Stolfus

Memorandum

To: US 6 CO 9 Project Team

From: Jeff Vasquez, EI

Andrew Amend, PE

Date: October 31, 2024

Re: US 6 - CO 9 Corridor Operations Study– Microsimulation Analysis Memo

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In 2023, the Colorado Department of Transportation (CDOT) identified the need to take a data-driven approach to corridor operations and safety to identify efficiency improvements for United States Highway 6 (US 6) and Colorado State Highway 9 (CO 9) within the context of existing and proposed land uses and infrastructure. As part of the corridor operations study, exploring opportunities to upgrade the I-70 Exit 205 interchange was identified as a key component to determine the potential corridor operations and safety improvements that different interchange configurations offer. Initially a high-level analysis of five interchange types was conducted using Federal Highway Administration's Capacity Analysis for Planning of Junctions (CAP-X) tool. A diamond and diverging diamond were identified as preferred interchange options due to cost since reconstruction of the I-70 bridges is not required with these two interchange types. The diamond and diverging diamond interchange (DDI) were then carried forward for additional analysis using microsimulation to better understand the traffic operational benefits of each interchange configuration. Refer to the *US 6 - CO 9 Corridor Operations Study - Access Management Summary* for additional details. This memo summarizes the microsimulation process and findings.

A microsimulation model was created for the US 6- CO 9 corridor to evaluate and understand traffic patterns at the I-70 Exit 205 interchange and adjacent intersections. PTV's Vissim software was used for the microsimulation analysis. The Vissim network focuses on the area extending from just north of 4th Street to just east of the Dillon Ridge Road/E Anemone Trail intersection. The Wildernest Road and Stephens Way loop were also modelled and included in the microsimulation.

Origin Destination

Streetlight data was obtained for the project to develop an understanding of vehicle's origins and destinations off the interchange. A total of 23 Streetlight gates were used for the project to help model the weaving and bottlenecking that occurs on the corridor. The data was used to obtain ratios of vehicles traveling to each destination. Then, the existing/projected traffic volume data was applied to these ratios to obtain representative volumes for the project. These origin-destinations were then inputted into Vissim using the vehicle routes function to model the trips off the I-70 interchange to their destinations off US 6 and CO 9.

VISSIM Calibration

Calibration is the first step of microsimulation modeling to ensure the Vissim model is representative of real traffic conditions on the corridor. It is an iterative process of adjusting the existing conditions model parameters until the simulated measures reasonably match the field measured performances. Following CDOT's Traffic Analysis and Forecasting Guidelines, the model calibration targets used for the US 6 CO 9 Vissim model were Traffic Volume Served, Travel Speed, and Queue Length.

Data collection was taken on Friday, March 24, 2023, from 4-5 PM. Additionally, a field visit was conducted the same day/time to verify traffic conditions and problem areas along the corridor. All available traffic data representative of this date and time was inputted into the model including roadway geometry, speed limits, traffic volumes, signal timings, intersection control, and pedestrian counts. The volumes for the peak hour from 4-5 PM were applied at 15-minute intervals using 4 different vehicle inputs to match current conditions. Signal timings that were implemented on the corridor during the observed period were obtained and inputted into the model. The iterative procedure was then applied, changing vehicle and driver parameters to match the March 24, 2023 conditions as closely as possible.

The calibration model simulated 10 1-hour simulation runs with each simulation beginning to record data after 15 minutes to allow the network to fill. Note that the Vissim simulations only record peak hour conditions. The project team agreed to focus on the one hour peak condition rather than analyzing the beginning of peak to end of peak. While the calibration condition was not near capacity, it was acknowledged that future conditions might be. Due to this, the simulations were modelled to the peak hour to avoid calibrating to the build-up and dissipation of those at-capacity conditions. With the study comparing many improvements and scenarios, understanding peak hour congestion was more time-effective than modelling beginning to end peak demand scenarios.

The calibration targets and results are listed below:

Simulated Measure	Calibration Target	Vissim Result
Traffic Volume Served	85% of network links must be within 10% of observed traffic volumes	100% of network links were within 10% of observed traffic volumes
Travel Speed	85% of network links must be within 10% of average observed speeds	79% of network links were within 10% of average observed speeds
Queue Length	Visually acceptable maximum queue lengths at critical locations	6/7 queue locations were within 3 vehicles. 1 queue location had a queue difference of 5 vehicles

Of the 3 calibration parameters, Traffic Volume Served and Queue length reached acceptable calibration targets. Travel speed was the one outlier which did not meet CDOT minimum requirements. While not far from the target, speeds were deemed acceptable as the recorded speeds obtained from the data source INRIX at all locations were taken at less than 0.1-mile-long increments and fluctuation in such a short section of road is expected. The same parameters that were altered in the calibration model were applied to all models for the project.

VISSIM Modeling

A total of nine Vissim models were created to analyze existing conditions against multiple interchange and access improvements within the limits of 4th St to Dillon Ridge Rd. The nine models are listed below, and details of each model and their improvements can be found in the *US 6 – CO 9 Corridor Operations Study - Access Management Summary*.

1. Diamond Interchange (No-Build)
2. Improved Diamond
3. DDI (Diverging Diamond Interchange)
4. DDI with Option 1 (Signalized ¾ Movements at Stephen's Way and Little Beaver)
5. DDI with Option 2 (Relocate Stephen's Way and Little Beaver)
6. DDI with Option 4 (Relocate Stephen's Way and Little Beaver with T-intersection for Commercial Access)
7. DDI with Option 5 (Signalized ¾ Movement at Stephen's Way)
8. Diamond Interchange with Option 4 (Relocate Stephen's Way and Little Beaver with T-intersection for Commercial Access)
9. Diamond Interchange with Option 5 (Signalized ¾ Movement at Stephen's Way)

Similar to the calibration model, each of these alternatives were analyzed for ten 1-hour simulation runs, allowing 15 minutes for the network to fill prior to data recording. Only the interchange improvements (Diamond Interchange – No Build, Improved Diamond, and DDI) were modeled for the Existing (2022) periods. All nine models were analyzed using the Interim (2035) and Future (2045) periods in the Friday 4-5 PM peak and the Sunday 12-1 PM peak, as selected for the project design conditions. For more details on the peak hour design conditions and projected traffic volumes refer to the *US 6 - CO 9 Corridor Operations Study - Access Management Summary*.

Note that the 2nd model: Improved Diamond was analyzed for existing conditions and showed negative results. Due to the additional right turn lanes proposed at the off-ramps in this model, bottlenecks and weaving movements were visually more problematic. While additional storage in this option was beneficial for the off-ramp queueing issue, traffic along the US 6 CO 9 corridor was negatively impacted and showed no benefit. The project team agreed to eliminate the additional right turn lanes for the Improved Diamond configuration from further analysis due to negative results but included additional storage for existing auxiliary lanes to better serve anticipated queues.

Projected traffic growth for the analysis years, as described in the *US 6 – CO 9 Corridor Operations Study - Access Management Summary* were inputted into the models and individual trip origin-destinations were created per each alternative to account for the varying movements and access restrictions in each scenario. This was performed for all alternatives.

Signal timings along the corridor were configured and optimized by CDOT staff using Synchro for each scenario/alternative, as explained in the *US 6 - CO 9 Corridor Operations Study - Access Management Summary*. The signal timings were exported from Synchro and imported into the Vissim model for all scenarios.

Upon modeling each scenario and inputting the origin-destinations, traffic volumes, access/interchange improvements, and signal timings, the models were watched closely to ensure traffic was operating as expected and any areas that were operating irregularly were identified. Link inputs and parameters were modified as necessary to ensure vehicle behaviors on the system were modeled accordingly. After the models were visually acceptable, Vissim result data was collected. The Vehicle Network Performance Results and Vehicle Travel Time Results were recorded and compared.

VISSIM Results

An important consideration in the US 6 CO 9 Corridor Operations Study was to analyze the interchange alone and compare the benefits of a DDI to the existing diamond interchange. The *Vissim Results Table – Interchange Analysis* located in the attachments section of this memo shows the comparison of a diamond interchange versus DDI with no additional modifications on the rest of the corridor.

Of all conditions analyzed, the Friday 2045 condition is representative of the peak condition as this scenario has the highest volumes and congestion compared to the others. Network capacity, as shown in the Vissim results tables, was calculated by taking the number of vehicles that passed through the network, then subtracting the vehicles removed and the vehicles in the network at the end of data recording. With a 10.7% increase in network capacity, the DDI can accommodate more traffic compared to the existing diamond interchange. Delay is reduced by approximately 31.6% of all recorded trips and the travel time performance also shows improvements, especially when looking at the trips from one end of the corridor to the other (29% improvement). Despite the DDI having the best operational results, LOS analyses described in the *US 6 – CO 9 Corridor Operations Study Access Management Summary* indicate that intersections adjacent to the interchange will be over capacity and limit the effectiveness of the improved interchange.

Using the same metrics, a comparison of the 8 models (Improved Diamond is excluded as this option was eliminated from further analysis) was conducted to evaluate the operations for each improvement. The *Vissim Results Table – Interchange and Sub-Area Options Analysis* located in the attachments section of this memo shows the comparison of all models, with green text* showing the best performing option, blue text** showing the 2nd best option, and red text*** showing the worst performing option.

From the *Vissim Results Table– Interchange and Sub-Area Options Analysis*, the DDI with option 4 shows the best operational results in every scenario. As shown in blue, both the DDI option 2 and DDI option 5 show benefits close to that of DDI option 4. Typically showing the least amount of benefit is the regular diamond interchange with option 5.

When evaluating the options for the diamond interchange, option 4 shows the best results. In the Friday 2045 scenario, the network capacity stays nearly equivalent to the no build option. However, the travel times from the interchange off-ramps and along the US 6 CO 9 corridor are significantly improved. While not comparable to the DDI Option 4 results, the diamond interchange option 4 shows notable improvements over the no-build option.

Looking only at the I-70 interchange at US 6 CO 9, the implementation of a DDI shows operational benefit. Out of all the improvements, the microsimulation models show that the implementation of a DDI with option 4 has the best operational results in future conditions. Retaining the existing diamond interchange and implementing the other access management measures as part of sub-area option 4 also shows operational improvements and could be considered a logical interim step towards the higher performing alternative in the future.

Attachments

Vissim Results Table – Interchange Analysis

Vissim Results Table – Interchange and Sub-Area Options Analysis

Appendix

Vissim Results Table – Interchange Analysis

Parameter	No-Build	DDI	DDI Opt. 1	DDI Opt. 2	DDI Opt. 4	DDI Opt. 5	Diamond Opt. 4	Diamond Opt. 5
	Friday 2045							
Network Capacity Compared to No-Build	-	10.7%	15.7%	17.1% **	19.3%*	16.1%	0.3% ***	6.2%
Percentage of Vehicles Entered/Exited Network Compared to No-Build	-	7.0%	8.4%	10.0% **	12.5%*	8.6%	-2.6% ***	4.0%
Average Total Delay on Network (min)	3.8	2.6	2.3	2.2 **	1.7*	2.2 **	3.0	3.2 ***
Weighted I-70 Off-Ramps Travel Time Performance Compared to No-Build	-	8% ***	16%	14%	27%*	20% **	15%	17%
Weighted US 6 CO 9 Travel Time Performance Compared to No-Build	-	29%	37%	37%	50%*	45% **	27%	13% ***
	Sunday 2045							
Network Capacity Compared to No-Build	-	6.0%	3.0%	7.8% **	9.9%*	3.6%	2.1%	-0.8% ***
Percentage of Vehicles Entered/Exited Network Compared to No-Build	-	4.4%	3.1%	4.7% **	6.7%*	3.2%	1.1%	-0.2% ***
Average Total Delay on Network (min)	3.2	2.2	2.6	2.1 **	1.6*	2.5	2.9	3.2 ***
Weighted I-70 Off-Ramps Travel Time Performance Compared to No-Build	-	16%	17%	26% **	34%*	15%	7%	-2% ***
Weighted US 6 CO 9 Travel Time Performance Compared to No-Build	-	-14%	-40% ***	-3%	15%*	-27%	4% **	-8%
	Friday 2035							
Network Capacity Compared to No-Build	-	9.8%	16.6%	17.7% **	19.2%*	15.6%	9.9%	7.4% ***
Percentage of Vehicles Entered/Exited Network Compared to No-Build	-	5.3% ***	9.4%	10.5% **	10.7%*	8.8%	7.3%	6.0%
Average Total Delay on Network (min)	4.0	3.3 ***	2.6	2.4 **	2.2*	2.6	3.1	3.3 ***
Weighted I-70 Off-Ramps Travel Time Performance Compared to No-Build	-	1% ***	13%	16% **	22%*	14%	8%	10%
Weighted US 6 CO 9 Travel Time Performance Compared to No-Build	-	20%	40%	42% **	49%*	42% **	26%	10% ***
	Sunday 2035							
Network Capacity Compared to No-Build	-	10.4%	10.8%	15.4% **	15.8%*	11.6%	3.5%	1.2% ***
Percentage of Vehicles Entered/Exited Network Compared to No-Build	-	6.5%	7.3%	8.9%*	8.9%*	7.8% **	1.7%	0.4% ***
Average Total Delay on Network (min)	3.2	2.3	2.1	1.7 **	1.6*	2.0	2.8	3.1 ***
Weighted I-70 Off-Ramps Travel Time Performance Compared to No-Build	-	19%	22%	34% **	36%*	23%	6%	0% ***
Weighted US 6 CO 9 Travel Time Performance Compared to No-Build	-	-11%	-12% ***	13%	22%*	-5%	15% **	5%

Vissim Results Table – Interchange and Sub-Area Options Analysis

Vissim Results Table – Interchange and Sub-Area Options Analysis

Parameter	No-Build	DDI	DDI Opt. 1	DDI Opt. 2	DDI Opt. 4	DDI Opt. 5	Diamond Opt. 4	Diamond Opt. 5
	Friday 2045							
Network Capacity Compared to No-Build	-	10.7%	15.7%	17.1% **	19.3%*	16.1%	0.3% ***	6.2%
Percentage of Vehicles Entered/Exited Network Compared to No-Build	-	7.0%	8.4%	10.0% **	12.5%*	8.6%	-2.6% ***	4.0%
Average Total Delay on Network (min)	3.8	2.6	2.3	2.2 **	1.7*	2.2 **	3.0	3.2 ***
Weighted I-70 Off-Ramps Travel Time Performance Compared to No-Build	-	8% ***	16%	14%	27%*	20% **	15%	17%
Weighted US 6 CO 9 Travel Time Performance Compared to No-Build	-	29%	37%	37%	50%*	45% **	27%	13% ***
	Sunday 2045							
Network Capacity Compared to No-Build	-	6.0%	3.0%	7.8% **	9.9%*	3.6%	2.1%	-0.8% ***
Percentage of Vehicles Entered/Exited Network Compared to No-Build	-	4.4%	3.1%	4.7% **	6.7%*	3.2%	1.1%	-0.2% ***
Average Total Delay on Network (min)	3.2	2.2	2.6	2.1 **	1.6*	2.5	2.9	3.2 ***
Weighted I-70 Off-Ramps Travel Time Performance Compared to No-Build	-	16%	17%	26% **	34%*	15%	7%	-2% ***
Weighted US 6 CO 9 Travel Time Performance Compared to No-Build	-	-14%	-40% ***	-3%	15%*	-27%	4% **	-8%
	Friday 2035							
Network Capacity Compared to No-Build	-	9.8%	16.6%	17.7% **	19.2%*	15.6%	9.9%	7.4% ***
Percentage of Vehicles Entered/Exited Network Compared to No-Build	-	5.3% ***	9.4%	10.5% **	10.7%*	8.8%	7.3%	6.0%
Average Total Delay on Network (min)	4.0	3.3 ***	2.6	2.4 **	2.2*	2.6	3.1	3.3 ***
Weighted I-70 Off-Ramps Travel Time Performance Compared to No-Build	-	1% ***	13%	16% **	22%*	14%	8%	10%
Weighted US 6 CO 9 Travel Time Performance Compared to No-Build	-	20%	40%	42% **	49%*	42% **	26%	10% ***
	Sunday 2035							
Network Capacity Compared to No-Build	-	10.4%	10.8%	15.4% **	15.8%*	11.6%	3.5%	1.2% ***
Percentage of Vehicles Entered/Exited Network Compared to No-Build	-	6.5%	7.3%	8.9%*	8.9%*	7.8% **	1.7%	0.4% ***
Average Total Delay on Network (min)	3.2	2.3	2.1	1.7 **	1.6*	2.0	2.8	3.1 ***
Weighted I-70 Off-Ramps Travel Time Performance Compared to No-Build	-	19%	22%	34% **	36%*	23%	6%	0% ***
Weighted US 6 CO 9 Travel Time Performance Compared to No-Build	-	-11%	-12% ***	13%	22%*	-5%	15% **	5%

Appendix

The following files are available for use and located on the Google Drive:
https://drive.google.com/drive/folders/1zh3UpMGGJz5ze8Kjpxe_IHWelGjx-kTI

- Appendices Matrix (Spreadsheet)
  a. Outline/details of all documents included in Appendices

- Vissim Models:
  1. Existing / No-Build
  2. Improved Diamond Interchange
  3. Diverging Diamond Interchange
  4. Diverging Diamond Interchange with Sub-Area Option 1
  5. Diverging Diamond Interchange with Sub-Area Option 2
  6. Diverging Diamond Interchange with Sub-Area Option 4
  7. Diverging Diamond Interchange with Sub-Area Option 5
  8. Diamond Interchange with Sub-Area Option 4
  9. Diamond Interchange with Sub-Area Option 5

- Vissim Results
  1. Vissim Calibration – March PM (Spreadsheet)
  2. Vissim Results Analysis (Spreadsheet)

- Streetlight Data
  1. Origin Destination Methodology (PDF)
  2. Streetlight Origin Destination Output Files (Spreadsheets)
  3. Streetlight Origin Destination Output Files for Cross Highway Traffic (Spreadsheets)
  4. Origin Destination Volumes (Spreadsheets)
     a. Includes Origin Destination percentages applied to Existing and Projected Volumes for all scenarios