume (vph)	Output Volume (vph)	Difference in Volumes (vph)	Input Speed (mph)	Output Speed (mph)
EB I-40 to S Agnew Ave	6365	6364	1	70	67
EB I-40 from Off at S Agnew Ave to On at S Agnew Ave	6080	6102	22	70	64
EB I-40 from S Agnew Ave to W Reno Ave	6745	6797	52	70	61
EB I-40 from W Reno Ave to Hudson Ave	5035	5127	92	70	61
EB I-40 from Hudson Ave to S Robinson Ave	3705	3795	90	70	66
EB I-40 from S Robinson Ave to S Byers Ave	5510	5704	194	70	61
EB I-40 from S Byers Ave to End of Segment*	5035	5150	115	70	54
Off-Ramp to S Agnew Ave	285	261	24	45	38
On-Ramp from S Agnew Ave	665	694	29	45	42
Off-Ramp to W Reno Ave	1710	1638	72	45	41
Off-Ramp to Hudson Ave	1330	1285	45	45	41
On-Ramp from S Robinson Ave	1805	1918	113	45	38
Off-Ramp to S Byers Ave	475	534	59	30	36
WESTBOUND DIRECTION					
WB I-40 to S Robinson Ave	5605	5604	1	70	65
WB I-40 from S Robinson Ave to Hudson Ave	3990	4060	70	70	66
WB I-40 from Hudson Ave to Western Ave	6270	5907	363	70	62
WB I-40 from Western Ave to S Agnew Ave	7505	7157	348	70	64
WB I-40 from Off at S Agnew Ave to On at S Agnew Ave	6460	6245	215	70	60
WB I-40 from S Agnew Ave to End of Segment	6745	6514	231	70	66
Off-Ramp to S Robinson Ave*	1615	1503	112	45	22
On-Ramp from Hudson Ave*	2280	1850	430	45	42
On-Ramp from N Western Ave	1235	1235	0	45	44
Off-Ramp to S Agnew Ave	1045	883	162	45	37
On-Ramp from S Agnew Ave	285	280	5	45	44

*   Problem Area